Specialty area: Body MRI Artifacts

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Highlights

1. MR image artifacts often arise from limitations of the system hardware, the spatial encoding process or the use of inappropriate techniques.
2. Understanding the cause of an artifact is pivotal in trying to cure it (or at least alleviate its symptoms).
3. Artifacts may potentially lead to diagnostic errors

Title: Artifacts in Clinical Practice: Causes & Cures

Target audience: Clinicians and technologists who want to understand the causes of, and cures for, many artifacts that can occur in body MRI

OUTCOME/Objectives: Recognise many common or unusual artifacts seen in body MRI and identify the most appropriate methods to cure them, or reduce their potential to cause diagnostic errors

PURPOSE: The purpose of this presentation is to illustrate how artifacts can arise either through hardware limitations or through the spatial encoding process, particularly when combined with human physiology and/or non-optimal imaging protocols.

METHODS: The problem has been studied by a collaboration between a Body MR Radiologist and an MR Physicist using examples obtained either in routine clinical practice or using phantoms/volunteers to illustrate the appearance of specific artifacts and provide additional insights into their causes. Hardware problems are simulated to demonstrate their effect on image quality. The causes of the artifacts will be traced back to basic MR physics where potential cures can be proposed.

RESULTS: Images will be presented illustrating a range of artifacts encountered in body MRI.

DISCUSSION: Whilst artifacts are common in MR imaging their causes are often non-intuitive because of the sophisticated image acquisition and reconstruction algorithms that are now routinely used in MR systems. An appreciation of MR physics allows one to understand the root cause of artifacts.

CONCLUSION: The first step in preventing artifacts from leading to diagnostic errors is to recognize and understand the artifacts.

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Body MRI Artifacts in Clinical Practice: Causes & Cures

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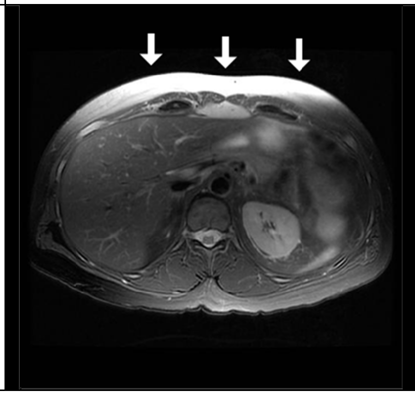
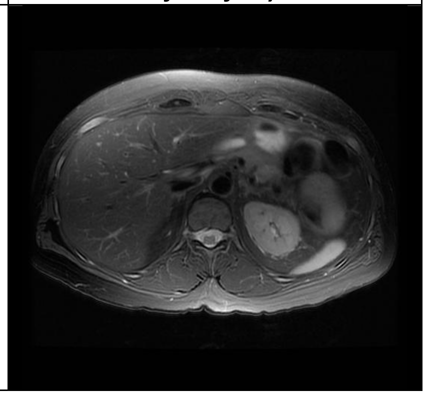
Effective optimization and interpretation of MR images involves an understanding of the source of image artifacts. This allows one to alter imaging techniques to prevent or minimize severity of artifacts, and to extract the information content inherent in some artifacts to add robustness to the overall exam interpretation. In this presentation, we will present several artifacts, considering their source, mechanisms and offering solutions, via numerous examples. Most of the examples in this table will be included in our presentation.

Source of Artifact	**Physics Description**	**Artefact Example**	**Correction/mitigation**	**Corrected Example** ***(or further example of same type of artefact)***
Hardware (Magnet) The static magnetic field needs to be extremely uniform for accurate spatial localisation and to minimise off-resonance artifacts. The uniformity is carefully optimised (shimmed) by the vendor.	The non-uniformity of the static magnetic field results in artifacts such as non-uniform fat saturation as shown here.		Ensure that the magnet is optimally shimmed by the vendor. Check the scanner gradient shim offsets for large values that may indicate ferromagnetic objects in the bore. Here the magnetic field is properly shimmed and the fat saturation is more uniform across the field-of-view (FOV)	

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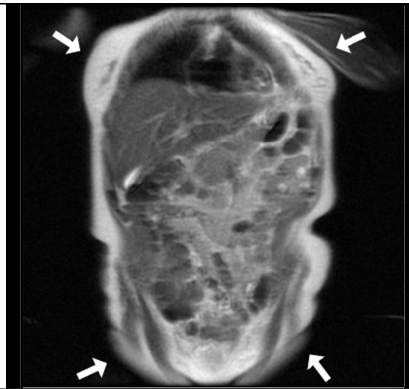
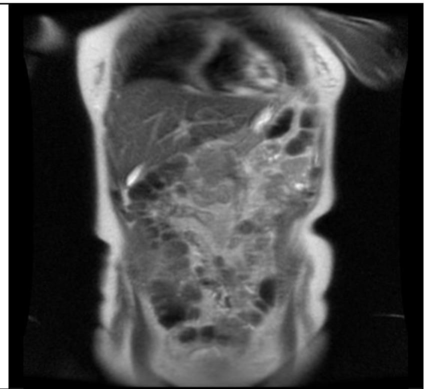
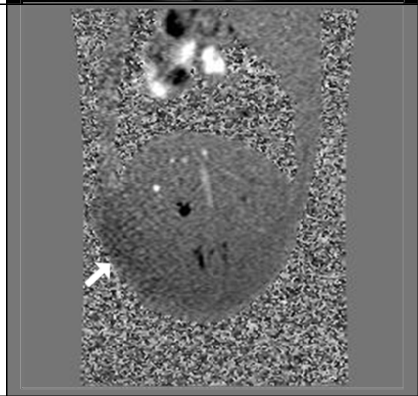
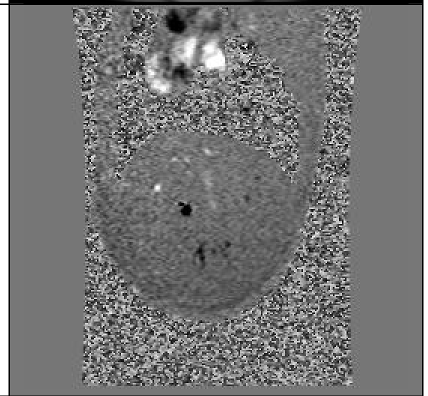
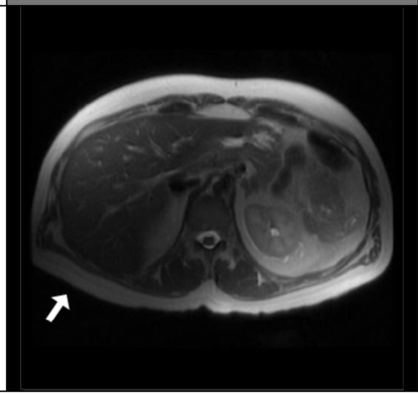
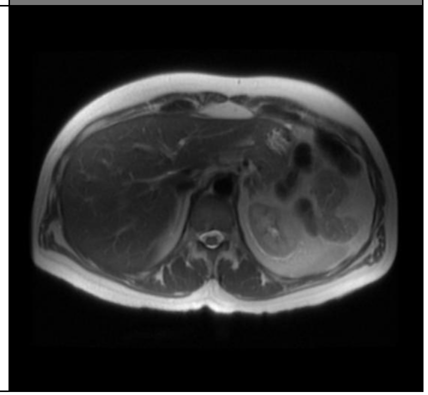
Hardware (Gradients) Gradients allow spatial localisation of the MRI signal. However they are subject to design constraints that limit their performance.	Non-linearity of the gradients results in geometric distortion of the object, particularly at the corners of the FOV as seen here		Gradient linearity is a design limitation, although the vendor can apply software corrections. In this case a 2D gradient warping algorithm has been applied to correct for the non-linearity	
Hardware (Magnets/Gradients) The MRI magnet cryostat is made of metal and therefore there are interactions between the gradients and the cryostat. These are reduced, but not eliminated, by having actively shielded gradients	Gradient switching can induced eddy currents in the magnet cryostat. These eddy currents distort the gradient waveforms. The result of this can be seen in this phase contrast image demonstrating blood flow in the liver. The eddy currents cause a spatial variation in the background phase of the liver.		In this image the gradient rise time has been increased which in turn reduces the eddy currents and thereby reduces the spatial variation in the background phase.	
Hardware RF (Reception/coils) Many MRI coils now comprised of multiple elements, any of which may fail. Similarly, as each coil is connected to a separate receiver, these may fail as well.	With multi-channel coils and receivers there is an increasing probability that one or more channels will fail. Resulting in signal drop-outs and image non-uniformity		Reconstruct the intermediate images to identify a failing coil or receiver channel (test using different coils)	

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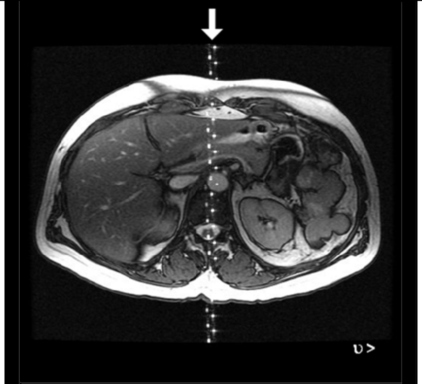
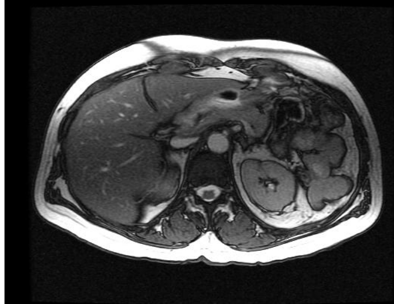
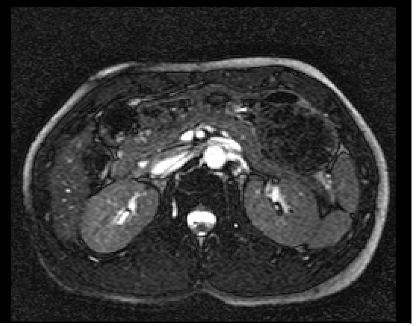
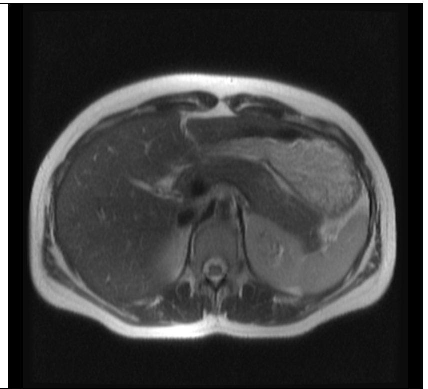
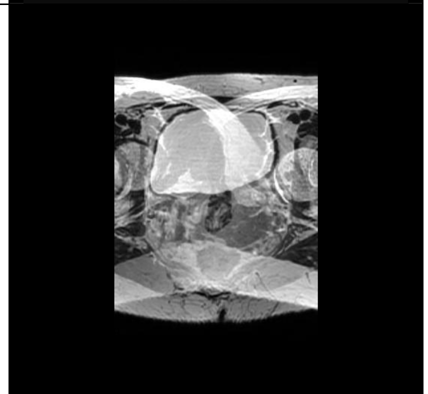
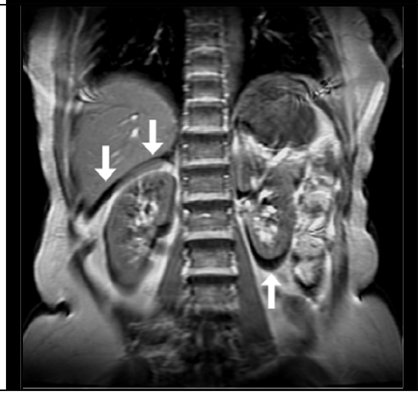
Hardware (Reconstruction computer) The reconstruction computer contains large amounts of memory that may get corrupted.	Corrupt memory on the reconstruction computer produced these artefacts when using a surface coil intensity correction filter.		Replace the reconstruction computer or its memory.	
Hardware (RF Cabin) The RF cabin is designed to stop extraneous RF signals from getting into the sensitive receiver electronics and also to stop the RF transmissions from interfering with electronic systems outside the magnet room	A failure of the RF cabin can allow extraneous signals resulting in signal spikes in the raw data that appear as noise lines in the reconstructed images. This is interference from an adjacent scanner with a faulty RF cabin.		Ensure that RF cabin seals are functional. Also ensure that there are no conducting cables passing through any waveguides as they may re-radiate external RF signals into the magnet room	
Patient related Any source of extraneous electric activity may be causative, including static electricity from wool or acrylic blankets or clothing, faulty light fixtures, etc.	Extraneous electrical activity may causes spikes in *k*-space, resulting in noise and stripes propagated across image		Remove the source of extraneous electrical activity, in this example an acrylic sweater.	

MR acquisition related In standard MR acquisition methods it is not possible to electronically filter the signal in the phase encode direction, unlike in the frequency encoding direction.	If the field-of-view (FOV) in the phase encoding direction is smaller than the size of the object then the pixel data aliases or appears to wrap-around in the phase encode direction		The FOV needs to be increased in the phase encoding direction in order to eliminate the wrap-around. This is at the cost of an increase in scan time. Alternatively no-phase-wrap techniques may be employed.	
MR acquisition related Similarly in 3D acquisition wrap-around artifact can occur in the slice encoding direction	Due to the poor slab selection in this 3D acquisition tissue signal outside the slice select field-of-view has aliased into this image. In this case the kidney signal has aliased into the liver.		Avoid strong signal outside the volume of interest, by proper choice and placement of the receiver coil related to the acquired volume, or use saturation bands. The use of better quality slab excitation pulses can also reduce the effect. This image also shows wrap-around in an axial reformat from a 3D coronal acquisition.	
MR acquisition related Chemical shift artifact of the first kind where signals from water and fat are spatially shifted in the frequency encoding direction.	The water/fat shift in pixels is inversely proportional to the receiver bandwidth. In this case a receiver bandwidth of 61Hz/pixel results in a shift of 3.6 pixels		Increasing the receiver bandwidth to 488 Hz/pixel reduces the chemical shift to 0.5 pixels at the cost of a decreased SNR	

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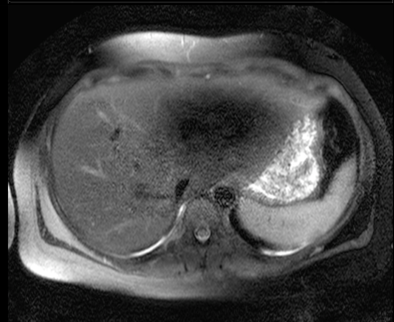
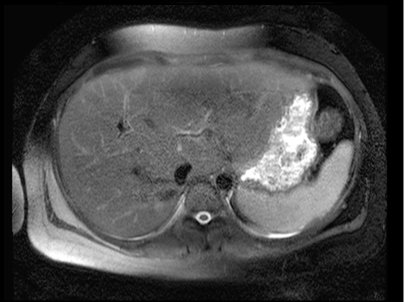
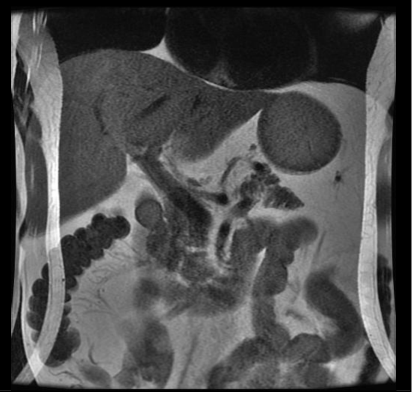
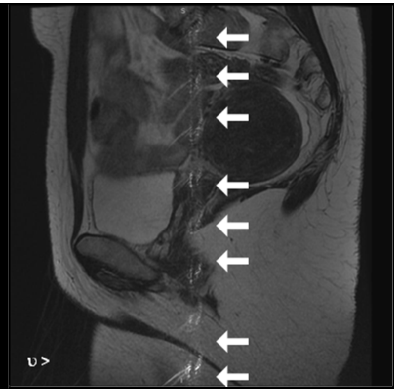
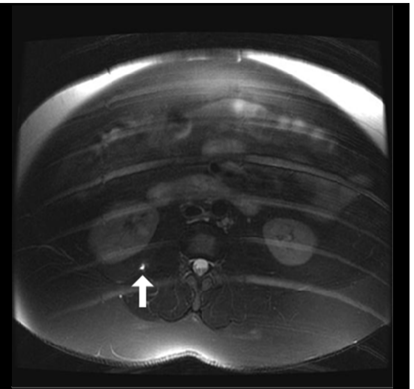
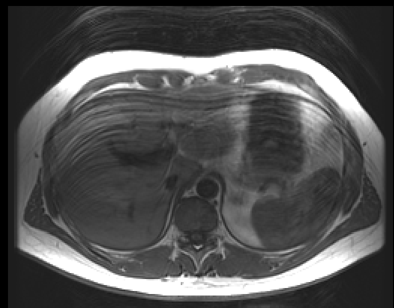
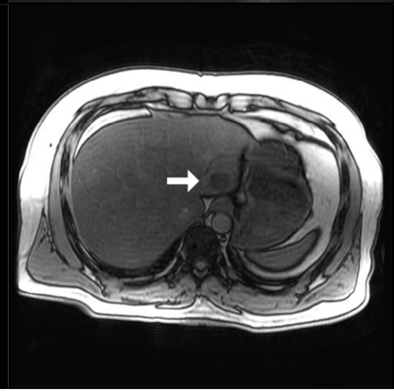
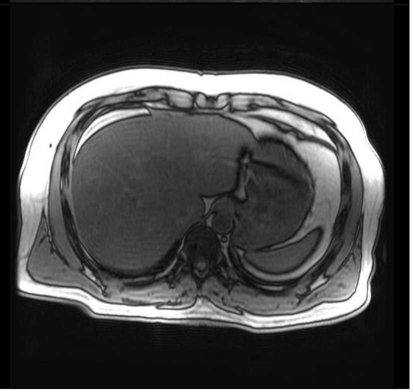
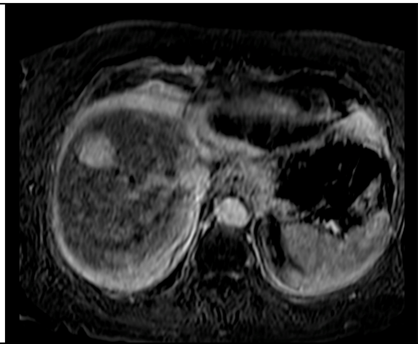
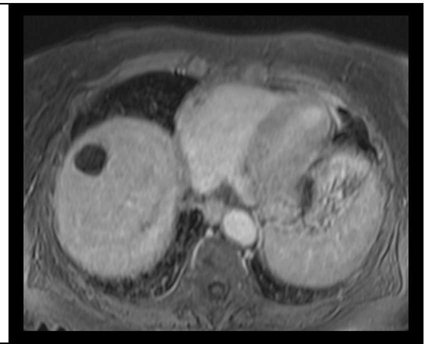
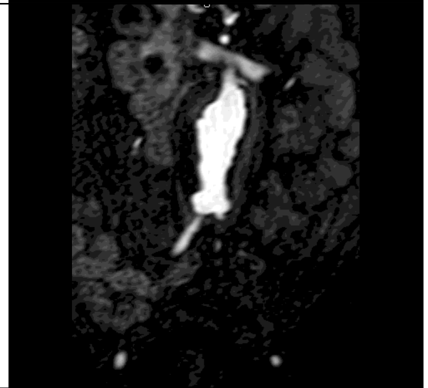
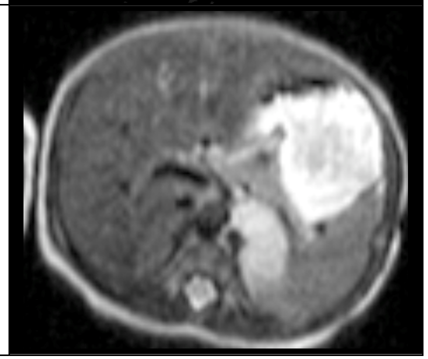
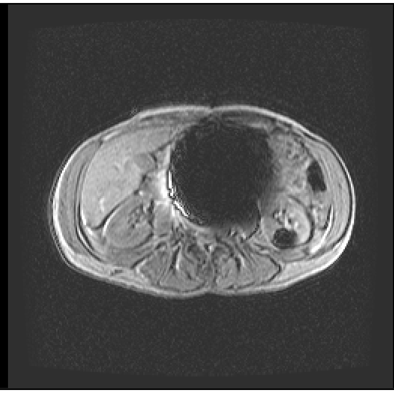
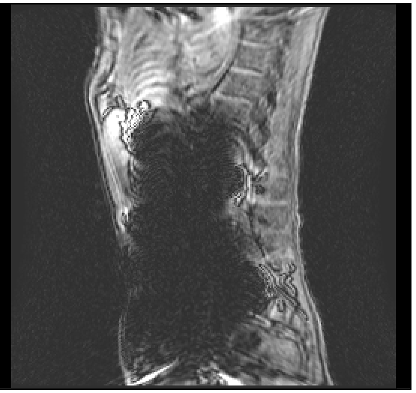
MR acquisition related Chemical shift artifact of the second kind where signals from fat and water in the same voxel cancel at certain echo times (TE) in a gradient echo acquisition	Water protons precess slightly faster than fat protons. At 1.5T water and fat are out of phase at a TE of 2.3ms resulting in a single voxel black border due to signal cancellation.		At a TE of 4.6ms water and fat are back in phase and the black border disappears. Note that this in and out-of-phase imaging method may also be used to help characterise fatty lesions.	
Patient & field strength related RF dielectric/standing wave artifact	At higher field strengths, e.g. 3T, the wavelength of the RF becomes comparable to the size of the body resulting in shading artefacts in the image. The dark region in this image is an example of such a dielectric shading artefact.		The use of high conductivity dielectric pads, as shown here, can reduce the effect. Vendors are now selling multi-channel transmit systems that can also help to reduce this effect. Lower field strengths, e.g. 1.5T and below, do not noticeably demonstrate this effect.	
MR acquisition related Parallel imaging artifacts	This artifact is typically seen when the field of view for an image-based parallel imaging technique such as SENSE is used with the field-of-view being too small or the acceleration factor being too high.		Increase the field-of-view or reduce the parallel imaging acceleration factor. Alternatively use a *k*-space based parallel reconstruction technique such as GRAPPA (shown here) that is robust against this type of artifact.	

MR acquisition related Signal from outside the FOV, but still within the coil, is aliased back into the images. These are known as peripheral signal artifacts.	This ribbon type artefacts (sometimes known as a cusp artifact) originates from signals that are generated away from the isocenter where the gradients are non-linear resulting in the precessional frequency of the spins being similar to that at isocenter. If active coils are present the signal produced will cause an aliasing artifact		This image shows a similar bright spot type artifact due to the same problem. When using multi-element array coils you should only select the receiver coils that match the desired FOV, so that these unwanted signals from outside the FOV are not detected by the coil.	
Patient motion related Artifact due to respiratory motion	This artifact is seen as multiple “ghosts” in the phase encode direction due to the modulation of the MR signal as the patient breathes		Signal averaging is one method to reduce the intensity of the ghosting artifact. In this case the data has been averaged four times. Since the motion is not correlated to the acquisition, the ghost signal intensity is reduced, at the cost of an increase in scan time.	
Patient motion related Artifact due to pulsatile flow in the aorta	Pulsatile flow results in a variation in intravascular signal during the acquisition. This variation in the raw MR signal appears as ghosting following Fourier transformation. Here a flow ghost from the aorta appears as a lesion in the liver.		Presaturation pulses above and below the imaging slice can eliminate the variation in intravascular signal, hence following Fourier transformation there are no ghosts.	

Patient motion related Misregistration artifact in subtraction images	The subject has moved between pre- and post- contrast images which, after subtraction, has resulted in artifactual signal enhancement of a cyst.		Carefully compare pre and post contrast source images, look for edge artifacts and boundaries, and use motion correction software if possible.	
MR technique related Poor timing of dynamic contrast injection related to acquisition in contrast-enhanced MRA.	The contrast agent bolus does not reach the target tissue at the same time as the centre of *k*-space is acquired. This results in poor enhancement of the lumen, but enhancement of the vessel edge.		Optimise the timing of the injection with respect to the contrast injection, or use a 4D time-resolved MRA technique	
Pulse sequence related Decay of signal during an echo-train readout causes images to appear blurred	Due to the T_2 decay during a fast spin echo readout period the point spread function is broadened resulting in a blurred image.		Reducing the echo train length (ETL) and/or the echo-spacing by increasing the receiver bandwidth decreases the width of the PSF and hence the apparent blurring.	

Patient related Magnetic susceptibility artifact from a metal implant	Artifact from an abdominal aortic stent seen on a gradient echo localiser image. The susceptibility gradients cause rapid dephasing of spins resulting in signal loss around the stent		The artifact could potentially have been reduced by using a (fast) spin echo imaging technique. Reducing the voxel volume and the TE in gradient echo imaging may also help to reduce the size of the artifact. This image shows the same artifact from the stent but in the sagittal plane.	

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