

# Improving Image Quality and Patient Safety in Magnetic Resonance Imaging: Lessons from High-Volume Clinical Practice-2025

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## ABSTRACT

Magnetic Resonance Imaging (MRI) is an essential tool in modern medical diagnostics that provides high-resolution, non-invasive visualization of soft tissues, the brain, spine, and musculoskeletal structures. While MRI offers exceptional diagnostic capability, maintaining high image quality and ensuring patient safety remains challenging, especially in high-volume healthcare settings. This review consolidates existing research and applied knowledge with more than ten (10) years of clinical experience to highlight strategies for optimizing MRI performance. However, key areas explored include patient safety protocols, positioning techniques, contrast agent administration, protocol standardization, and equipment calibration. Conversely, emphasis is laid on integrating technical expertise with patient-centered approaches to reduce motion artifacts, prevent adverse outcomes, and improve diagnostic accuracy. Additionally, workflow efficiency and interdisciplinary collaboration are critical components for successful MRI operations in busy hospitals. The present review concludes by providing actionable recommendations for technologists, radiologists, and healthcare institutions to enhance MRI service quality, promote patient safety, and support the effective use of imaging resources.

**Keywords:** Magnetic Resonance Imaging, MRI Safety, Image Quality, Patient Positioning, Quality Assurance, Clinical Practice

## INTRODUCTION

Magnetic Resonance Imaging (MRI) is one of the most advanced and widely used diagnostic imaging techniques in modern medicine. Its ability to produce detailed images of soft tissues without exposing patients to ionizing radiation makes it crucial in diagnosing and monitoring neurological, musculoskeletal, cardiovascular, and abdominal conditions (McRobbie *et al.*, 2021). For several years, improvements in MRI hardware, software, and imaging techniques have significantly strengthened diagnostic accuracy and clinical decision-making (Reeder *et al.*, 2018).

Despite these advancements in technology, achieving consistently high image quality while ensuring patient safety remains a major challenge in routine healthcare practice. MRI involves strong static magnetic fields, rapidly changing gradient fields, and radiofrequency energy, all of which are potential risks. If not properly managed (Shellock and Crues, 2004). These risks increase in high-activity hospital environments, where time constraints, patient anxiety, and machine load can negatively affect scan quality and safety compliance (Kanal *et al.*, 2013).

However, patient-related factors such as improper positioning, involuntary motion, discomfort, and inadequate communication can lead to image artifacts that compromise diagnostic value (Bernstein *et al.*, 2017). Similarly, insufficient safety screening may lead to serious incidents involving ferromagnetic objects, implanted medical devices, or unsuitable contrast administration (Shellock, 2020). These challenges emphasize the important role of the MRI technologist in balancing technical accuracy with patient-centered care.

In addition to patient-related cases, equipment performance and protocol selection play essential roles in MRI results. Routine quality assurance (QA), equipment adjustment, and workflow improvement are necessary to maintain image consistency and diagnostic reliability across different patient populations and clinical indications (Parker *et al.*, 2021). Without structured QA programs, image degradation and system errors may go unnoticed, which will potentially affect clinical interpretation.

High patient output further complicates MRI service delivery, especially in tertiary hospitals and urban healthcare centers. In such settings, efficient workflow management and close collaboration between MRI technologists, radiologists, and clinical teams are essential to maintaining safety standards and image quality (Brown *et al.*, 2018). therefore, effective communication ensures that clinical questions are clearly understood and that imaging protocols are appropriately tailored to individual patients.

Furthermore, this review aims to examine the factors influencing image quality and patient safety in MRI, with a focus on high-volume clinical practice. By combining evidence from existing literature with practical clinical experience, this review highlights best practices, common challenges, and achievable solutions for improving MRI performance. The aim is to provide practical guidance that supports safer imaging, enhances diagnostic accuracy, and promotes high standards of care in various healthcare settings.

### **Patient Safety in Magnetic Resonance Imaging**

Patient safety is a fundamental aspect of Magnetic Resonance Imaging practice. Unlike other imaging modalities, MRI does not use ionizing radiation; however, the presence of strong static magnetic fields, gradient magnetic fields, and radiofrequency (RF) energy introduces safety concerns that must be carefully managed (Shellock and Crues, 2004). therefore, ensuring patient safety requires strict adherence to screening procedures, effective communication, and continuous monitoring throughout the imaging process.

### **MRI Safety Screening**

Comprehensive pre-scan safety screening is the first and most important step in preventing MRI-related adverse effects. Patients must be thoroughly evaluated for the presence of ferromagnetic objects, implanted medical devices, and previous surgical procedures that may threaten the magnetic field environment (Kanal *et al.*, 2013). Failure to identify contraindicated implants, such as non-MRI-compatible pacemakers or aneurysm clips, can lead to serious injury or equipment damage.

Therefore, standardized screening questionnaires, together with verbal confirmation and physical inspection when necessary, are recommended to reduce human error (Shellock, 2020). In fast-paced clinics/ units, consistent use of safety checklists helps maintain safety standards irrespective of time pressures and patient turnover.

### **Patient Positioning and Comfort**

Proper patient positioning plays a dual role in ensuring both safety and image quality. Incorrect positioning can lead to patient discomfort, increased motion artifacts, and prolonged scan times (McRobbie *et al.*, 2021). In most cases, poor positioning may contribute to nerve compression or thermal injury due to RF heating.

However, patient comfort is important for long examinations such as brain, spine, and musculoskeletal MRI studies. Therefore, clear communication, adequate padding, and the use of immobilization devices help minimize patient movement and anxiety, thereby improving both safety and diagnostic outcomes (Bernstein *et al.*, 2017).

### **Contrast Agent Safety**

Gadolinium-based contrast agents (GBCAs) are widely used in MRI to enhance tissue characterization and detect lesion respectively. Although generally safe, contrast administration carries potential risks, especially in patients with renal impairment (Prince and Semelka, 2019). Nephrogenic systemic fibrosis (NSF), though rare, remains a concern in patients with severe kidney dysfunction.

To reduce risk, renal function assessment, appropriate agent selection, and adherence to recommended dosing guidelines are essential (Kanda *et al.*, 2016). Continuous patient observation during and after contrast administration is also necessary to detect and manage allergic or adverse reactions promptly.

### **Infection Control Practices**

Infection prevention is an often under-recognized aspect of MRI safety. High patient throughput increases the risk of cross-contamination if proper cleaning protocols are not followed. Therefore, MRI coils, patient tables,

positioning aids, and accessories must be routinely disinfected according to institutional and international infection control guidelines (Rutala and Weber, 2016).

Furthermore, the use of disposable covers, hand hygiene, and routine equipment cleaning reduces the risk of healthcare-associated infections and protects both patients and staff.

### **Staff Training and Safety Culture**

A strong safety culture supported by continuous education is essential for effective MRI practice. Regular training ensures that MRI technologists remain up to date with evolving safety standards, new device compatibility information, and emergency response procedures (Kanal *et al.*, 2013). In large-scale facilities, ongoing professional development helps prevent self-approval and reinforces best practices.

### **Optimizing Image Quality in Magnetic Resonance Imaging**

High-quality MRI images are essential for accurate diagnosis and effective patient management. Image quality in MRI is influenced by several factors, including patient cooperation, positioning, protocol selection, and equipment performance. In high-volume clinical environments, maintaining consistent image quality can be challenging, thereby making structured optimization strategies necessary (Reeder *et al.*, 2018).

### **Patient Preparation and Motion Control**

Patient motion remains one of the most common causes of image degradation in MRI. Voluntary movement, involuntary motion such as breathing, and physiological processes can produce artifacts that reduce image clarity and diagnostic value (McRobbie *et al.*, 2021). Proper patient preparation, with a clear explanation of the procedure and expected scan duration, plays essential role in minimizing motion.

Furthermore, the use of positioning aids, padding, and immobilization devices helps improve patient comfort and reduces movement during image acquisition (Bernstein *et al.*, 2017). In some cases, breath-hold techniques and respiratory gating are used to improve image quality in abdominal and thoracic imaging.

### **MRI Protocol Selection and Optimization**

Appropriate protocol selection is central to producing diagnostically useful images. MRI protocols must be tailored to the clinical question, anatomical region, and patient condition. Standardized protocols help ensure consistency across examinations while reducing scanning errors and unnecessary repeat imaging (Kanal *et al.*, 2013).

However, advanced radiofrequency (RF) pulses such as diffusion-weighted imaging, fast spin echo, and fat suppression techniques enhance lesion detection and tissue characterization (Parker *et al.*, 2021). However, protocol optimization must balance image resolution, scan time, and patient tolerance, especially in congested healthcare facilities.

### **Coil Selection and Signal Optimization**

The use of appropriate radiofrequency (RF) coils affects signal-to-noise ratio (SNR) and overall image quality significantly. Dedicated surface coils provide higher signal strength for specific anatomical regions, such as the spine, knee, or shoulder, compared to general-purpose body coils (McRobbie *et al.*, 2021).

Regular inspection and maintenance of coils are requisite to prevent signal loss, artifacts, and inconsistent image quality. Faulty coils can compromise diagnostic accuracy if not promptly identified and replaced (Reeder *et al.*, 2018).

### **Equipment Calibration and Quality Assurance**

Routine quality assurance (QA) and equipment calibration are essential for maintaining optimal MRI performance. QA procedures typically include phantom testing, gradient system evaluation, RF uniformity

checks, and software verification (Parker *et al.*, 2021). These measures help detect system drift, hardware malfunctions, and image inconsistencies before they affect clinical scans.

In over-crowded hospitals, scheduled QA programs ensure that imaging standards are maintained despite heavy equipment usage. Without consistent QA, subtle image distortion may go unnoticed, potentially leading to misinterpretation by radiologists (Shellock, 2020).

### **Role pressurizes the MRI departments of the MRI Technologist**

MRI technologists play a central role in image quality optimization. Their expertise in patient positioning, protocol adjustment, and real-time image evaluation allows for immediate correction of artifacts and technical errors (Brown *et al.*, 2018). However, continuous professional development ensures that technologists remain familiar with evolving imaging techniques and safety standards.

Effective communication between technologists and radiologists further enhances image quality by ensuring that imaging protocols are aligned with diagnostic expectations and clinical needs.

### **Workflow Efficiency and Interdisciplinary Collaboration in MRI Practice**

Efficient workflow management is essential for delivering high-quality MRI services, most especially in congested clinical environments. MRI examinations are time-consuming and capital-intensive, requiring careful coordination between personnel, equipment, and patients. However, poor workflow organization can lead to prolonged scan times, patient dissatisfaction, compromised image quality, and increased safety risks (Brown *et al.*, 2018).

### **Workflow Management in High-Volume MRI Units**

High patient output puts pressure on MRI departments, especially in tertiary hospitals and urban healthcare centers. Poor planning/ scheduling, delayed patient preparation, and faulty equipment can disrupt workflow and reduce overall efficiency (Parker *et al.*, 2021). Structured appointment systems, pre-scan patient education, and standardized protocols help reduce delays and minimize unnecessary repeat scans.

Additionally, efficient workflow also depends on the ability of MRI technologists to adapt protocols based on patient condition and clinical indication. Flexibility in scan planning, along with adherence to safety and quality standards, allows departments to balance speed with diagnostic accuracy (Reeder *et al.*, 2018).

### **Role of Interdisciplinary Collaboration**

Interdisciplinary cooperation is a major component of effective MRI practice. Close communication between MRI technologists, radiologists, referring physicians, nurses, and support staff ensures that imaging studies address specific clinical questions (Kanal *et al.*, 2013). When clinical information is clearly communicated, imaging protocols can be appropriately tailored to improving diagnostic yield and reducing unnecessary imaging.

Therefore, radiologist feedback is very valuable in refining protocols and addressing recurrent image quality issues. Regular case reviews and departmental meetings strengthen shared understanding of diagnostic expectations and technical limitations (McRobbie *et al.*, 2021).

### **Documentation and Communication**

Accurate documentation supports continuity of care and patient safety in MRI services. Clear recording of patient history, safety screening results, contrast administration details, and technical observations assists radiologists in image interpretation and reduces the likelihood of clinical errors (Shellock, 2020).

Effective communication with patients is also important. Explaining procedures, scan times, and safety instructions helps reduce anxiety and improves patient cooperation during imaging. Improved patient collaboration is associated directly with reduced motion artifacts and improved image quality (Bernstein *et al.*, 2017).

## Staff Training and Professional Development

Continuous professional development is essential for maintaining high standards of MRI practice. Advances in imaging technology, evolving safety guidelines, and new clinical applications require ongoing education for MRI technologists and radiology staff (Parker *et al.*, 2021). Training programs focused on workflow optimization, patient communication, and technical skills enhance departmental efficiency and safety culture.

Furthermore, In high-volume environments, investment in staff training contributes to reduced error rates, improved morale, and better patient net-results (Brown *et al.*, 2018).

## Challenges in High-Volume MRI Clinical Practice

Despite technological advancements and established safety guidelines, MRI practice in high-volume clinical settings continues to face several operational and healthcare challenges. One of the most significant issues is time-consuming. High patient demand often leads to shortened preparation times, which can affect thorough safety screening, patient education, and optimal positioning (Brown *et al.*, 2018). When these steps are rushed, the risk of safety incidents and poor image quality increases.

Patient-related factors also pose risks. Anxiety, claustrophobia, pain, and inability to remain still during long scan times frequently result in motion artifacts and incomplete studies (McRobbie *et al.*, 2021). These issues are more evident in elderly patients, pediatric populations, and persons with chronic conditions, often requiring repeat imaging or protocol adjustments.

Also, resource limitations further complicate MRI service delivery, especially in developing healthcare systems. Limited access to advanced coils, delayed equipment maintenance, and insufficient staffing can negatively affect image quality and workflow efficiency (Reeder *et al.*, 2018). In some facilities, inconsistent quality assurance programs lead to undetected system drift and gradual image degradation.

Another ongoing challenge is maintaining up-to-date knowledge of evolving MRI safety standards and device compatibility. The increasing number of implanted medical devices requires continuous review of safety information to prevent adverse effects (Shellock, 2020). Without regular training, staff may depend on outdated practices, thereby increasing risk in the MRI environment.

## RECOMMENDATIONS AND BEST PRACTICES

To address the challenges identified, a combination of technical, organizational, and patient-centered approach is essential. First, standardized MRI safety screening protocols should be strictly implemented for all patients, regardless of workload or time constraints. The use of structured checklists and double-verification systems can significantly reduce human error (Kanal *et al.*, 2013).

Second, patient preparation and communication should be prioritized. Clear explanations of scan procedures, duration, and noise levels help reduce anxiety and improve patient cooperation, leading to better image quality and fewer repeat scans (Bernstein *et al.*, 2017). Adequate padding and positioning aids should be routinely used to enhance comfort and stability.

Third, regular quality assurance and equipment maintenance must be integrated into departmental workflows. Routine phantom testing, coil inspection, and system calibration ensure consistent imaging performance and early detection of technical issues (Parker *et al.*, 2021). These practices are important in high-impact environments where equipment is utilized.

Also, continuous professional development for MRI technologists and radiology staff is important. Training programs focused on safety updates, protocol optimization, and workflow efficiency help maintain high standards of practice and strengthens safety culture (Shellock, 2020).

Finally, interdisciplinary collaboration should be encouraged through regular meetings, protocol reviews, and feedback sessions between technologists and radiologists. This collaborative approach ensures that imaging protocols are in accordance with diagnostic needs and clinical priorities (Brown *et al.*, 2018).

## CONCLUSION

Magnetic Resonance Imaging remains a cornerstone of modern diagnostic medicine, offering exceptional soft tissue contrast and diagnostic versatility. However, the complexity of MRI technology, together with high patient volumes, presents ongoing challenges related to image quality, patient safety, and workflow efficiency. This review highlights the importance of integrating technical expertise with patient-centered care, standardized safety practices, and solid quality assurance programs.

Lessons from congested clinical practice demonstrate that optimal MRI results depend not only on advanced technology but also on skilled personnel, effective communication, and interdisciplinary collaboration. Therefore, by implementing structured safety screening, optimizing imaging protocols, maintaining equipment performance, and investing in continuous staff training, healthcare institutions can enhance diagnostic accuracy while reducing risk.

Furthermore, future efforts should focus on developing innovative workflow solutions, expanding access to training, and adopting emerging imaging technologies that further improve safety and efficiency. Therefore, strengthening these areas will support the delivery of high-quality MRI services and contribute to improved patient care across diverse clinical settings.

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