Planning and Positioning in MRI
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### Abbreviations

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<th>Description</th>
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<tr>
<td>ABER</td>
<td>arm abducted and externally rotated</td>
<td>LVLA</td>
<td>left ventricle and left atrium</td>
</tr>
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<td>ACC</td>
<td>adrenocortical carcinoma</td>
<td>LVOT</td>
<td>left ventricular outflow tract</td>
</tr>
<tr>
<td>ACL</td>
<td>anterior cruciate ligament</td>
<td>MCL</td>
<td>medial collateral ligament</td>
</tr>
<tr>
<td>ACTH</td>
<td>adrenocorticotropic hormone</td>
<td>MFH</td>
<td>malignant fibrous histiocytoma</td>
</tr>
<tr>
<td>ADIR</td>
<td>arm abducted and internally rotated</td>
<td>MIP</td>
<td>maximum intensity projection</td>
</tr>
<tr>
<td>ALPSA</td>
<td>anterior labroligamentous periosteal sleeve avulsion</td>
<td>MR</td>
<td>magnetic resonance</td>
</tr>
<tr>
<td>ASIS</td>
<td>anterior superior iliac spine</td>
<td>MRA</td>
<td>magnetic resonance angiography</td>
</tr>
<tr>
<td>ATT</td>
<td>anterior tibial tendon</td>
<td>MRCP</td>
<td>magnetic resonance</td>
</tr>
<tr>
<td>AVM</td>
<td>arteriovenous malformation</td>
<td>MRI</td>
<td>cholangiopancreatography</td>
</tr>
<tr>
<td>BPH</td>
<td>benign prostatic hyperplasia</td>
<td>MS</td>
<td>multiple sclerosis</td>
</tr>
<tr>
<td>CBD</td>
<td>common bile duct</td>
<td>NOF</td>
<td>neck of femur</td>
</tr>
<tr>
<td>CLPM</td>
<td>condyle lateral-pterigoide muscle</td>
<td>NPC</td>
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<tr>
<td>CN</td>
<td>cranial nerves</td>
<td>OA</td>
<td>osteoarthritis</td>
</tr>
<tr>
<td>CPA</td>
<td>cerebellopontine angles</td>
<td>PCC</td>
<td>pheochromocytoma</td>
</tr>
<tr>
<td>CSF</td>
<td>cerebrospinal fluid</td>
<td>PCL</td>
<td>posterior cruciate ligament</td>
</tr>
<tr>
<td>CT</td>
<td>computerised tomography</td>
<td>PFD</td>
<td>pelvic floor dysfunction</td>
</tr>
<tr>
<td>CTN or STN</td>
<td>classic or structural trigeminal neuralgia</td>
<td>PTT</td>
<td>posterior tibial tendon</td>
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<tr>
<td>DRUJ</td>
<td>distal radio-ulnar joint</td>
<td>PVNS</td>
<td>pigmented villonodular synovitis</td>
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<tr>
<td>ECG</td>
<td>electrocardiogram or electrocardiograph</td>
<td>RA</td>
<td>rheumatoid arthritis</td>
</tr>
<tr>
<td>ECRCP</td>
<td>endoscopic retrograde cholangiopancreatography</td>
<td>RARE</td>
<td>rapid acquisition and relaxation enhancement</td>
</tr>
<tr>
<td>FABS</td>
<td>flexion and abduction in supination</td>
<td>RCC</td>
<td>renal cell carcinoma</td>
</tr>
<tr>
<td>FAI</td>
<td>femoro-acetabular impingement</td>
<td>REZ</td>
<td>root exit zone</td>
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<tr>
<td>FDL</td>
<td>flexor digitorum longus</td>
<td>RF</td>
<td>radiofrequency</td>
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<tr>
<td>FHL</td>
<td>flexor hallucis longus</td>
<td>RVOT</td>
<td>right ventricular outflow tract</td>
</tr>
<tr>
<td>FNH</td>
<td>follicular nodular hyperplasia</td>
<td>SCC</td>
<td>squamous cell carcinoma</td>
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<tr>
<td>GBM</td>
<td>glioblastoma multiforme</td>
<td>SL</td>
<td>scapholunate</td>
</tr>
<tr>
<td>GRE</td>
<td>gradient echo</td>
<td>SLAP</td>
<td>superior labral anterior posterior</td>
</tr>
<tr>
<td>HAGL</td>
<td>humeral avulsion glenoid ligament</td>
<td>SNHL</td>
<td>sensorineural hearing loss</td>
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<tr>
<td>HCC</td>
<td>hepatocellular carcinoma</td>
<td>SOC</td>
<td>synovial osteochondromatosis</td>
</tr>
<tr>
<td>IAC</td>
<td>internal auditory canal</td>
<td>SOL</td>
<td>space occupying lesion</td>
</tr>
<tr>
<td>IV</td>
<td>intravenous</td>
<td>SSFP</td>
<td>single shot fast spin echo</td>
</tr>
<tr>
<td>IVC</td>
<td>inferior vena cava</td>
<td>SSNHL</td>
<td>sudden sensorineural hearing loss</td>
</tr>
<tr>
<td>LCL</td>
<td>lateral collateral ligament</td>
<td>SST</td>
<td>suprapsinatous tendon</td>
</tr>
<tr>
<td>LPM</td>
<td>lateral pterygoid muscle</td>
<td>TFCC</td>
<td>triangular fibrocartilage complex</td>
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<td></td>
<td></td>
<td>TMJ</td>
<td>temporomandibular joint</td>
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In everything we do, family should come first. For me, the effort that has gone into producing this work would be meaningless if those I hold most dear had failed to believe in it and support me. No child could have wanted for greater support in pursuing an education than that with which my siblings and I have been blessed by our parents. This is true inheritance.

My brother Neil Bright has shared his considerable knowledge of anatomy and pathology throughout my professional life. All those books and gory images you showed me as a child came to something. At least the rest of the family won’t mind me showing them a picture from this one after dinner!

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For my parents, Jack and Irene, who gave each of their children the only real inheritance that matters—a sound education and an open and tolerant mind.

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Introduction

When commencing in magnetic resonance imaging, the range of pulse sequences, variable appearances of pathology and image orientation may overwhelm trainees. The approach taken in the writing of this text reflects the intended audience, namely radiographers actually performing the examination, operating the scanner. Most, if not all sites are under the direction of a radiologist who prescribes pulse sequences and ultimately reports on the outcomes, but it is the radiographer sitting at the operator console who must know the imaging planes and degree of coverage required, just as they would for an X-ray or CT examination. This text aims to address this issue, focusing upon patient positioning and image planning, with a limited description of what may be demonstrated in each scan plane.

MRI is dictated not only by anatomical region, but also by pathological extent and body habitus. While each site will have a preferred approach for scanning each body region, there are basic principles that can be learned. Once the basic principles of good positioning are developed, what was once purely rote knowledge will become applied wisdom, establishing the foundations necessary for the lateral thought processes necessary to manage complex cases.

A detailed discussion of physics, scan parameters and safety is outside the scope of this text. Most sites will have routine scans programmed for their most common examinations. Nevertheless, a brief overview of some of the considerations required in building a pulse sequence follows and should be borne in mind by the trainee. More detailed information is available in the many excellent resources already available both in print and via the internet.

Safety

The importance of vigilance in screening every person who enters the MRI environment cannot be overstated. Careful and repeated screening (at the time of booking, when registering at reception, when changing and before entering the scan room) by the staff at each point provides the best opportunity to prevent injury to the patient, support companions and staff.

Not all sites ask a patient to change into a cotton or disposable paper examination gown, although this is to be encouraged. This simple requirement dramatically reduces the possibility of a patient entering the scan room with objects in their pockets that may be rendered obsolete by the high field strength (e.g. credit cards) or may pose a threat as a projectile (e.g. keys, pocket knife). In combination with removing dental implants and all jewellery, a patient divested of all metal ensures maximal field
administered gadolinium-based contrast media, especially when indications point toward renal disease. There is a burgeoning volume of information related to both contrast media and implant safety. The reader is directed to the many excellent resources available, often at very little cost. A list of suggested support resources may be found at the end of this introduction.

Artefacts

As with any radiological examination, motion will degrade image quality. Making the patient as comfortable as possible will minimise the potential for motion. Supporting limbs, padding around the head, placing a sponge under the knees to alleviate back pain, can all assist in preventing patient motion. Again, use only padding supplied by a reputable MRI vendor. Do not grab a sandbag from the nearest X-ray room—it’s not always just sand!

Another common artefact encountered by the trainee in MRI is phase wrap (aliasing). Always check the phase direction and assess whether the field of view is sufficient to encompass the anatomy. If not, there are three options—changing the phase direction, increasing the field of view or applying phase oversampling (no phase wrap). Each of these carries a potential cost; be sure you are aware of the impact of making a change.

Ghosting is due to the pulsation of arterial flow causing tracks across an image in the phase direction. Again, altering the phase direction so that the artefact does not track over the anatomy of interest may be an acceptable remedy, but perhaps better would be applying a saturation pulse just outside the field of view to null the signal of inflowing blood. In the head and neck, the saturation pulse would be placed inferiorly to null blood as it flows into the head; in the rest of the body, the pulse would generally be applied superior to the field of view.
A saturation pulse is also helpful in nulling the signal from respiratory motion in the abdomen. Images of the abdomen and pelvis will often benefit from a saturation pulse applied over the subcutaneous fat of the abdomen or diaphragm. For imaging of the spine, a saturation pulse placed just anterior to the vertebra will reduce artefact from swallowing and aortic pulsation, but be careful not to saturate the signal if there is a paraspinal lesion.

There are many other artefacts that may be encountered, including but not limited to truncation, Gibb’s artefact and chemical shift. These are less related to patient position and slice orientation. A comprehensive description, explanation and management strategy for each of these and many other MRI artefacts can be found in a physics text.

Image weighting

Image weighting is a function of pulse repetition time (TR) and echo time (TE) (see table below), combined with the method employed to generate the echo. Rapid acquisition and relaxation enhancement (RARE, also known as fast spine echo, turbo spin echo) produces true T2 image contrast, the refocusing pulses minimising the effects of field inhomogeneities. Gradient echo (GRE, also known as fast field echo) does not compensate for the effects of field inhomogeneities, generating T2* contrast. In addition, RARE employs a 90° excitation pulse (or nearly 90°), while GRE uses a much lower flip angle, anywhere between 10° and 60°. These fundamental differences impact on scan time, image quality and most importantly, image characteristics.

It is the combination of signal characteristics demonstrated on images in multiple imaging planes that assists in the determination of disease aetiology and differential diagnosis. While inhomogeneities generated by metallic implants such as spinal fusion or dental implants will degrade image quality, distorting anatomy and ruining fat saturation, this feature can be exploited to better demonstrate pathological processes such as microscopic bleeds in the brain or iron loading in the liver.

The fundamental difference in pulse sequence designs results in entirely differing parameters. In addition, field strength impacts on parameter values. Regardless of whether there are pre-loaded scans on your scanner, there will be occasions where you will be required to ‘build’ or manipulate a pulse sequence to meet the requirements of the particular pathology you are examining, or to ameliorate artefactual signal anomalies. The radiographer must be familiar with the appropriate range of parameters for the field strength at which they operate and for the specific type of pulse being used.

Imaging coils

Defining anatomical boundaries for MRI provides a means of determining the area for inclusion when choosing an appropriate radiofrequency coil and planning a pulse sequence. Each imaging coil will have a specified field of view that must be taken into account by the radiographer when selecting an appropriate device. Many coils are designed with a particular task in mind, but are generally adapted in clinical use for imaging of more than one region of the body.

<table>
<thead>
<tr>
<th>Image weighting</th>
<th>Repetition time (TR)</th>
<th>Echo time (TE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Short</td>
<td>Short</td>
</tr>
<tr>
<td>Proton density (PD)</td>
<td>Long</td>
<td>Short</td>
</tr>
<tr>
<td>T2/T2*</td>
<td>Long</td>
<td>Long</td>
</tr>
</tbody>
</table>
Radiofrequency coil design has developed dramatically, and this will no doubt continue. Many sites still use older designs producing images of high spatial and contrast resolution. The radiographer needs to be aware of which coils are receive-only and which are transmit–receive. A receive-only coil detects emitted radiofrequency from the body after excitation has been induced by the intrinsic body coil incorporated in the scanner itself. In contrast, a transmit–receive coil both generates the excitation radiofrequency pulse and receives the emitted signal.

Various coil designs exploiting the benefits of combining coil elements have been developed. Linear polarised, circular (quadrature) polarised and phased array coils all have their own advantages and limitations, which can be studied elsewhere. The important thing to remember is that the protons closest to the imaging coil generate the highest signal. Detecting signal from protons deep within the tissues (e.g. within the abdomen) requires a coil of larger dimensions, but this also increases noise. Hence, selecting a coil with a field of view and physical design that best fits the region of interest is the first step in maximising image signal. The imaging coils that follow are used as examples only of the various forms and designs available.

Coils such as those in Figures I.1 and I.2 are suitable for imaging when a large field of view is required.

While these coils are suitable for imaging of the body (e.g. chest, heart, abdomen, hamstrings), they may also be used when patient body habitus or illness places constraints on traditional positioning. For example, a patient who is unable to lie on their back for an examination of the thoracic spine, may better tolerate the procedure when allowed to lie decubitus and imaged using a coil such as that in Figure I.1.

Breast imaging is performed prone, the breasts hanging into a cavity surrounded by elements built into the coil (Fig. I.3). These coils may include stabilising paddles. Compression is not required for MRI of the breast; the paddles simply serve as a
The picture also shows superior end of the spine coil attached to the head and neck coils. The neck coil may be removed if only an examination of the head is needed, although it may remain in place even if you don’t need it for a particular exam. More coils with correspondingly more elements may be added to these two coils if greater coverage is needed.

The longer the examination duration, the more uncomfortable a patient may become. The ability to combine elements for multi-region imaging increases the utility of the individual coil modules, and makes imaging of multiple pathologies or clinical indications less cumbersome for the radiographer and decreases examination times.

Joints between long bones are best examined using coils designed for the region of interest. Imaging of the knee or elbow, using the ‘Superman’ position described in Chapter 5.2, p 186, may be performed with coils such as those in Figures I.7 and I.8. The chimney in the coil in Figure I.8 makes it suitable for also imaging the ankle and foot, although dedicated foot and ankle coils have also been designed (Fig I.9). A wrist coil is shown in Figure I.10.

A flexible coil (Fig I.11) is available in two sizes. It enables imaging of anatomy that may be distorted

**Figure I.4** 16-channel head-neck-spine coil (GE Healthcare).

**Figure I.5** 16-channel head-neck-spine coil, face and chest elements (GE Healthcare).

**Figure I.6** Head and neck matrix coils (Siemens).
by disease or injury, making it difficult to fit a joint into a coil moulded to the usual body contours.

Small anatomical areas, such as the digits of the hand or foot, require dedicated coils with a small field of view (Fig I.12). Small dual coils are also useful for examination of the temporomandibular joints using a frame to support the coils (Fig I.13).

Imaging coils of the shoulder have possibly the greatest variation in design (Figs I.14–I.16). The coils shown here are merely a sample of the many options available. The coil in Figure I.16 may also be used for imaging of other joints, including the hip and elbow.
A specialised coil may be used for imaging of anatomy deep within the pelvis. Such intracavity coils (Fig I.17) provide a small field of view and high signal of structures close to the receiver, such as the prostate, rectum, uterus and anal sphincters. Coils are generally moulded for the particular region of interest; a rectal coil will sit above the sphincters and is therefore not ideal for imaging of the anal sphincters. These coils may often be coupled with other external coils such as that in Figure I.3, and are disposed of once the examination is complete.

Knowing the characteristics of the radiofrequency coil being used and the degree of coverage required...
for the area and pathology under examination is crucial to producing images of high signal quality. Time spent learning about imaging coil hardware from texts and papers on this subject will be rewarded with comprehension that will enable the radiographer to resolve many issues due to artefacts, save time and generate images of high spatial and contrast resolution.

Suggested support resources

The websites listed here are of long standing, high repute and hence unlikely to cease to exist in the near future. They offer support to those working with MRI throughout the world, regardless of their specific discipline. All websites were accessible on 14 March 2011.

Section for Magnetic Resonance Technologists

With chapters in the Australia–New Zealand and Belgium–Netherlands regions as well as across the United States, the Society for Magnetic Resonance Technologists (SMRT) has supported MR radiographers throughout the world for twenty years. With the quarterly Educational Seminars, regional meetings, annual international conference held in conjunction with the International Society for Magnetic Resonance in Medicine (ISMRM), and the associated journals, this organisation provides the widest possible range of educational resources available to the greatest number of people. Make use of the resources on offer and your membership fees will be more than well rewarded.

http://www.ismmr.org/smrt/

MRI List Server

Free to members and non-members alike, this mail server operated and maintained by the Section for Magnetic Resonance Technologists (SMRT) provides contact with other MR imaging professionals throughout the world. The cumulative body of knowledge of the individuals in this group represents an enormous resource that has assisted and enabled the sharing of information in a bipartisan manner for over a decade.

http://www.ismmr.org/smrt/listserv.htm

Society for Cardiovascular Magnetic Resonance

Specifically for those involved in cardiovascular MRI. This site provides much support for both members and non-members alike, although some resources require membership.

http://www.scmr.org/

MRIsafety.com

Set up and maintained by Dr Frank Shellock, this website is invaluable for quickly identifying implant particulars.

http://www.mrisafety.com

The Adelaide MRI website

Created and maintained by Greg Brown, this resource provides a wealth of information for the MR radiographer. It has been an invaluable tool for countless radiographers over the years and is a useful first port of call for any technical or practical concern.

http://www.users.on.net/~vision/
Section 3

Chest and abdomen

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Chapter 3.1 Mediastinum

Indications:

- Mediastinal mass, e.g. thymic enlargement, lymphoma, congenital cysts.
- Neurogenic lesions, e.g. thoracic meningoceles, schwannomas, malignant nerve sheath tumours, sympathetic ganglia tumours.
- Differentiation between lymph nodes and vascular anomalies, particularly in patients for whom iodinated contrast is contraindicated for CT.
- Assessment of vascular anomalies of the chest (in conjunction with MRA), e.g. thoracic aortic dissection or aneurysms.

Figure 3.1 Divisions of the mediastinum.
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Coils and patient considerations

Contained within the chest between the pleurae and bounded anteroposteriorly by the sternum and thoracic vertebrae, the mediastinum refers to all the contents of the thoracic cavity except the lungs. Consensus for further division of the mediastinal compartments has been elusive, with some authors describing anterior, middle and posterior compartments. Other investigators describe a superior compartment with the inferior compartment being divided into three sections from anterior to posterior. Regardless of the morphologic convention employed, delineation of disease may include assessment of the heart, great vessels, thymus, trachea and left and right main bronchi, oesophagus, various nerves and lymph nodes.

The lack of signal-producing tissues in the lungs makes MRI an unsuitable technique for investigation of most pulmonary disorders, but it may be a useful adjunct for the demonstration of mediastinal lesions after CT or angiography. Lesions suspected to involve or originate in the spinal column often benefit from MRI in conjunction with CT to fully delineate disease pathogenesis. For patients who are subject to an increased lifetime accumulated risk of neoplastic disease due to breast or lung irradiation (e.g. young women with Hodgkin’s lymphoma, lung cancer, breast cancer), MRI may be considered an appropriate alternative for monitoring of nodal disease, metastatic invasion to the heart or the investigation of cardiac function.

Inconsistent breath holds will limit image quality and potentially result in an incomplete examination. Respiratory gating used with free breathing techniques enables image triggering at a consistent point within the respiratory cycle. A respiratory bellows also allows the operator to monitor the patient’s compliance with breath hold scans, alerting the operator to gradual exhalation during image acquisition or an inability to hold the breath for too long. It is useful to fit the bellows on every patient during preparation and to coach each one about breathing instructions before the examination. Advantage should be taken of options on scanners that facilitate pre-recorded breathing instructions.

Cardiac gating may also be useful, particularly for demonstration of the mediastinal lymph nodes close to the pericardium or thymus. While anatomic coverage in this section is quite broad, focus may be needed on a specific portion of the mediastinum. Direction from a radiologist should be sought to ensure the appropriate targeted examination is performed. A large area surface coil is required (see Figs 1.1 & 1.2).
3.1.1 Imaging planes: Routine sequences

Position:
- Supine, head first
- Arms above the head permits a smaller field of view for long axis imaging (coronal), as well as facilitating the examination of patients with a more solid body habitus.

Other considerations:
- Patients who suffer from claustrophobia may prefer a feet-first orientation, if possible. Removing or using only a low pillow under the head may help the patient feel less encumbered, keeping distance between the face and top of the bore.
- The bellows should be positioned over the area of greatest expansion and contraction.
- If the bellows is positioned under the anterior portion of an imaging coil, consider placing the bellows along the side of the chest where the weight of the coil will not restrict its movement. Sponges or dielectric pads placed either side of the bellows also prevent the bellows from being compressed.

Axial

Alignment:
- True axial.

Coverage:
Superior to inferior:
- Thoracic inlet to diaphragmatic crura

Lateral to medial:
- Chest wall on each side

Posterior to anterior:
- Thoracic spinous processes to sternum.

Demonstrates:
- Contents of the mediastinum, comparative with direct acquisition CT images.
- Morphology of the great vessels and heart, with specific examination of each of the inferior mediastinal compartments.
- Lymph node location and size.
Coronal

Alignment:
- True coronal.

Coverage:
- As for axial plane.

Demonstrates:
- Contents of the mediastinum, comparable with reformatted CT images.
- Morphology of the great vessels and heart, with delineation of the superior and inferior mediastinal compartments.
- Lymph node location and size.
- Costophrenic angles and lung apices.

**Figure 3.4** Coronal planned on an axial image. (North Shore Radiology)

**Figure 3.5** Coronal planned on a sagittal image. (North Shore Radiology)
3.1.2 Imaging planes: Supplementary sequences

Sagittal

Alignment:
• True sagittal.

Coverage:
• As for axial plane.

Demonstrates:
• Contents of the mediastinum, comparable with reformatted CT images.
• Morphology of the great vessels and heart, with delineation of the superior and inferior mediastinal compartments.

Figure 3.6 Sagittal planned on a coronal image.
(North Shore Radiology)

Figure 3.7 Sagittal planned on an axial image.
(North Shore Radiology)