

# Cochlear Implants and MRI

## Technical Guidance on Magnetic Fields and Heating

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### 1. Introduction

This guidance document is intended to provide information to the MRI professional, primarily MRI physicists and radiographers, on some of the technical aspects related to interactions between the cochlear implant (CI) and the electro-magnetic fields of the MRI scanner. The information is not exhaustive but gives general principles on several aspects that can affect CI scanning, in particular static magnetic field interactions, field strength considerations, artefacts, heating and off-label circumstances. Refer to your Magnetic Resonance Safety Expert (MRSE) for further advice or clarification.

### 2. Disclaimer

This information is provided for educational purposes only and neither the authors, IPEM, nor the BCIG accept any liability in relation to the use of this information. MRI scanner operator and/or radiologists are responsible for verifying compliance with all scan conditions identified in the product labelling. You must always check and follow the latest MRI guidance from the implant manufacturer and comply with the product labelling, being aware that it may be country specific.

### 3. Static Magnetic Field Interactions

#### 3.1 General considerations

There are two components to the force on an implant magnet in MRI; translational and rotational forces.

Firstly, the translational force caused by the magnetic attraction between the two magnets. This is at a maximum, not in the centre of the bore as is often believed, but around the bore entrance near **where the spatial gradient field is maximum**. The scanner manufacturer's instructions will include a diagram showing the static magnetic field spatial gradient distribution. This means, somewhat counterintuitively, the CI may experience more force during a pelvis or lumbar spine scan than a head scan.

**It is important to keep the spatial gradient experienced by the CI magnet at a minimum**, which is why it is recommended to position the patient on a dockable table outside of the scan room, instruct the patient to keep their head still, and pass through the area of high spatial gradient slowly. Where a dockable table is not available, the patient's head is more likely to pass through areas of high magnetic field spatial gradient when getting on to the table, increasing the risk of discomfort and magnet dislocation. See BCIG guidance on writing a protocol <https://www.bcig.org.uk/safety/>.

Secondly, the rotational torque on the CI magnet whereby it will try to align with the main magnetic field of the MRI scanner. The purpose of the splint in the head bandage is primarily to resist this twisting force on the CI magnet during the scan. This is why there must be good contact between the splint and the CI magnet. Some designs of CI have a fixed magnet which negates the need for this, or a diametrically polarised magnet whereby the magnet can freely align with scanner magnetic field. These may remove the need for a head wrap bandage.

#### 3.2 Demagnetisation of CI magnet

A small amount of demagnetisation of the implant magnet may occur due to an MRI scan. This risk is reduced for modern (diametrically opposed or fixed) magnets. Typically, this occurs on the first scan and does not get worse with subsequent MRI scans. Where possible, retention issues should be solved by replacing the external magnet with a stronger version.

#### 3.3 Polarity reversal of CI magnet

On occasion an implant magnet may fully flip in its pocket and not require surgical intervention to re-seat. In this situation the external magnet should also be reversed.

There persists an 'urban myth' that the MRI scanner can demagnetise and remagnetise the CI magnet with the opposite polarity, however this is considered physically implausible. All verified reports of polarity reversal are due to the implant magnet flipping within its silicone pocket.

#### 3.4 1.5 T versus 3.0 T scanners

Note that while many new generation implants can be scanned at 3T without magnet removal, older devices require magnet removal at 3T. For some older types of implants the manufacturer may recommend removal of magnet even at 1.5T. Some of the earliest types of implants are MR Unsafe and scanning these implants is not recommended. Always check the latest manufacturer guidance.

In general, the additional risks and issues, such as artefact, at 3T outweigh the benefit of increased signal which is gained by going to a higher field strength magnet. This means CIs should usually be scanned at 1.5T.

The decision to scan at 3T or 1.5T must be made in light of the following considerations:

Surgical risks	All previous generation implant magnets require removal at 3T. Surgical risks include damage to implant, scar tissue formation and infection. Magnet removal can only be performed a limited number of times due to scar formation.  Surgical risks must be weighed up against benefits including reduced artefact and increased patient comfort.
Heating risks	SAR outputs at 3T are much higher, up to 4 times that of 1.5T.
Sequence limitations	SAR limits specified by the manufacturer can be much lower at 3T (e.g. <math><0.4\text{W/kg}</math> at 3T vs. <math><1\text{W/kg}</math> at 1.5T) making it more challenging to acquire a full clinical protocol.
Image artefact	With the implant magnet in place (where this is allowed) there will be much greater artefact at 3T than 1.5T.  Even with the magnet removed, artefact can extend up to 5cm radius at 3T (device dependent). This would be reduced at 1.5T

**Table 1** Considerations for 1.5T vs 3.0T scanning

#### 4. Artefact Reduction Techniques

When performing head scans with the implant magnet in place a significant signal void artefact will be seen.

Sequence parameters should be optimised to minimise the extent of the artefact. Optimisations are specific to the scanner, sequence and clinical indication and it is recommended that guidance is sought from your MR Safety Expert (MRSE) / MR physicist.

In general, use of a fast/turbo spin echo sequence with short echo spacing (fast gradient mode), thin slices, high receive bandwidth and utilising parallel imaging acceleration will help. Receive bandwidth should be as high as possible (low water-fat-shift), while retaining adequate SNR. Increasing matrix size and Echo Train Length (ETL) will reduce the geometric distortion but significantly reduce SNR and increase SAR. SNR loss may be counteracted by increasing the number of signal averages (NSA) at the cost of acquisition time. Distortion correction should be on. If fat saturation is required inversion recovery methods (STIR) should be used in preference to spectral fat suppression. Gradient echo sequences should be avoided. The artefact will have different appearances in different planes and acquiring in other planes may yield more useful information.

There are a number of manufacturer-specific metal artefact reduction sequences (e.g. Philips O-MAR; Siemens SEMAC, Advanced WARP; GE MAVRIC/MAVRIC-SL) that may be utilised if available and can give very good results. However, be aware that these can often be very long sequences and have very high SAR outputs that

may be prohibitive depending on the specific device SAR limitations. Compressed Sense SEMAC, where available, considerably reduces acquisition time and SAR making this a viable option.

## 5. Heating

You must be aware of and comply with the specific SAR limits of the CI device you are scanning to avoid significant heating of the device.

Where the manufacturer specifies Normal Mode (whole body (wb) SAR < 2.0 W/kg, head SAR < 3.2 W/kg) the scan should be begun in Normal Mode. If a scan sequence will exceed these limits the operator will be warned, at which point they can take action to reduce the SAR before the sequence is run.

Where more restrictive conditions are specified (e.g. wb-SAR < 1.0 W/kg) the operator must actively monitor the SAR using the scanner's real-time SAR monitor. Please refer to your system manual and/or the manufacturer's Applications Specialist for advice on how to do this on your particular system.

Optimisations are specific to the scanner, sequence and clinical indication and it is recommended that guidance is sought from your MR Safety Expert / MR physicist and radiologist. Below is general guidance on modifying scan parameters to reduce SAR. As well as reducing SAR, bear in mind the additional conflicting demands of minimising scan time, adequate signal, adequate contrast and minimising image artefact.

### 5.1 General principles for SAR reduction

- Use 'low SAR' RF mode. This increases RF pulse duration, decreasing RF amplitude. Minimum TE and TR may increase, changing tissue contrast. Cross talk between slices may be increased.
- Reduce the number of slices to a minimum and use longest acceptable TR. May increase scan time.
- Use a small flip angle. This will reduce SNR and may change contrast.
- Reduce refocusing angle for fast spin echo sequences from 180° to 135°-150°. Reduces SNR, minor contrast change.
- Reduce echo train length (or turbo factor) for fast spin echo sequences. Increases scan time.
- For T2 or PD weighted spin echo sequences, increase TR. Increases scan time
- For T1 weighted spin echo sequences, use longest acceptable TR to achieve desired contrast.
- Consider using gradient echo sequences where possible, particularly for T1 weighted imaging, but only if artefact is not a concern.
- Use parallel imaging where possible. May reduce SNR and introduce artefacts.
- Avoid saturation pulses including fat sat, spatial sat, magnetisation transfer and adiabatic pulses.
- Reducing number of phase encode steps by decreasing resolution or using rectangular FOV (depending on anatomy).
- Alternate higher and low SAR sequences in your protocol and leave gaps between sequences to allow cooling

## 6. Off-label circumstances

Where a patient has previously had the implant receiver-stimulator removed, it is possible that part of the electrode array is retained. This is particularly common where an ABI electrode is retained when the receiver stimulator is removed, due to the difficulty of removing these electrodes surgically. Alternatively the electrode array of a cochlear implant may be retained in the cochlea for reimplant at a later date.

Implant manufacturers do not recommend MRI scanning of patients with retained electrodes due to the risk of heating causing damage to surrounding tissues.

The actual risks in non-standard situations are hard to determine exactly, but it is thought that being part of an incomplete circuit with damaged insulation increases the heating risk compared to a complete system.

It is not recommended that scans are performed outside of the manufacturer's instructions i.e. "off-label". It must also be noted that liability for implant related harm for off-label scans lies with the hospital/Trust rather than the manufacturer. However, in exceptional circumstances if it is believed that the clinical benefit to the patient outweighs the potential risk then scanning may be considered following the procedure set out in section 4.11.4 of the MHRA Guidelines for Magnetic Resonance Imaging Equipment in Clinical Use (Feb 2021).