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How to Use This Book

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INTRODUCTION

This book has been written with the intention of providing a step-by-step explanation of the most common examinations currently carried out using magnetic resonance imaging (MRI). It is divided into two parts.

Part 1 contains reviews or summaries of those theoretical and practical concepts that are frequently discussed in Part 2. These are:

- protocol parameters and trade-offs
- pulse sequences
- flow phenomena and artefacts
- gating and respiratory compensation (RC) techniques
- patient care and safety
- contrast agents.

These summaries are not intended to be comprehensive but contain only a brief description of definitions and uses. For a more detailed discussion of these and other concepts, the reader is referred to MRI physics books. *MRI in Practice* by C. Westbrook and J. Talbot (Wiley Blackwell, 2019, fifth edition) is a particularly useful companion to this book.

Part 2 is divided into the following examination areas:

- head and neck
- spine

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- chest
- abdomen
- pelvis
- upper limb
- lower limb
- paediatric imaging.

Each anatomical region is subdivided into separate examinations. For example, the section entitled *Head and neck* includes explanations on imaging the brain, temporal lobes, pituitary fossa, and so on. Under each examination, the following categories are described:

- common indications
- basic anatomy
- equipment
- patient positioning
- slice prescription
- suggested protocol
- protocol optimization
- patient considerations
- contrast usage.

COMMON INDICATIONS

These are the most usual reasons for scanning each area, although occasionally some rarer indications are included.

BASIC ANATOMY

Simple anatomical diagrams are provided for most examination areas to assist the reader.

EQUIPMENT

This contains a list of the equipment required for each examination and includes coil type, gating leads, bellows and immobilization devices. The correct use of gating and RC is discussed in Part 1 (see *Gating and respiratory compensation techniques*). The coil types described are the most common currently available. These are as follows.

- *Volume coils* that both transmit and receive radiofrequency (RF) pulses and are specifically called transceivers. Most of these coils are quadrature in design, which means that they generate two RF fields perpendicular to each other. This maximises coupling between the coils and the spin population, thus improving image quality factors such as the signal-to-noise ratio (SNR). Volume coils often encompass large areas of anatomy and yield a uniform signal across the whole field of view (FOV). The head and body coil are examples of this type of coil.
- *Linear phased array coils* consist of multiple coils and receivers. The signal from the receiver of each coil is combined to form one image. The image has the advantages of both a small coil (improved SNR) and those of the larger volume coils (increased coverage). Therefore, linear phased array coils can be used either to examine large areas such as the entire length of the spine, or to improve signal uniformity and intensity in small areas such as the breast.

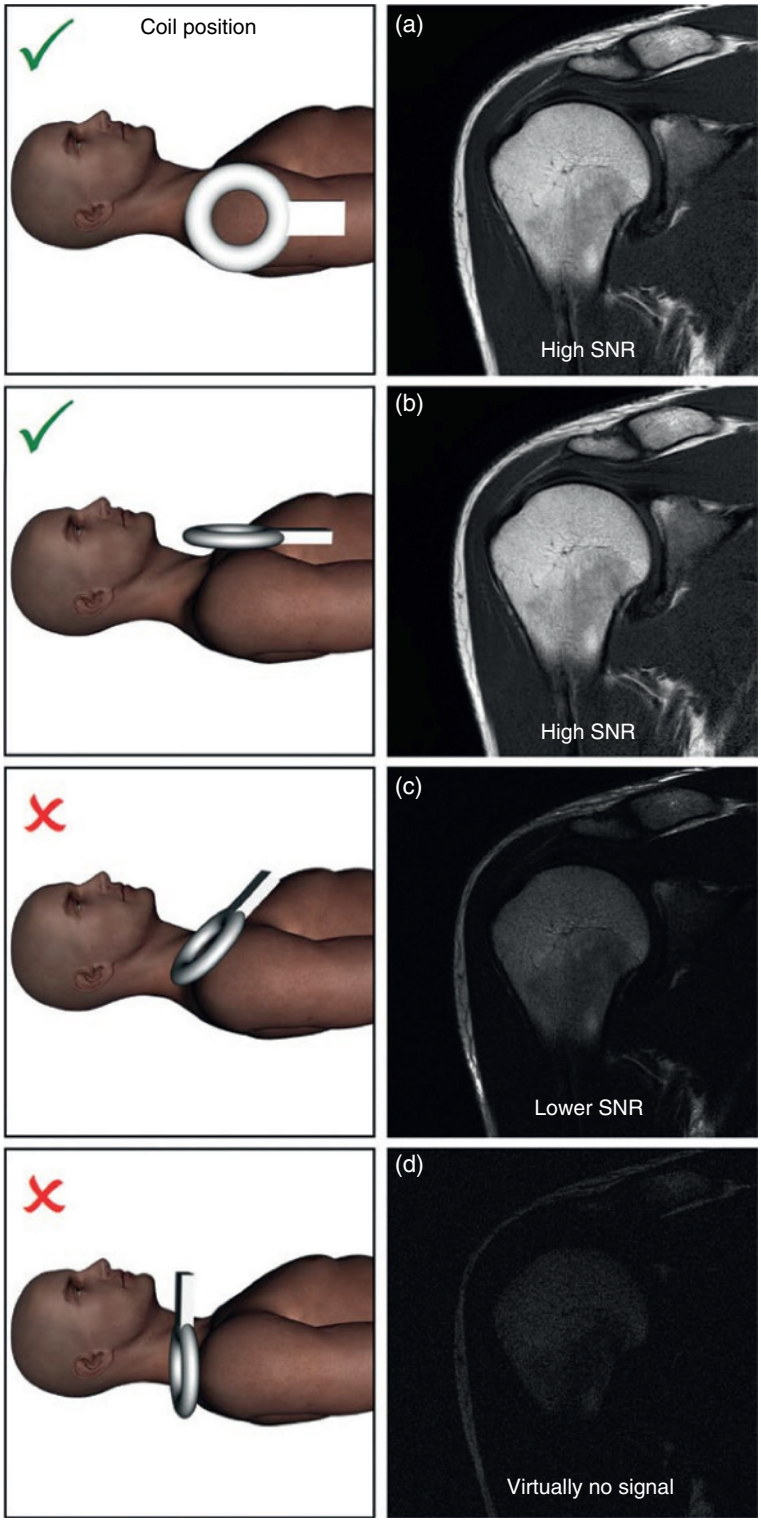


Figure 1.1 Correct placement of a flat surface receive coil.

- *Volume phased array (parallel imaging)* uses the data from multiple coils or channels arranged around the area under examination to decrease scan time, increase phase resolution or a combination of both. Additional software and hardware are required. The hardware includes several coils perpendicular to each other or one coil with several channels. The number of possible coils/channels varies but currently ranges from 2 to 32 for routine imaging and up to 128 for cardiac imaging. During data acquisition, each coil fills its own lines of *k*-space (e.g., if two coils are used together, one coil fills the even lines of *k*-space and the other the odd lines. *k*-space is therefore filled either twice as quickly or with twice the phase resolution in the same scan time). The number of selected coils/channels is generically called the reduction factor and is similar in principle to the turbo factor (TF)/echo train length (ETL) in fast or turbo spin echo (FSE/TSE) (see *Pulse sequences*). Every coil/channel produces a separate image that often displays aliasing artefact (see *Flow phenomena and artefacts*). Software called sensitivity encoding and additional algorithms remove this artefact and combine the images from each coil/channel to produce a single unwrapped image. This technology can be used in most examination areas and with any pulse sequence. It is often discussed in the *Protocol optimization* section in Part 2.
- *Surface/local coils* are traditionally used to improve the SNR when imaging structures near to the skin surface. They are often specially designed to fit a certain area and in general they only receive signal. Surface coils increase SNR compared with volume coils. This is because they are placed close to the region under examination increasing signal amplitude that is generated in the coil, while noise is only received in the vicinity of the coil. However, surface coils only receive signal up to the edges of the coil and to a depth equal to the diameter of the conductive loop of the coil. To visualize structures deep within the patient, either a volume, linear or volume phased array coil or, more rarely, a local coil inserted into an orifice must be utilized (e.g., a rectal coil).

The choice of coil is one of the most important factors that determines the SNR. When using any type of coil remember to:

- Check that the cables are intact and undamaged.
- Check that the coil is plugged in properly and that the correct connector box is used.
- Ensure that the receiving side of the coil faces the patient. This is usually labelled on the coil itself. Note that both sides of the coil usually receive signal, but coils are designed so that one side receives optimum signal. This is especially true of shaped coils that fit a certain anatomical area. If the wrong side of the coil faces the patient, signal is lost, and image quality suffers.
- Place the coil as close as possible to the area under examination.
- The coil should not directly touch the patient's skin as it may become warm during the examination and cause discomfort. A small foam pad placed between the skin surface and the coil is usually sufficient insulation.
- Ensure that the coil does not move when placed on the patient. A moving coil during data acquisition always produces a moving image.
- Ensure that the receiving surface of the coil is parallel to the *z* (long) axis of the magnet. This guarantees that the transverse component of magnetization is perpendicular to the coil and that maximum signal is induced. Placing the coil at an angle to this axis, or parallel to the *x* or *y* axis, results in a loss of signal (Figure 1.1). Note that the axes discussed here relate to a superconducting magnet. Open systems may label their axes differently, but the principle remains the same. To generate signal in a receiver coil on any type of system, the receiver coil must be located perpendicular to the transverse component of magnetization.

PATIENT POSITIONING

This contains a description of the correct patient position, placement of the patient within the coil and proper immobilization techniques. Centring and landmarking are described relative to the laser light system on a superconducting system as follows (Figure 1.2):

- The *longitudinal alignment light* refers to the light running parallel to the bore of the magnet in the *z axis*.
- The *horizontal alignment light* refers to the light that runs from left to right of the bore of the magnet in the *x axis*.
- The *vertical alignment light* refers to the light that runs from the top to the bottom of the magnet in the *y axis*.

It is assumed in Part 2 that the following areas are examined with the patient placed head-first in the magnet:

- head and neck (all areas)
- cervical, thoracic and whole spine
- chest (all areas)
- abdomen (for areas superior to the iliac crests)
- shoulders and upper limb (except where specified).

The remaining anatomical regions are examined with the patient placed feet-first in the magnet. These are:

- pelvis
- hips
- lower limbs.



Figure 1.2 Positioning of the alignment lights.

SLICE PRESCRIPTION

This section describes the anatomical landmarks for slice prescription and angulation of imaging planes used in each examination area. All protocols begin with a three-plane localizer from which slices are prescribed. Imaging coordinates are provided for at least one plane in the three-plane localizer acquisition.

SUGGESTED PROTOCOL

This is intended as a guideline only. Almost every centre uses different protocols depending on the type of system and radiological preference. However, this section can be helpful for those practitioners scanning without a radiologist, or where the examination is so rare that perhaps neither the radiologist nor the practitioner knows how to proceed. The protocol description is mainly limited to scan plane, weighting, pulse sequence(s) and why it is used. For details of suggested protocol parameters see Table 2.1.

It must be stressed that all the protocols listed are only a reflection of the authors' practice and research. However, the protocols provided in this section are considered to be the most commonly used. In most examinations, there is a section reserved for *Additional techniques*. These are not regarded as routine but may be included in the examination. Of course, some practitioners may regard what we call 'additional' as 'routine', and vice versa.

PROTOCOL OPTIMIZATION

This section is subdivided into:

- ***Technical issues:*** This includes a discussion of the relationship of SNR, CNR, spatial resolution and scan time pertaining to each examination. Suggestions on how to optimize these factors are described (see *Protocol parameters and trade-offs*). The correct use of pulse sequences and various imaging options are also discussed (see also *Pulse sequences)*.
- ***Artefact problems:*** This contains a description of the common artefacts encountered and ways in which they can be eliminated or reduced (see also *Flow phenomena and artefacts*).

PATIENT CONSIDERATIONS

This encompasses the condition of the patient, including symptoms and claustrophobia. Suggestions to overcome these are given (see also *Patient care and safety*).

CONTRAST USAGE

The reasons for administering a contrast agent in each examination area are discussed. The use of contrast agents varies widely according to radiological preferences. This section should be used as a guide only (see also *Contrast agents*).

SUMMARY

Follow this 10-point plan for good radiographic practice:

1. Review all cases carefully and select appropriate protocols.
2. Have flexible protocols that can reflect the needs of each individual clinical case.
3. Regularly review your protocols and procedures and benchmark them against current best practice.
4. Have clear diagnostic goals including the minimum accepted protocol necessary to obtain a useful diagnostic/clinical outcome.
5. Regularly review your protocols and procedures.
6. Understand the capabilities of your system.
7. Recognize your limitations and, if necessary, refer to another site rather than risk an incomplete or diagnostically unacceptable procedure.
8. Educate all levels of staff to new procedures and/or system capabilities.
9. Be safety paranoid to ensure your unit does not fall victim to the dreaded MRI incident.
10. Most importantly, enjoy your patients and give them the highest standard of care possible.

TERMS AND ABBREVIATIONS USED IN PART 2

Wherever possible, generic terms have been used to describe protocol parameters, particularly pulse sequences and imaging options. Explanations of these can be found in the various sections of Part 1. To avoid ambiguity, the specific following terms have been used:

- *Fat suppression:* includes all fat suppression techniques such as fat saturation (FAT SAT), spectrally selective inversion recovery (SPIR) and Dixon methods.
- *Gradient moment nulling (GMN):* gradient moment rephasing (GMR) and flow compensation (FC).
- *Oversampling:* no phase wrap, anti-aliasing and anti-foldover
- *Rectangular FOV:* rectangular or asymmetric FOV
- *Respiratory compensation (RC):* phase reordering and respiratory triggering techniques

Abbreviations are used throughout the book for simplification purposes. A summary of these can be found in Table 1.1. In addition, Table 1.2 summarizes the slice prescription parameters for each examination in Part 2 and a comparison of acronyms used by certain vendors to describe pulse sequences and imaging options is given in Table 3.1 (see *Pulse sequences* in Part 1).

Table 1.1 Abbreviations used in this book.

A	Anterior
AC	Number of acquisitions
ACL	Anterior cruciate ligament
ACPC	Anterior–posterior commissure axis
ACR	American College of Radiologists
ADC	Apparent diffusion coefficient
ADEM	Acute disseminating encephalomyelitis
AIDS	Autoimmune deficiency syndrome

(*Continued*)

Table 1.1 (Continued)

ASIS	Anterior superior iliac spine
ASTM	American Society for Testing and Materials
AVM	Arteriovenous malformation
AVN	Avascular necrosis
BFFE	Balanced fast field echo
BGRE	Balanced gradient echo
BOLD	Blood oxygenation level dependent
CDH	Congenital dislocation of the hips
CE-MRA	Contrast enhanced magnetic resonance angiography
CNR	Contrast to noise ratio
CNS	Central nervous system
COPD	Chronic obstructive pulmonary disease
CSE	Conventional spin echo
CSF	Cerebral spinal fluid
CSI	Chemical shift imaging
CSR	Chemical shift ratio
CT	Computer tomography
CVA	Cerebral vascular accident
DE Prep	Driven equilibrium magnetization preparation
DTI	Diffusion tensor imaging
DWI	Diffusion weighted imaging
EAM	External auditory meatus
ECG	Electrocardiogram
EKG	Electrocardiogram (US spelling)
EPI	Echo planar imaging
ETL	Echo train length
FA	Fractional anisotropy
FAT SAT	Fat saturation
FC	Flow compensation
FDA	Food and Drug Administration
FFE	Fast field echo
FID	Free induction decay
FIESTA	Free induction echo stimulated acquisition
FISP	Free induction steady precession
FLAIR	Fluid attenuated inversion recovery
FLASH	Fast low angled shot
fMRI	Functional magnetic resonance imaging

Table 1.1 (Continued)

FOV	Field of view
FSE	Fast spin echo
Gd	Gadolinium
GFE	Gradient field echo
GMN	Gradient moment nulling
GMR	Gradient moment rephasing
GRASS	Gradient recalled acquisition in the steady state
GRE	Gradient echo
GRE-EPI	Gradient echo – echo planar imaging
HASTE	Half acquisition single-shot turbo spin echo
HIE	Hypoxic ischemic event
I	Inferior
IAM	Internal auditory meatus
ICP	Intracranial pressure
IM	Intramuscular
IR	Inversion recovery
IR-FSE	Inversion recovery – fast spin echo
IR prep	Inversion recovery magnetization preparation
IV	Intravenous
IVC	Inferior vena cava
L	Left
MDA	Medical Devices Agency
MIP	Maximum intensity projection
MOTSA	Multiple overlapping thin slab acquisition
MP RAGE	Magnetization prepared rapid acquisition gradient echo
MR	Magnetic resonance
MRA	Magnetic resonance angiography
MRCP	Magnetic resonance cholangiopancreatography
MRE	Magnetic resonance enterography
MRI	Magnetic resonance imaging
MRS	Magnetic resonance spectroscopy
MS	Multiple sclerosis
MSK	Musculoskeletal
MT	Magnetization transfer
MVS	Multi-voxel spectroscopy
NEX	Number of excitations

(Continued)

Table 1.1 (Continued)

NSA	Number of signal averages
NSF	Nephrogenic systemic fibrosis
P	Posterior
PC	Phase contrast
PC-MRA	Phase contrast magnetic resonance angiography
PD	Proton density
Pe	Peripheral
PEAR	Phase encoding artefact reduction
PET	Proton emission tomography
ppm	Parts per million
PRESS	Point resolved spectroscopy
PSIF	Reverse FISP
R	Right
RC	Respiratory compensation
REST	Regional saturation technique
RF	Radio frequency
ROI	Region of interest
RR	R to R interval
S	Superior
SAR	Specific absorption rate
SAT	Saturation
SE-EPI	Spin echo – echo planar imaging
SNR	Signal to noise ratio
SPAMM	Spatial modulation of magnetization
SPGR	Spoiled gradient recalled acquisition in the steady state
SPIR	Spectrally selective inversion recovery
SS	Single shot
SS-EPI	Single-shot echo planar imaging
SSFP	Steady-state free precession
SS-FSE	Single-shot fast spin echo
SS-GRE-EPI	Single-shot gradient echo EPI
STEAM	Stimulated echo acquisition mode
STIR	Short TAU inversion recovery
SVS	Single-voxel spectroscopy
SW	Susceptibility weighted
TE	Time to echo
TF	Turbo factor

Table 1.1 (Continued)

TFE	Turbo field echo
TI	Time to inversion
TIA	Transient ischaemic attack
TLE	Temporal lobe epilepsy
TMJ	Temporomandibular joint
TOF	Time of flight
TOF-MRA	Time of flight magnetic resonance angiography
TR	Time to repeat
True FISP	Siemens version of balanced gradient echo
TSE	Turbo spin echo
VENC	Velocity encoding
VNR	Velocity to noise ratio
VOI	Volume of interest
VQ	Ventilation perfusion scan

Table 1.2 Summary of slice prescription criteria.

Area	Plane	Angle	Prescription	Coverage
Brain	Sagittal	parallel to falx cerebri	lateral borders of each temporal lobe	foramen magnum to vertex and occiput to frontal lobe
	Axial	parallel to falx cerebri and ACPC line	foramen magnum to superior surface of the brain	occipital lobe to frontal lobe and both temporal lobes
	Coronal	perpendicular to ACPC line	cerebellum to frontal lobe	foramen magnum to vertex and both temporal lobes
Temporal lobes	Sagittal	parallel to falx cerebri	lateral borders of each temporal lobe	foramen magnum to vertex and occiput to frontal lobe
	Axial	parallel to temporal lobes and falx cerebri	inferior aspect of temporal lobes to superior border of body of corpus callosum	occipital lobe to frontal lobe and both temporal lobes
	Coronal	perpendicular to axial slices and parallel to falx cerebri	posterior cerebellum to anterior border of genu of corpus callosum	foramen magnum and vertex and both temporal lobes
IAMs and posterior fossa	Sagittal	parallel to falx cerebri	through IAMs on both sides	foramen magnum to superior body of corpus callosum and both temporal lobes
	Axial	perpendicular to falx cerebri and parallel to both IAMs	through the IAMs and posterior fossa	occipital lobe to frontal lobe and both temporal lobes
	Coronal	parallel to falx cerebri and a line between both IAMs	posterior border of cerebellum to clivus	foramen magnum to vertex and both temporal lobes

(*Continued*)

Table 1.2 (Continued)

Area	Plane	Angle	Prescription	Coverage
Pituitary fossa	Sagittal	parallel to falx cerebri	through the pituitary fossa	inferior edge of sphenoid sinus to the superior portion of the lateral ventricles
	Axial	parallel to falx cerebri	floor of the pituitary fossa to circle of Willis	occipital lobe to frontal lobe and both temporal lobes
	Coronal	parallel to falx cerebri	posterior to anterior clinoids	inferior border of sphenoid sinus to superior portion of lateral ventricles and both temporal lobes
Orbits	Sagittal	parallel to rectus muscles and parallel to optic nerve (single orbit)	left to right lateral walls of bony orbit or entire brain (optic neuritis)	foramen magnum to vertex and from occipital to the frontal lobe
	Axial	perpendicular to falx cerebri (in true plane or orientated to optic nerve)	inferior margin to above superior margin of orbits	lens of eye, globe, optic nerves and chiasm
	Coronal	perpendicular to optic nerve	optic chiasm to lens of the orbit	left and right lateral walls of the orbit
Paranasal sinuses	Sagittal	perpendicular to hard palate	through paranasal sinuses	foramen magnum to vertex
	Axial	perpendicular to nasal septum	inferior border of maxillary sinuses to superior edge of frontal sinuses	sphenoid sinus, tip of nose and lateral borders of all paranasal sinuses
	Coronal	perpendicular to hard palate	posterior portion of sphenoid sinus to tip of nose	inferior margin of maxillary sinuses to superior border of frontal sinuses
Pharynx	Sagittal	parallel to cervical spine	left to right lateral walls of pharynx	skull base to thyroid cartilage
	Axial	perpendicular to cervical spine	thyroid cartilage to base of skull	soft tissues of neck
	Coronal	parallel to cervical spine	posterior border of cervical cord to anterior surface of neck	skull base to sternoclavicular joints
Larynx	Sagittal	parallel to cervical spine	left to right skin surfaces of the neck	superior border of hard palate to sternoclavicular joints
	Axial	parallel to vocal cords	through laryngeal cartilages and vocal cords	both lateral skin surfaces of the neck
	Coronal	perpendicular to vocal cords	posterior surface of trachea to anterior surface of neck	superior border hard palate to sternoclavicular joints
Thyroid/ parathyroid	Axial	perpendicular to cervical spine	through thyroid	both lateral skin surfaces of neck
	Coronal	parallel to cervical spine	through thyroid	mandible to arch of the aorta
Salivary glands	Sagittal	parallel to cervical spine	left to right skin surfaces of the neck	base of the skull to hyoid bone

Table 1.2 (Continued)

Area	Plane	Angle	Prescription	Coverage
	Axial	perpendicular to cervical spine	from superior aspect of EAM to angle of jaw or through submandibular glands	all skin surfaces of neck
	Coronal	perpendicular to hard palate and nasal septum	vertebral bodies to superior alveolar process	cervical lymph node chain and skull base
TMJs	Sagittal	perpendicular to mandibular condyles and parallel to long axis of mandibular condyle	through each TMJ	both TMJs
	Axial	orthogonal	through both TMJs	both TMJs
	Coronal	parallel to mandibular condyles	through both TMJs	both TMJs
Cervical spine	Sagittal	parallel to long axis of spinal cord	from left to right lateral borders of vertebral bodies	base of skull to T2
	Axial	perpendicular to spinal cord and either parallel to disc space or perpendicular to lesion	lamina below to lamina above disc	bony cervical spine and surrounding soft tissue
	Coronal	parallel to long axis of spinal cord	posterior aspect of spinous processes to anterior border of vertebral bodies	base of skull to T2 and left to right borders of neck
Thoracic spine	Sagittal	parallel to the long axis of the spinal cord	from left to right lateral borders of vertebral bodies	C7 to conus
	Axial	perpendicular to spinal cord and either parallel to disc space or perpendicular to lesion	lamina below to lamina above disc	bony thoracic spine and surrounding soft tissue
	Coronal	long axis of spinal cord	posterior aspect of spinous processes to anterior border of vertebral bodies	C7 to conus
Lumbar spine	Sagittal	parallel to spinal canal	left to right lateral borders of vertebral bodies	conus to sacrum
	Axial	parallel to each disc space	lamina below to lamina above disc	exit foramina from T12 to S1
	Coronal	parallel to long axis of spinal canal	posterior aspect of spinous processes to anterior border of vertebral bodies	conus to sacrum
Whole spine	Sagittal	parallel to long axis of spinal cord	left to right lateral borders of vertebral bodies	base of skull to sacrum
	Axial	parallel to spinal cord	base of skull to sacrum or ROI	bony spine and surrounding soft tissue
Lungs and mediastinum	Coronal	orthogonal	posterior chest muscles to sternum	apices to lung bases
	Axial	orthogonal	apices to lung bases	entire chest to skin surfaces

(*Continued*)

Table 1.2 (Continued)

Area	Plane	Angle	Prescription	Coverage
Heart and great vessels	Coronal	orthogonal	posterior chest muscles to sternum	apices to lung bases
	Axial	orthogonal	inferior border of heart to superior aspect of arch of aorta	entire chest to skin surfaces
	LA view	parallel to intraventricular septum	through left ventricle	entire chest cavity
	Four chamber	through apex of left ventricle and mitral valve	through left ventricle	entire chest cavity
	SA view	parallel to mitral valve	through left ventricle	entire chest cavity
Thymus	Axial	orthogonal	through thymus	entire chest to skin surfaces
Breast	Sagittal	orthogonal	sternum to axilla	superior axillary tail to nipple and pectoralis muscle and chest wall
	Axial	orthogonal	superior axillary tail to inferior margins of breast(s)	superior axillary tail to nipple and pectoralis muscle and chest wall
Axilla	Sagittal	orthogonal	from sternoclavicular joint to humerus	both axillae or single axilla
	Axial	orthogonal	through both axillae and supraclavicular fossae	both axillae
	Coronal	orthogonal	posterior chest muscles to sternum	both axillae
Brachial plexus	Sagittal	perpendicular to long axis of symptomatic brachial plexus	spinal cord to medial aspect of humerus	C3 to aortic arch
	Axial	perpendicular to long axis of C4 to C7	arch of aorta to C3	both shoulders and anterior neck
	Coronal	parallel to long axis of C4 to C7	posterior aspect of cervical cord to sternoclavicular joints	C3 to aortic arch
Liver/biliary system	Coronal	orthogonal	posterior abdominal peritoneum to anterior abdominal wall	pubis symphysis to diaphragm
	Axial	orthogonal	diaphragm to inferior margin of liver	whole abdomen to skin surfaces
Kidneys/ adrenals	Coronal	orthogonal	posterior abdominal peritoneum to anterior abdominal wall	pubis symphysis to gastric ventricle
	Axial	orthogonal	inferior margin of kidneys to superior aspect of adrenals	whole abdomen to skin surfaces
Pancreas	Coronal	orthogonal	posterior abdominal peritoneum to anterior abdominal wall	pubis symphysis to gastric ventricle
	Axial	orthogonal	through pancreas	whole abdomen to skin surfaces

Table 1.2 (Continued)

Area	Plane	Angle	Prescription	Coverage
Bowel	Coronal	orthogonal	from posterior abdominal peritoneum to anterior abdominal wall	pubis symphysis to the gastric ventricle
	Axial	orthogonal	gastric ventricle to pubis symphysis	whole abdomen to skin surfaces
Prostate	Sagittal	perpendicular to prostatic/rectal junction	left to right margins of prostate and seminal vesicles	pubis symphysis to iliac crests
	Axial	orthogonal or perpendicular to prostatic/rectal junction	pelvic floor to above seminal vesicles	prostate gland and surrounding structures
	Coronal	parallel to prostatic/rectal junction	posterior margin of prostate to symphysis pubis	pubis symphysis iliac crests
Rectum and testes	Coronal	orthogonal	coccyx to anterior border of pubis symphysis	pubis symphysis to iliac crests
	Axial	orthogonal	pelvic floor to iliac crests or through ROI	buttocks and rectum and to skin surfaces
Ovaries and cervix	Coronal	orthogonal	coccyx to anterior border of pubis symphysis	pubis symphysis iliac crests
	Sagittal	orthogonal	left to right pelvic side walls	pubis symphysis to the iliac crests
	Axial	orthogonal	pelvic floor to iliac crests or through ROI	whole pelvis to skin surfaces
Shoulder	Coronal	parallel to supraspinatus muscle tendon	infraspinatus posteriorly to supraspinatus anteriorly	superior edge of acromion to inferior aspect of subscapularis muscle, deltoid muscle and distal third of supraspinatus muscle
	Sagittal	parallel to supraspinatus tendon	medial to glenoid cavity to bicipital groove	distal portion of joint capsule to superior border of acromion
	Axial	orthogonal	from superior acromioclavicular joint (including the supraspinatus muscle) to inferior margin of glenoid	bicipital groove to distal supraspinatus muscle
Humerus	Coronal	parallel to long axis of humerus and aligned with glenohumeral joint or humeral epicondyles	glenoid to proximal radius and ulna	whole humerus to skin surfaces
	Sagittal	parallel to long axis of humerus and aligned with glenohumeral joint or humeral epicondyles	glenoid to proximal radius and ulna	whole humerus to skin surfaces
	Axial	perpendicular to long axis of the humerus	to include lesions seen on coronal or sagittal images	whole humerus or through ROI

(*Continued*)

Table 1.2 (Continued)

Area	Plane	Angle	Prescription	Coverage
Elbow	Coronal	parallel to a line joining humeral epicondyles	posterior to anterior skin surfaces	whole elbow joint to skin surfaces
	Sagittal	perpendicular to a line joining humeral epicondyles	medial to lateral borders of elbow	whole elbow joint to skin surfaces
	Axial	perpendicular to long axis of humerus and forearm	distal humerus to proximal radius and ulna	whole elbow joint to skin surfaces
Forearm	Coronal	parallel to humeral epicondyles or to distal radio-ulnar joint	posterior to anterior margins of forearm	whole of forearm from wrist to elbow
	Sagittal	perpendicular to humeral epicondyles or to distal radio-ulnar joint	posterior to anterior margins of forearm	whole of forearm from wrist to elbow
	Axial	perpendicular to coronal slices	well above and below lesions seen in sagittal and coronal planes	whole forearm to skin surfaces
Wrist and hand	Coronal	parallel to proximal row of carpus	left to right skin surfaces of wrist	inferior border of carpal bones to distal portion of forearm
	Sagittal	perpendicular to coronal plane	left to right skin surfaces of wrist	inferior border of carpal bones to distal portion of forearm
	Axial	parallel to proximal row of carpal bones	through ROI	distal radioulnar joint to include triangular fibrocartilage
Hips	Coronal	angled to compensate for positional rotation of pelvis, demonstrating femoral heads equally on each side	posterior to anterior margins of musculature of hip	junction of ilium and superior acetabulum to below lesser trochanter
	Sagittal	perpendicular to superior surface of femoral head	lateral aspect of greater trochanter through articular portions of acetabulum	proximal margin of femoral shaft (below the lesser trochanter) to greater sciatic notch
	Axial	parallel to superior surface of both femoral heads	above articular portion of acetabulum to superior edge of lesser trochanter	junction of ilium and superior acetabulum to below lesser trochanter
Femur	Coronal	parallel to long axis of femur	anterior to posterior skin surfaces of thigh	entire length of femur
	Sagittal	parallel to the long axis of the femur	from the left to right skin surfaces of the thigh	entire length of femur
	Axial	perpendicular to long axis of the femur	prescribed to extend from well below, to well above lesions seen on coronal or sagittal images	entire thigh to skin surfaces
Knee	Coronal	parallel to posterior surfaces of femoral condyles	femoral condyles to anterior margin of patella	superior edge of patella to inferior edge of tibial tuberosity

Table 1.2 (Continued)

Area	Plane	Angle	Prescription	Coverage
	Sagittal	parallel with ACL	lateral to medial collateral ligaments	superior edge of patella to below tibial tuberosity
	Axial	perpendicular to posterior surfaces of femoral condyles	superior surface of patella to tibial tuberosity	entire knee to skin surfaces
Tibia and fibula	Coronal	parallel to interosseous ligament	posterior to anterior skin surfaces of calf	whole of tibia and fibula to skin surfaces
	Sagittal	perpendicular to the interosseous ligament	left to right skin margins of calf	whole of tibia and fibula to skin surfaces
	Axial	perpendicular to long axis of the tibia	well above and below lesions seen in sagittal and coronal planes	whole calf to skin surfaces
Ankle	Coronal	parallel to transmalleolar line	Achilles tendon to base of proximal metatarsals	inferior border of calcaneum to distal portion of tibia
	Sagittal	parallel to mortise axially, to distal tibia coronally	from the lateral to medial aspects of the ankle	distal tibia to the sole of the foot and the tarsometatarsal joints
	Axial	perpendicular to long axis of distal tibia	superior margin of tibiofibular margin to bottom of calcaneum and base of fifth metatarsal	entire ankle joint to skin surfaces
Foot	Coronal	proximally parallel to bases of the first to fourth metatarsals	metatarsophalangeal joints to tarsometatarsal joints	whole foot to skin surfaces
	Sagittal	perpendicular to plane joining base of first to fourth metatarsals	lateral to medial aspects of foot	sole of foot to distal tibia
	Axial	perpendicular to metatarsals	metatarophalangeal joints to tarsometatarsal joints	whole foot to skin surfaces

CONCLUSION

To use this book:

- Find the required anatomical region and then locate the specific examination.
- Study the categories under each section. It is possible that all the categories are relevant if the examination is being performed for the first time. However, there may be occasions when only one item is appropriate. For example, there could be a specific artefact that is regularly observed in chest examinations, or image quality is not up to standard in lumbar spine protocols. Under these circumstances, read the subsection entitled *Protocol optimization*.
- If the terms used, or concepts discussed in Part 2 are unfamiliar, then turn to Part 1 and read the summaries described there.