MRI Artefacts: causes, recognition and practical solutions

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Abstract: MRI artefacts are image features that do not accurately represent the anatomy or tissue properties being examined. They can obscure findings, mimic disease, compromise measurements, or provide useful diagnostic contrast. This narrative review summarises common artefacts related to patient motion and flow, field-of-view and k-space sampling, chemical shift, susceptibility and metal, B_0/B_1 nonuniformity, radiofrequency interference, cross-talk, partial-volume effects, echo-planar imaging, balanced steady-state free precession, and cardiac MRI. It describes their underlying mechanisms, typical appearances, recognition clues, and practical mitigation strategies. Recognition depends on artefact geometry and encoding direction, sequence dependence, repeatability across images, anatomic plausibility, and clinical context. Management options include patient preparation and synchronisation; adjustments to field of view, encoding direction, bandwidth, echo time, voxel size, and shimming; alternative sampling or acceleration methods; and dedicated metal-artefact-reduction or reconstruction techniques. The review also considers artificial intelligence-based correction, troubleshooting, technologist responsibilities, and quality assurance. Because mitigation can affect signal-to-noise ratio, spatial resolution, contrast, and scan time—and may alter diagnostic information—select correction for the clinical task and assess the result for diagnostic adequacy. A mechanism-based approach helps distinguish artefacts from pathology, guide targeted corrections, and identify persistent system-related problems.

Keywords: magnetic resonance imaging; MRI artefacts; image quality; artefact recognition; artefact reduction; quality assurance; SNR

I. Introduction

Magnetic resonance imaging has become an important part of modern diagnostic imaging because of its superior soft-tissue contrast resolution, isotropic multiplanar capabilities, and ability to provide structural, functional, and quantitative information without using ionising radiation. Even with such advantages, image formation in MRI is technically very complex and is also influenced by a number of physical and physiological factors.

An artefact is an image feature that does not correspond to the actual anatomy or tissue property under examination. In an MRI image, artefacts may appear as signal loss, geometric distortion, displacement, blurring, banding, ghosting, or unexpected structures. Some of these artefacts are readily recognisable as technical phenomena, whereas others may closely resemble pathology.

Artefact recognition therefore has a twofold clinical importance. First, artefacts may reduce image quality sufficiently to obscure important anatomy or pathology. Second, an artefact may mimic disease and result in an incorrect diagnosis. Earlier literature emphasised that artefacts and foreign bodies may be mistaken for pathology, and that recognising the underlying mechanism is essential for appropriate interpretation. Therefore, it is important to recognise these artefacts, especially those that mimic pathology, based on a basic understanding of their origin, as they can lead to incorrect diagnosis and serious after-effects on the patient's health and outcomes.

The 2015 review by Krupa and Bekiesińska-Figatowska remains a useful foundation because it demonstrates the wide range of artefacts encountered in routine MRI, including truncation, motion, aliasing, chemical shift, susceptibility-related artefacts, and artefacts associated with metallic and other foreign bodies.[1] RadioGraphics primer by Noda et al. emphasised that MRI artefacts may originate from hardware, software, pulse sequences, tissue heterogeneity, and patient movement and that individual mitigation strategies have their own trade-offs.[2]

Over the years, MRI systems have evolved towards higher field strengths, faster gradients, multichannel RF systems, parallel imaging, compressed sensing, quantitative techniques, diffusion imaging, and increasingly complex reconstruction algorithms. The modern approach of artefact reduction involves firstly identifying the artefact, then determining its likely source, understanding its sequence dependence, modifying acquisition parameters, and when necessary, selecting an alternative sequence or reconstruction method. This review therefore focuses on a practical framework for MRI artefact management, from artefact identification to correction.

These developments have improved diagnostic capability but have also introduced new sources of artefacts. Therefore, new strategies to reduce them are required.

II. Classification of MRI Artefacts

No single universally accepted classification system exists because several mechanisms can contribute to the same artefact. For practical purposes, MRI artefacts can be divided into the following categories:

Table 1: Practical classification of common MRI artefacts[1], [2], [3], [4]

Category	Examples	Interpretive use
Patient and motion	Voluntary, respiratory, cardiac, pulsatile, peristaltic, swallowing, and eye motion	Can produce ghosts, blur, or inconsistent anatomy; check direction and repeatability.
Sampling and reconstruction	Wraparound, Gibbs ringing, partial volume, radial streaks, parallel-imaging or compressed-sensing errors	Consider field of view, sampling, voxel size, trajectory, and reconstruction.
Magnetic-field and RF	Susceptibility, B0/B1 nonuniformity, dielectric effects, chemical shift, RF interference	Look for distortion, signal loss, failed fat suppression, shading, or zipper lines.
Sequence-related	Flow, cross-talk, EPI distortion, bSSFP banding, fat-suppression failure	Compare sequence dependence and acquisition settings before assuming pathology.
Implant and foreign-body	Metal-related signal void, pile-up, distortion, and fat-suppression failure	Relate the pattern to implant location and select a targeted metal-reduction strategy.
Hardware and system	Coil malfunction, gradient problems, frequency instability, shielding faults	Persistence across patients or sequences warrants equipment and QA review.

This broad categorisation aligns with established MRI artefact literature, which groups artefacts by field imperfections, motion, and limitations in signal sampling and image reconstruction.

III. Physical Basis of MRI Artefacts

In MRI, image formation involves spatially encoding MR signals with frequency- and phase-encoding gradients, sampling in k-space, and then Fourier reconstruction. Consequently, any error or limitation affecting the magnetic field, RF transmission, gradient performance, signal acquisition, patient position, or the sampling process may appear in the final image as an artefact.

A key principle is that artefacts often have predictable relationships with acquisition parameters. For example: Increasing receiver bandwidth can reduce chemical-shift and susceptibility-related displacement. Increasing field of view can reduce wrap-around. Increasing matrix size can improve spatial resolution. Shortening echo time can reduce susceptibility-related signal loss.

Increasing parallel imaging can shorten acquisition time but may reduce signal-to-noise ratio. Radial sampling can reduce certain motion artefacts but may generate streak artefacts if sampling is inadequate. Dedicated metal artefact reduction sequences can reduce distortion but often increase acquisition time.

So, artefact management should not be considered as an isolated post-processing procedure but is fundamentally connected to MRI protocol design.

IV. Motion Artefacts

4.1 Mechanism

Motion is among the most common causes of degraded MRI examinations. Because MRI data are acquired sequentially in k-space rather than as a single instantaneous measurement, movement during acquisition results in inconsistent spatial information. Motion can be random, periodic, respiratory, cardiac, vascular, gastrointestinal, swallowing-related, or related to patient discomfort.

Motion artefacts are particularly prominent in the phase-encoding direction.

4.2 Imaging appearance

Typical appearances include: repeated anatomy, ghosting, blurring, signal misregistration, incomplete suppression and anatomical discontinuity.

Periodic motion tends to produce regularly spaced ghost images, whereas irregular motion may produce less predictable blurring and loss of spatial resolution.

The 2022 RadioGraphics primer notes that gating can reduce periodic movement such as respiration and cardiac motion, whereas random movement may require immobilisation, radial acquisition, faster sequences, or other motion-reduction techniques.[2]

4.3 Causes

Important causes include: patient anxiety, pain, inadequate immobilisation, long acquisition time, respiratory motion, cardiac pulsation, swallowing, bowel movement, paediatric movement, neurological disorders, and inability to cooperate.

4.4 Practical correction

The first approach should be to prevent causes that can produce artefact. So

- explain the examination clearly to the patient,
- ensure patient comfort,
- provide appropriate cushions and immobilisation,
- minimise examination duration,
- use respiratory or cardiac gating when appropriate,
- use breath-hold techniques,
- select faster sequences,
- change phase-encoding direction when this moves the artefact away from the region of interest.

In cardiac MRI, ECG gating and respiratory control are fundamental. Cardiac MRI study papers similarly emphasise breath-holding, respiratory navigation, and ECG gating as methods for controlling respiratory and cardiac motion.[5], [6] .

4.4 Modern approaches:

Motion correction has increasingly incorporated: radial sampling, PROPELLER/BLADE techniques, prospective motion correction, navigator-based correction, retrospective correction, image-registration techniques, deep learning. [7], [8] .

Recently, deep-learning approaches have been extensively investigated for retrospective MRI motion correction. Spieker et al. reviewed learning-based methods and highlighted that MRI motion correction remains challenging because of the diversity of sequences, anatomies, pathologies, and motion patterns.[8]. A 2026 systematic review and meta-analysis further reported substantial promise for AI-based motion artefact detection and correction. Still, they identified limited generalizability, dependence on suitable training data, and risk of visual distortions as major limitations. [9]

V. Aliasing or Wrap-Around Artefact

5.1 Mechanism

Aliasing artefact occurs when the field of view used during acquisition is smaller than the anatomy being sampled. Structures that are outside the selected field of view are mapped to the opposite side of the image due to aliasing. It most commonly occurs in the phase-encoding direction. In three-dimensional imaging, wrap-around may also occur in the slice or slab direction.

5.2 Appearance

Anatomy outside the FOV appears superimposed on the opposite side of the image. This is easy to recognise because the anatomy mapped inside the FOV maintains recognisable anatomical characteristics but appears displaced.

5.3 Correction:

Practical solutions include: increasing the field of view, increasing phase oversampling, changing phase-encoding direction and applying saturation bands.

Noda et al. specifically recommend appropriate FOV and phase-encoding direction planning, with additional oversampling considerations for three-dimensional acquisitions to avoid wrap-around artefact.[2]

As mentioned in a study, aliasing can be compensated for by increasing the FOV, placing saturation bands on areas outside the desired FOV to prevent unwanted signal from folding back into the image (4), changing the phase- and frequency-encoding directions, and oversampling in the phase- or frequency-encoding direction.[3] .

VI. Gibbs or Truncation Artefact

As low sampling leads to aliasing artefacts, an insufficient extent of sampling from truncation can create another artefact in the spatial domain[3] . Gibbs artefact is caused by the reason that the MR signal is truncated in k-space because it has to be finitely sampled.[3] . Thus, due to loss of high spatial frequency information, Gibbs artefact is produced.[3] .

Appearance:

It typically appears as alternating bright and dark lines adjacent to sharp high-contrast boundaries. Truncation artefact is typically more severe in the phase-encoding direction because Gibbs ringing is more prominent at the lower spatial resolutions used in this direction to reduce imaging time.[3].

Examples include

- spinal cord,
- cerebrospinal fluid interfaces,
- brain-CSF boundaries,
- cardiac structures.

The artefact may occasionally mimic pathology, particularly in the spinal cord.

Correction:

To reduce this artefact, we can use few approaches that include: increasing acquisition matrix size, increasing spatial resolution, using appropriate filtering to smoothen the image, and increasing sampling of high spatial frequencies but causes increase in acquisition time and decreasing the SNR[3] .

However, aggressive filtering may reduce genuine anatomical detail.

VII. Chemical-Shift Artefact:

Chemical-shift artefacts arise from the difference in resonance frequency between fat and water.

Two major manifestations are recognized.

7.1 Type 1 chemical shift

Type I chemical-shift artefact results in spatial misregistration between fat and water and occurs predominantly along the frequency-encoding (readout) direction [1], [2], [3] . It typically appears as a bright band on one side and a dark band on the opposite side of a fat–water interface, because the frequency displacement causes fat and water signals to be assigned to adjacent spatial locations. [1], [3]

The magnitude of this artefact is influenced by the difference between the resonance frequencies of fat and water, the magnetic-field strength, and the receiver bandwidth.[1], [3], [10]

7.2 Type 2 chemical shift

Type 2 chemical-shift artefact is associated with opposed-phase cancellation and is particularly relevant to gradient-echo imaging. [1], [3]

When fat and water protons within the same voxel are acquired at an opposed-phase echo time, their signals partially or completely cancel, producing a dark signal at fat–water interfaces.[1], [3]

7.3 Reduction strategies

Chemical-shift artefact can be reduced by increasing the receiver bandwidth, which decreases the spatial displacement produced by the fat–water frequency difference. [2], [3], [10]

Increasing the frequency-encoding matrix can also reduce the apparent displacement associated with chemical-shift artefact.[2], [3]

Selection of an appropriate frequency-encoding direction can help position chemical-shift artefact away from structures of diagnostic interest.[3]

Fat-suppression techniques can reduce artefacts associated with fat signal and improve visualization of fat–water interfaces. [2], [3]

Appropriate selection of echo time and other sequence parameters is important, particularly for gradient-echo imaging in which in-phase and opposed-phase signal behaviour affects image appearance.[1], [10]

Water–fat separation techniques, including Dixon-based methods, may also be used when appropriate to separate fat and water signals and improve image interpretation.[3]

VIII. Susceptibility Artefact

Susceptibility artefacts in MRI results from local variations in magnetic susceptibility between adjacent tissues or materials, which produce local perturbations of the main magnetic field (B0) and consequently cause frequency shifts, signal loss, and geometric distortion. [1], [3], [10]

Common sources of susceptibility differences include air–tissue interfaces, blood products, calcification, metallic objects, and surgical materials. These effects are particularly prominent where there is a large difference in magnetic susceptibility between adjacent structures. [1], [3], [10]

Susceptibility artefacts generally become more pronounced with increasing magnetic-field strength, longer echo time (TE), and gradient-echo-based sequences, because these conditions increase the influence of local field variations on the acquired signal. [1], [3], [10]

8.1 Imaging Appearance

Susceptibility effects may produce signal voids or signal loss, geometric distortion, signal pile-up, and spatial misregistration around regions with substantial magnetic-field perturbation.[1], [3], [10]

The appearance and severity of the artefact depend on the susceptibility difference, magnetic-field strength, sequence type, echo time, voxel dimensions, and orientation of the acquisition relative to the susceptibility interface. [3], [10]

Susceptibility artefacts are particularly important in brain MRI, susceptibility-weighted imaging, diffusion-weighted and echo-planar imaging, and examinations involving metallic implants[3], [10], [11].

8.2 Reduction Strategies

Susceptibility-related signal loss and distortion can be reduced by using a shorter TE, because there is less time for local frequency differences to produce phase dispersion and signal loss[3], [10]. When clinically appropriate, spin-echo or fast spin-echo techniques may be preferred over gradient-echo techniques, because the refocusing pulse reduces some susceptibility-related dephasing effects[3], [10]. Increasing the receiver bandwidth can reduce the spatial displacement associated with local off-resonance frequencies and therefore decrease susceptibility-related geometric distortion[3], [10].

Using smaller voxel dimensions can reduce intravoxel dephasing and improve spatial localization, although this may result in reduced signal-to-noise ratio or increased acquisition time[3], [10]. Appropriate selection of the phase-encoding direction can help position susceptibility-related distortion away from clinically important anatomy when the artefact is directionally predictable[3]. For examinations involving metallic implants, dedicated metal-artefact-reduction techniques such as view-angle tilting (VAT), SEMAC, and MAVRIC can provide substantially greater artefact reduction than conventional parameter optimization alone. [11]

8.3 Practical Recognition

A susceptibility artefact should be suspected when signal loss, geometric distortion, or signal pile-up occurs adjacent to metal, air–tissue interfaces, blood products, or other structures with markedly different magnetic susceptibility. [1], [3], [10]

Recognition is particularly important because susceptibility-related signal abnormalities can sometimes mimic pathology or obscure clinically relevant anatomy.[1], [3]

IX. Metal-Induced Artefacts

Metal is a clinically important source of MRI artefacts because metallic implants can cause substantial local magnetic-field perturbations. These effects may produce signal loss, signal pile-up, geometric distortion, failed fat suppression, and spatial misregistration, potentially obscuring anatomy adjacent to implants [11], [12], [13], [14].

Metal-related artefacts are encountered around hip and knee prostheses, spinal implants, fixation devices, dental hardware, surgical clips, and vascular devices. Recognition is important because artefact-related appearances may obscure anatomy or be mistaken for pathology[11], [12], [14].

9.1 Conventional Optimization:

Initial optimization for controlling metal artefacts include shortening TE, increasing receiver bandwidth, reducing voxel size, increasing the acquisition matrix, using fast spin-echo rather than gradient-echo techniques when appropriate, and selecting the frequency-encoding direction to control the location of distortion. These approaches can reduce metal-related signal loss and geometric displacement but may involve trade-offs in SNR, spatial resolution, or scan time[11], [12], [13].

9.2 Dedicated Metal-Artefact Reduction Techniques:

View-angle tilting (VAT) applies an additional gradient during readout to reduce in-plane geometric distortion caused by off-resonance near metallic implants [11], [12], [13].

Slice-encoding for metal artefact correction (SEMAC) adds additional spatial encoding in the slice direction and is designed to address through-plane distortion that conventional techniques cannot adequately correct. Its major limitation is increased acquisition time[11], [13], [14].

Multi acquisition variable-resonance image combination (MAVRIC) acquires images at multiple frequency offsets and combines them to recover signal displaced by metal-induced field variations. It can substantially reduce metal-related artefacts, although acquisition time and image characteristics may be affected [11], [13], [14].

9.3 Practical Approach

Contemporary metal-artefact management combines parameter optimization, acquisition strategies, dedicated sequences, and reconstruction methods rather than relying on a single technique. Current approaches include VAT, SEMAC, MAVRIC, parallel imaging, gradient-warping correction, iterative reconstruction, and emerging deep-learning methods [11], [13], [14].

X. Fat-Suppression Failure:

Fat-suppression failure in MRI image occurs when the technique cannot adequately separate fat signal from water signal because of magnetic-field nonuniformity, susceptibility effects, or limitations of the selected fat-suppression method. These problems are particularly relevant near metallic implants and in anatomically challenging regions[2], [3], [11], [12], [13], [14], [15].

10.1 Causes and Appearance

Common causes include B0 inhomogeneity, B1-related nonuniformity, susceptibility from metallic implants, inadequate shimming, and limitations of frequency-selective fat suppression. The resulting images may show residual, patchy, geographic, or asymmetric fat signal, which can reduce lesion conspicuity and potentially mimic pathology [2], [3], [11], [12], [13], [14], [15].

10.2 Practical Fat-Suppression Techniques

The appropriate solution depends on the anatomical region, sequence, field strength, and underlying cause.

- Optimize shimming when B0 nonuniformity is responsible for incomplete frequency-selective suppression [3].
- STIR can provide more robust fat suppression in areas with substantial B0 inhomogeneity or susceptibility, although it has limitations and is not interchangeable with frequency-selective techniques in all clinical applications [2], [3] .
- Dixon-based techniques use chemical-shift information to separate water and fat and can provide more uniform fat suppression when conventional frequency-selective suppression is unreliable [3]
- Near metallic implants, susceptibility-induced frequency shifts can cause both geometric distortion and failure of conventional fat suppression. Dedicated metal-artefact-reduction approaches such as VAT, SEMAC, and MAVRIC may improve visualization and fat suppression around implants. [11], [12], [13], [14]
- Appropriate sequence and parameter optimisation, including bandwidth and other acquisition parameters, can further reduce artefact-related degradation [11], [12], [13], [14].

XI. RF and Zipper Artefacts

Radiofrequency (RF) interference is caused by unwanted RF noise entering the MRI system. The RF shielding of the MRI room is designed to exclude external RF signals; however, stray RF noise can enter the system, for example from electronic equipment brought into or operating near the MRI environment [3]

The characteristic appearance is a narrow line or band across the image, often resembling a zipper; therefore, RF interference is also referred to as the zipper artefact. The location and appearance of the artefact depend on the characteristics of the interfering RF signal [3]

11.1 Common Causes

Common sources include RF noise from electronic devices and inadequate or compromised RF shielding of the MRI room. External devices may produce RF signals within a frequency bandwidth that generates visible lines or bands in the reconstructed image [3]

11.2 Recognition:

Zipper artefact is seen as a linear or band-like signal across the MRI image. it is not anatomical or patient-related abnormality. Such continuous appearance of patterns across examinations should prompt consideration of an environmental or equipment-related RF source [3]

11.3 Practical Correction:

The primary approach is to identify and eliminate the source of RF interference into the MRI scanner room. This includes ensuring that the MRI examination-room door is properly closed during the exam and checking whether the peripheral electronic devices are MRI compatible. Removing the source of RF interference should eliminate the artefact [3].

XII. B_0 Inhomogeneity

B0 inhomogeneity refers to spatial nonuniformity of the main static magnetic field. MRI assumes a sufficiently homogeneous B0 field for accurate spatial encoding and frequency-dependent techniques; deviations from this assumption can produce image artefacts [3]

B0 inhomogeneity may arise from imperfect shimming, patient anatomy, air–tissue interfaces, metallic objects or implants, and the use of higher

magnetic-field strengths. Local susceptibility differences can create spatial variations in the magnetic field, particularly at air–tissue and metal–tissue interfaces [3], [10]

12.1 Imaging Effects

The appearance and severity of B0-related artefacts depend on the magnitude and spatial distribution of the field variation and on the sequence used. B0 inhomogeneity can cause geometric distortion, signal loss, inadequate fat suppression, and off-resonance banding, with susceptibility-related effects becoming more prominent at higher field strengths [3], [10]

These effects are particularly important in gradient-echo, balanced SSFP, and echo-planar imaging, which are sensitive to local frequency offsets and magnetic-field variations [3]

12.2 Practical Correction

The first-line approach for B0-related problems is appropriate shimming over the region of interest. Additional strategies depend on the artefact and sequence and may include shortening TE, increasing receiver bandwidth, selecting a less B0-sensitive sequence, changing the phase-encoding direction, or using an alternative acquisition technique [3].

For susceptibility-related distortion, spin-echo techniques are generally less sensitive than gradient-echo techniques, while shorter TE, smaller voxel size, increased receiver bandwidth, and appropriate phase-encoding orientation can reduce the severity of the artefact [3].

XIII. B1 Inhomogeneity and Dielectric Effects

B1 inhomogeneity refers to spatial variation in the applied radiofrequency (RF) magnetic field. Nonuniformity of the RF transmit field can produce spatial variations in image signal intensity and becomes more relevant with increasing magnetic-field strength [3], [10]

At higher field strengths, particularly 3 T, RF wavelength effects within tissue can produce dielectric or standing-wave phenomena. These may result in regional signal enhancement, signal loss, and overall image nonuniformity, particularly in large body regions [3], [10]

13.1 Imaging Appearance

B1-related nonuniformity may appear as regional bright or dark areas and spatial variations in signal intensity. It can also contribute to nonuniform fat suppression [3], [10].

13.2 Practical Correction

Practical approaches include:

- RF shimming to improve transmit-field homogeneity [3].
- Dielectric pads to modify the local RF field and reduce signal nonuniformity [3].
- Multichannel RF transmission/parallel transmission where available[3].

Using a lower field strength, such as 1.5 T instead of 3 T when clinically appropriate [3], [10].

The choice of correction depends on scanner hardware, field strength, anatomy, and the clinical application [3], [10].

XIV. Flow and Pulsation Artefacts

Flow-related artefacts arise from moving blood, cerebrospinal fluid (CSF), or other moving spins during MRI acquisition. Moving spins can accumulate phase shifts that are not completely refocused, producing signal loss and ghosting. The appearance and severity depend on flow velocity, direction, sequence, and acquisition timing. [1], [3], [16] .

Pulsatile motion associated with the cardiac cycle and CSF flow can produce periodic ghosting, particularly along the phase-encoding direction. Such artefacts may obscure anatomy or mimic pathology. [1], [16], [17].

14.1 Imaging Appearance

Common appearances include:

- Ghosting from periodic flow or pulsation.
- Signal loss associated with flowing spins.

- Intravascular signal changes depending on sequence and flow characteristics.
- Phase-encoding direction–dependent artefacts[1], [3], [16].

Flow artefacts are particularly important in cardiac, vascular, brain/spine, and abdominal MRI, where blood, CSF, respiration, and other physiological motion may influence image quality.[1], [3], [16], [17].

14.2 Practical Correction

Management depends on the source of the artefact and the sequence being used:

- Flow compensation (gradient-moment nulling) can reduce phase errors caused by moving spins [3]
- Spatial prestarvation/saturation bands can suppress signal from inflowing spins before acquisition [3], [16].
- Cardiac or respiratory gating/synchronization can reduce artefacts related to periodic physiological motion [1], [3], [16], [17].
- Appropriate sequence selection can reduce sensitivity to flow and pulsation.
- In cardiac MRI, targeted shimming and reduction of TR can help mitigate flow-related band artefacts in bSSFP imaging [5]
- Changing the phase-encoding direction may move residual ghosting away from the region of diagnostic interest [2]

14.3 Recognition by the Technologist

Suspect a flow or pulsation artefact when repeated structures or ghost images occur at regular intervals, particularly adjacent to major vessels, the heart, or CSF spaces. Recognition of the direction and periodicity of the artefact can help distinguish it from true anatomical abnormalities.[1], [2], [16].

XV. Cross-Talk Artefact

Cross-talk occurs when the RF excitation profile of one slice partially excites adjacent slices. Because an RF pulse does not have a perfectly rectangular spatial profile, tissue near the boundaries of neighboring slices may receive additional RF excitation and become partially saturated. This reduces the available longitudinal magnetisation when the adjacent slice is subsequently acquired [1], [2], [10], [18].

15.1 Imaging Appearance

Cross-talk typically produces reduced or nonuniform signal intensity between adjacent slices. The effect is particularly relevant in multislice 2D acquisitions when slices are closely spaced or acquired with insufficient separation [1], [2], [10], [18].

In multi-angle acquisitions, such as oblique spinal imaging, overlapping excitation profiles can produce band-like areas of signal loss in adjacent slices [1], [2], [18]

15.2 Practical Correction

Cross-talk can be reduced by:

- Increasing the interslice gap, which decreases overlap between the excitation profiles of neighbouring slices.[2], [18]
- Using interleaved acquisition, allowing greater longitudinal magnetisation recovery between excitation of neighbouring slices [2], [18]
- Optimising the RF pulse/slice profile to reduce excitation outside the prescribed slice [18]
- Using 3D acquisition when clinically appropriate, which avoids the same type of adjacent-slice excitation interaction encountered in conventional multislice 2D acquisition [18]

Increasing the interslice gap reduces cross-talk but creates unsampled tissue between slices, which can compromise anatomical coverage and potentially miss small lesions. Therefore, select the gap according to the clinical protocol rather than increasing it indiscriminately. [2], [18]

15.3 Recognition by the Technologist

Cross-talk should be suspected when adjacent slices show unexpected signal reduction or nonuniformity, particularly in closely spaced multislice 2D

acquisitions. Reviewing the slice gap, slice orientation, and acquisition method can help identify the artefact. [1], [2], [18]

XVI. Partial-Volume Artefact

Partial-volume effects occur when a single voxel contains more than one tissue type. The measured signal represents contributions from the tissues within that voxel, which can reduce boundary contrast and affect the accurate depiction or measurement of small anatomical structures. [1], [2], [19].

The effect becomes more pronounced when voxel dimensions are large relative to the structures being imaged, particularly with thick slices and limited spatial resolution. This can obscure small lesions, blur tissue boundaries, and introduce errors in anatomical volume measurements. [19], [20].

16.1 Imaging Appearance

Partial-volume effects may appear as blurred or poorly defined tissue boundaries, reduced conspicuity of small structures, and inaccurate estimates of lesion size or volume. The impact depends on voxel dimensions, slice orientation, tissue contrast, and the structure's size and position relative to the voxel. [19], [20].

16.2 Practical Correction

Partial-volume effects can be reduced by:

- Using thinner slices to improve spatial resolution in the slice direction.[20]
- Reducing voxel dimensions when higher spatial resolution is required [19], [20]
- Using isotropic 3D acquisitions, where appropriate, to support multiplanar reconstruction with consistent spatial resolution [20]
- Selecting the imaging plane carefully to depict small structures and tissue boundaries better [20]

These approaches involve trade-offs: smaller voxels generally reduce signal-to-noise ratio (SNR), while higher-resolution acquisitions may require longer scan times. Protocol optimisation should therefore balance spatial resolution, SNR, acquisition time, and the diagnostic task. [19], [20] .

16.3 Recognition by the Technologist

Consider partial-volume effects when small structures or lesions appear poorly defined, particularly when their dimensions approach or fall below the acquired voxel dimensions. Review slice thickness, voxel size, and imaging orientation to determine whether acquisition parameters limit anatomical depiction. [19], [20]

XVII. Echo-Planar Imaging Distortion

Echo-planar imaging (EPI) is a rapid MRI acquisition technique widely used in diffusion-weighted imaging (DWI), diffusion tensor imaging (DTI), functional MRI (fMRI), and selected perfusion applications. However, EPI is particularly sensitive to off-resonance effects because it acquires multiple k-space lines sequentially with relatively low effective bandwidth in the phase-encoding direction. Local magnetic-field inhomogeneity can therefore produce substantial spatial displacement [2], [3], [10], [21].

17.1 Causes and Imaging Appearance

EPI distortion is commonly associated with B0 inhomogeneity and susceptibility differences, particularly at air–tissue interfaces such as the paranasal sinuses and skull base. These effects may produce:

- Geometric distortion: stretching, compression, or displacement of anatomical structures.
- Signal loss: intravoxel dephasing in regions of strong susceptibility variation.
- Image blurring: signal decay during prolonged EPI readouts.
- Spatial misregistration: mismatch between EPI images and anatomical reference images [3], [10], [21] .

Distortion is often most prominent along the phase-encoding direction. Its severity depends on local off-resonance, effective echo spacing, readout duration, field strength, and acquisition parameters. [21], [22] .

17.2 Practical Correction

Correction should be selected according to the dominant artefact:

- Improve B0 shimming to reduce local magnetic-field inhomogeneity [3], [10], [21] .
- Use parallel imaging to shorten the effective EPI readout and reduce geometric distortion, while accounting for potential SNR loss [21] .
- Reduce echo spacing where scanner hardware and protocol permit, thereby reducing phase-encoding displacement [21] .
- Acquire reversed phase-encoding images when supported by the protocol, enabling distortion estimation and correction during reconstruction [21] .
- Use field-map-based correction to estimate off-resonance-related spatial displacement and unwarp distorted images [22] .
- Consider alternative or segmented EPI acquisitions when clinically appropriate and when the reduction in distortion justifies the additional acquisition or reconstruction complexity [21] .

These approaches do not necessarily recover signal that has been completely lost because of severe intravoxel dephasing. Geometric correction and signal-loss mitigation should therefore be considered separate objectives. [3], [10], [21] .

17.3 Recognition by the Technologist

Suspect EPI distortion when anatomical structures appear displaced, stretched, compressed, or poorly aligned with corresponding structural images, particularly near air–tissue interfaces. The technologist should review shimming, phase-encoding direction, echo spacing, and available distortion-correction options. [2], [3], [21], [22] .

XVIII. bSSFP Banding Artefact

Balanced steady-state free precession (bSSFP) is widely used in cardiac MRI because it provides high signal-to-noise efficiency and strong contrast between blood and myocardium. However, it is sensitive to off-resonance effects from magnetic-field inhomogeneity, which can produce characteristic dark bands and localised signal loss. [3], [5], [10], [23]

Banding occurs when local off-resonance shifts the steady-state signal into a signal-minimum region of the bSSFP frequency-response profile. Field inhomogeneity, repetition time (TR), and RF phase-cycling conditions influence the artefact. It can be particularly problematic at higher field strengths, including 3 T cardiac imaging. [5], [10], [23] .

18.1 Imaging Appearance

The characteristic appearance is one or more dark bands crossing anatomical structures, with reduced signal intensity or signal void within the affected regions. In cardiac MRI, these bands may cross the myocardium or blood pool and can mimic anatomical abnormalities. Their position depends on the local magnetic field and acquisition settings. [5], [23]

18.2 Practical Correction

Banding can be reduced by:

- Reducing TR: a shorter TR decreases the phase accumulated from off-resonance between successive RF excitations [5], [23]
- Improving B0 shimming: optimise field homogeneity over the region of interest, particularly the heart in cardiac MRI.[3], [5], [23]
- Performing a frequency scout: acquire images at different centre frequencies and select the setting that moves banding away from the region of diagnostic interest [5]
- Using phase-cycled acquisitions: acquire images with different RF phase-cycling angles and combine them to reduce banding, where the additional scan time is acceptable [23], [24]
- Considering an alternative sequence when banding persists and compromises diagnostic interpretation[3], [5]

These measures may reduce or relocate banding, but they do not guarantee complete elimination. The choice depends on the clinical application, available

scanner options, and acceptable acquisition time. [5], [23], [24]

18.3 Recognition by the Technologist

Suspect a bSSFP banding artefact when a sharply defined dark band crosses high-signal structures and does not conform to expected anatomy. In cardiac MRI, comparison with another sequence or a frequency-scout acquisition can help establish whether the apparent abnormality is artefactual. [5], [23]

XIX. Cardiac MRI Artefacts

Cardiac MRI (CMR) is susceptible to artefacts because image acquisition must account for continuous cardiac motion, respiration, blood flow, and sequence-specific effects. These artefacts may obscure myocardial abnormalities or mimic disease, making recognition and appropriate correction essential. [5], [6], [16]

Common artefacts and their management

- Cardiac and respiratory motion: May cause ghosting, blurring, and misregistration. ECG synchronisation, breath-holding, respiratory navigation, or free-breathing real-time imaging can improve image quality, depending on patient cooperation and rhythm. [5], [6], [16]
- bSSFP banding and flow artefacts: Off-resonance may produce dark bands or signal loss, particularly at 3 T. Targeted cardiac shimming, shorter repetition time (TR), and frequency-scout imaging can help reduce these artefacts. [5], [6]
- Dark-rim artefact: Appears as a transient dark band at the blood–myocardium interface during first-pass perfusion imaging and may mimic a subendocardial perfusion defect. Its transient appearance and fading over subsequent cardiac cycles help distinguish it from true pathology [5], [6].
- Incomplete myocardial nulling: Incorrect inversion-time selection during late gadolinium enhancement (LGE) imaging can alter myocardial signal and lead to misinterpretation. A T1 scout can guide inversion-time selection; phase-sensitive inversion recovery (PSIR) can reduce dependence on precise inversion time. [5]
- Device-related artefacts: Cardiac implantable electronic devices can cause signal voids, distortion, and false high signal that may mimic myocardial scar. Wideband LGE techniques can reduce these artefacts when available and appropriate [5], [25]
- Phase-contrast aliasing: Occurs when blood-flow velocity exceeds the selected velocity-encoding (VENC) range, causing incorrect velocity representation. Increasing VENC and, where appropriate, applying phase-unwrapping post-processing can help correct it [5], [16] .

Practical approach: Review the sequence and artefact pattern, correlate suspicious findings across sequences or imaging planes, and repeat or modify the acquisition as needed. Do not interpret an apparent perfusion defect, scar, or focal signal abnormality in isolation when an artefact is plausible. [5], [6] .

XX. Advanced Artefact-Reduction Techniques

Advanced acquisition and reconstruction techniques can reduce scan time and improve motion resistance, but their effectiveness depends on the sequence, anatomy, and reconstruction settings. They may also introduce noise, blurring, or reconstruction artefacts. [2], [3]

20.1 Parallel Imaging

Parallel imaging uses spatial information from multiple receiver coils to accelerate acquisition by under-sampling k-space. Shorter acquisition times reduce motion, but excessive acceleration or unfavourable coil geometry may reduce signal-to-noise ratio (SNR), amplify noise, and cause residual aliasing or reconstruction artefacts.[2], [3]

20.2 Compressed Sensing

Compressed sensing reconstructs images from under-sampled k-space using sparsity constraints. It can shorten acquisition and reduce motion-related degradation, particularly in suitable dynamic or free-breathing examinations. However, the sampling pattern and reconstruction settings may affect image

texture, sharpness, and residual artefacts.[3], [26], [27]

20.3 PROPELLER/BLADE and Radial Sampling

Radial and rotating-blade techniques repeatedly sample the centre of k-space, making them relatively resistant to certain in-plane motion effects. They can be useful in brain and abdominal imaging and in patients who cannot remain completely still. Limitations include longer acquisition in some implementations, blurring, and streak artefacts when sampling is inadequate or motion is substantial. [2], [3]

Select these techniques based on the suspected artefact and clinical requirement rather than applying them routinely to every examination.

20.4 Low-Field MRI as an Artefact-Reduction Strategy

Lower-field MRI can reduce susceptibility-related artefacts around metallic implants because magnetic-field perturbations generally decrease with field strength. Phantom studies comparing 0.55 T with 1.5 T and 3 T have demonstrated smaller metal-related artefacts at lower field strengths. A 2025 study of six patients with titanium total hip arthroplasty also reported reduced artefacts and higher diagnostic confidence at 0.55 T than at 3 T. However, these findings should not be generalised to every implant material or examination; lower-field systems may have lower signal-to-noise ratio, and the need for dedicated metal-artefact-reduction sequences remains dependent on the clinical application [11], [15], [28], [29]

XXI. Artificial Intelligence in MRI Artefact Correction

Artificial intelligence (AI), particularly deep learning, is being investigated for automated artefact detection, motion correction, denoising, bias-field correction, and image reconstruction. These methods may improve image quality and reduce the need for repeat acquisitions, but their performance varies with the imaging sequence, anatomy, training data, and artefact type [8], [30], [31] .

Recent reviews of AI-based motion correction report promising results but identify limited generalizability, dependence on representative training data, and inconsistent evaluation methods as important barriers to clinical implementation. [8], [9]

A further concern is that reconstruction algorithms may introduce smoothing or visually plausible but anatomically inaccurate features. Therefore, assess AI-corrected images for preservation of diagnostic anatomy and relevant pathology; improved visual appearance alone does not establish diagnostic accuracy. [9], [32] .

AI should currently be regarded as a developing adjunct to appropriate acquisition, artefact recognition, and conventional correction methods—not as a universal replacement for them.

XXII. Practical Troubleshooting of MRI Artefacts

A systematic approach can help identify artefact sources, select appropriate corrections, and avoid unnecessary repeat acquisitions. The correction should be guided by the artefact's appearance, spatial direction, sequence dependence, and clinical significance.[2], [3]

Step 1: Characterise the artefact. Determine whether it appears as ghosting, wrap-around, ringing, signal loss, geometric distortion, shading, or a zipper-like line. Note its direction and whether it occurs on one sequence or across multiple sequences.

Step 2: Identify the likely source. Consider patient motion, respiration, blood flow, field inhomogeneity, susceptibility, undersampling, coil problems, and external radiofrequency interference. Compare other sequences or previous images when available. [2], [3]

Step 3: Apply a targeted correction. Select the change most appropriate to the suspected cause—for example, improving immobilisation or gating for motion, increasing the field of view for aliasing, adjusting bandwidth or echo time for susceptibility-related distortion, or optimising shimming for field inhomogeneity. Use dedicated techniques when conventional adjustments are insufficient.[2], [3], [11]

Step 4: Evaluate the result. Compare the corrected images with the original acquisition. Confirm that the artefact has improved without unacceptable loss of signal, spatial resolution, or diagnostic information.

Step 5: Escalate persistent problems. If an artefact recurs across patients or sequences, investigate possible coil, hardware, or radiofrequency-interference causes. Follow local quality-control procedures and refer persistent equipment-related problems to qualified service personnel or an MRI physicist. [33]

The objective is not simply to produce a visually cleaner image, but to preserve the anatomical and pathological information required for diagnosis.

Table 2. Major MRI Artefacts, Recognition and Practical Management

Artefact	Typical appearance	Common cause	First-line correction
Motion/ ghosting	Blurring, repeated anatomy or ghosts	Patient, respiratory or cardiac motion	Immobilisation, breath-holding or gating; consider faster or motion-robust sequences
Aliasing (wrap-around)	Anatomy from outside the FOV appears over the image	FOV too small in the phase-encoding direction	Increase FOV, use phase oversampling or change phase-encoding direction
Gibbs ringing	Parallel bright and dark lines near sharp boundaries	Limited k-space sampling	Increase spatial resolution or matrix where appropriate
Chemical shift	Bright/dark bands at fat–water interfaces	Frequency difference between fat and water	Increase receiver bandwidth; use appropriate fat suppression
Susceptibility	Signal void, distortion or signal pile-up	Local magnetic-field differences, metal or air–tissue interfaces	Shorter TE, higher bandwidth, smaller voxels or a less susceptibility-sensitive sequence
RF/zipper	Narrow line or band across the image	External RF interference or shielding problems	Check the source of interference and RF-room integrity
B_0 inhomogeneity	Distortion, signal loss or uneven fat suppression	Field nonuniformity, anatomy, metal or inadequate shimming	Optimise shimming and sequence parameters
B_1 inhomogeneity	Regional bright/dark shading	Nonuniform RF transmission or reception	Optimise coil positioning and RF settings; consider dielectric management when appropriate.
Flow/pulsation	Ghosting or signal loss near vessels or CSF spaces	Moving spins and pulsatile flow	Flow compensation, pre-saturation or cardiac gating, depending on the sequence
Cross-talk	Reduced signal in adjacent slices	Incomplete slice-selective excitation	Increase interslice gap or use interleaved acquisition
Partial-volume effect	Blurred boundaries or obscured small structures	Multiple tissues within a voxel	Reduce voxel dimensions or slice thickness where appropriate
EPI distortion	Stretching, compression or displacement, often near air–tissue interfaces	Off-resonance and susceptibility during EPI acquisition	Improve shimming, reduce effective EPI readout duration or apply validated distortion correction.
bSSFP banding	Dark bands crossing anatomy	Off-resonance in the steady-state signal profile	Improve shimming, shorten TR or use frequency-scout/phase-cycling methods

Artefact	Typical appearance	Common cause	First-line correction
Metal-related artefact	Signal void, distortion, pile-up or failed fat suppression	Metal-induced field perturbations	High bandwidth and dedicated methods such as VAT, SEMAC or MAVRIC when available

Abbreviations: FOV, field of view; TE, echo time; TR, repetition time; EPI, echo-planar imaging; bSSFP, balanced steady-state free precession; RF, radiofrequency; CSF, cerebrospinal fluid; VAT, view-angle tilting; SEMAC, slice-encoding for metal artefact correction; MAVRIC, multi-acquisition variable-resonance image combination.

XXIII. Role of the MRI Technologist

MRI technologists play a central role in artefact prevention and recognition because they can minimise many artefacts through appropriate patient preparation, positioning, coil selection, and acquisition-parameter optimisation. Before scanning, technologists should review relevant surgical and implant history, remove unnecessary metallic objects, position and immobilise the patient appropriately, and provide clear instructions to minimise motion.

During acquisition, they should verify coil positioning, field of view (FOV), and phase-encoding direction; recognise characteristic artefacts; and apply targeted corrections when technically appropriate. Document and investigate persistent or newly appearing artefacts, particularly when similar abnormalities occur across multiple examinations. Consider repeat acquisition when necessary and clinically justified. These practices support image quality while reducing avoidable repeat scans. [2], [3], [7], [34].

XXIV. Quality Assurance and Equipment Monitoring

Routine MRI quality assurance is essential to detect equipment-related artefacts and identify performance degradation before it compromises diagnostic image quality. Relevant QA checks include geometric accuracy, signal-to-noise ratio (SNR), image uniformity, radiofrequency (RF) performance, gradient performance, coil integrity, frequency stability, ghosting, and measurement reproducibility.

A newly appearing artefact, particularly one recurring across multiple patients or examinations, should prompt investigation rather than being attributed automatically to patient-related factors. The technologist should document the problem and notify the responsible service personnel or medical physicist when indicated. QA procedures and testing intervals should follow the manufacturer's recommendations and the institution's established quality-control programme [33], [34].

XXV. Clinical Impact of MRI Artefacts

MRI artefacts can compromise diagnostic interpretation by obscuring anatomical structures, reducing lesion conspicuity, or producing appearances that mimic disease. Signal loss and geometric distortion may conceal small lesions or abnormalities near metallic implants, while artefacts affecting signal intensity, diffusion, perfusion, or tissue boundaries may limit reliable lesion characterisation. Conversely, artefact-related abnormalities may be mistaken for pathology, potentially prompting unnecessary investigations.

When artefacts substantially reduce diagnostic image quality, repeat acquisition may be necessary, increasing examination time, scanner utilisation, and patient inconvenience. In examinations involving implants or postoperative anatomy, artefacts may also limit assessment of complications or disease recurrence. Recognising artefacts and determining whether they affect the clinical question are therefore essential to avoid misinterpretation and guide appropriate corrective action. [1], [2], [3], [7], [11]

XXVI. Discussion

MRI artefact management requires more than recognising image abnormalities; it requires understanding the physical or technical mechanisms that produce them. A mechanism-based approach links characteristic appearances to likely causes and supports targeted correction during acquisition. For

example, wrap-around suggests inadequate field of view (FOV), zipper artefacts may indicate radiofrequency interference, and signal loss adjacent to metal may reflect susceptibility-related field perturbations. This approach provides a practical framework for MRI technologists and radiologists while helping avoid unnecessary repeat acquisitions. [1], [2], [3], [7]

Recent developments have expanded the options available for difficult imaging situations. Metal-artefact-reduction techniques, including view-angle tilting (VAT), slice-encoding metal artefact correction (SEMAC), and multi-acquisition variable-resonance image combination (MAVRIC), can improve visualisation near implants. However, residual distortion and trade-offs in scan time or image quality may remain. Lower-field MRI has also shown potential for reducing susceptibility-related artefacts around certain metallic implants. However, results from phantom and limited clinical studies should not be generalised to all implant materials or examinations. [11], [15], [28] .

AI-based methods are being investigated for automated artefact detection, motion correction, denoising, and image reconstruction. These methods may reduce some artefacts and, in selected applications, the need for repeat acquisition. Nevertheless, performance depends on the training data, acquisition protocol, anatomy, and artefact type. A visually improved image does not necessarily guarantee preservation of diagnostic information; therefore, AI-corrected images require appropriate clinical validation and assessment for loss or alteration of anatomical detail. [8], [9], [30], [31] .

Overall, effective artefact management depends on combining prevention, optimised acquisition parameters, dedicated correction sequences, appropriate reconstruction methods, and systematic image-quality assessment. No single technique suits every artefact. The preferred strategy should address the suspected mechanism while preserving diagnostic information, with persistent or unexplained artefacts prompting equipment investigation when indicated.

XXVII. Limitations

This article is a narrative review intended to provide a clinically oriented overview of common MRI artefacts, their recognition, and available mitigation strategies. It was not designed as a systematic review or meta-analysis; therefore, the literature selection may not encompass all relevant studies, and the findings should not be interpreted as an exhaustive or quantitatively ranked assessment of artefact-reduction methods.

The evidence discussed is heterogeneous in study design, scanner field strength, anatomical region, acquisition protocol, and outcome assessment. Some techniques have been evaluated primarily in phantom or feasibility studies, whereas others have been investigated in clinical populations. This limits direct comparison and may restrict the generalizability of reported findings. Evidence for AI-based methods is particularly difficult to compare because studies differ in training datasets, reconstruction approaches, validation procedures, and image-quality metrics.

Furthermore, reduced artefact severity or improved visual image quality does not necessarily establish improved diagnostic accuracy or patient outcomes. Artefact-reduction methods may involve trade-offs in scan time, signal-to-noise ratio, spatial resolution, tissue contrast, and image texture. The appropriate technique must therefore be selected based on the artefact, clinical indication, available scanner technology, and the need to preserve diagnostic information.

XXVIII. Future Directions

Future developments in MRI artefact management are likely to focus on automated artefact detection, prospective motion monitoring, adaptive acquisition, and more efficient reconstruction. AI-based methods may help identify artefact patterns and recommend corrective actions, while physics-informed reconstruction and combinations of parallel imaging and compressed sensing may support faster acquisitions. Further improvements in low-field MRI and dedicated metal-artefact-reduction techniques may also expand imaging options for patients with metallic implants [8], [9], [11], [28], [30], [31].

Another important direction is integrating image-quality assessment into the acquisition workflow. In principle, automated systems could identify motion, inadequate field of view, nonuniform fat suppression, or recurring equipment-related artefacts and alert the technologist before the examination is completed. However, these applications require appropriate technical and clinical validation before routine implementation. Future methods should be evaluated not only for artefact reduction and computational efficiency but also for preservation of anatomical detail, diagnostic accuracy, and reproducibility. The long-term objective is to combine reliable artefact prevention, targeted correction, and expert clinical oversight rather than rely on post-processing alone.

XXIX. Conclusion

MRI artefacts arise from interactions among patient-related factors, tissue properties, magnetic-field nonuniformity, hardware, acquisition parameters, and image reconstruction. Effective management depends on recognising characteristic appearances, understanding the underlying mechanisms, and selecting corrections appropriate to the clinical application.

Patient preparation, optimised acquisition parameters, and appropriate sequence selection can reduce many artefacts. Dedicated techniques for metal-artefact reduction, accelerated acquisition, and AI-assisted reconstruction offer additional options. Still, their effectiveness varies by application and may involve trade-offs in scan time, signal-to-noise ratio, spatial resolution, or preservation of anatomical detail.

A systematic approach—recognising the artefact, identifying its likely cause, applying a targeted correction, and verifying the resulting image—remains central to reliable MRI practice. Collaboration among MRI technologists, radiologists, medical physicists, and service personnel is essential when artefacts persist or suggest equipment malfunction. Ultimately, judge artefact reduction not solely by visual image improvement, but by whether diagnostic information is preserved and image quality remains adequate for the clinical question.

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