

Clinical Radiology

Curriculum 2021



Clinical
Radiology

The Royal College of Radiologists

Guidance for the First FRCR Examination

Introduction

The First FRCR Examination ensures that candidates have gained knowledge of the physical principles that underpin diagnostic medical imaging and of the anatomy needed to perform and interpret radiological studies. It forms part of the programme of assessment of the Specialty Training Curriculum for Clinical Radiology.

The first FRCR examination comprises two modules: Anatomy and Scientific Basis of Imaging (physics). As the knowledge assessed in this examination is essential to clinical radiology practice, this examination should be completed during the first year of clinical radiology training (ST1).

Training programmes should provide specific teaching in radiological anatomy and basic sciences prior to the first sitting of the exam in March of ST1, supplemented by practical training and private study.

The purpose statements, learning outcomes and syllabus of each of the modules is given below to assist candidates, and those involved in their training, in understanding the scope of the First FRCR examination. Further information on the examination can be found on the RCR website.

First FRCR Examination (Anatomy)

The First FRCR Examination (Anatomy) assesses the knowledge of anatomy as shown by radiological studies. It does not assess knowledge of surgical anatomy, surface anatomy or cadaveric anatomy, but applied anatomy that is relevant to clinical radiology.

Radiological anatomy is a cornerstone of clinical radiology for several reasons:

- A sufficient understanding of the radiological anatomy is a prerequisite to performing any radiological study
- Radiologists need a thorough knowledge of normal radiological anatomy so as to be able to recognise abnormalities
- Radiologists need to be able to articulate the anatomical site of any abnormality accurately to clinical colleagues

The purpose of the examination is to assess whether those undertaking specialty training in clinical radiology have an appropriate knowledge of the anatomy that underpins all radiological imaging including radiography, fluoroscopy, angiography, computed tomography (CT), ultrasound imaging and magnetic resonance imaging (MRI). This should build on basic knowledge of anatomy from previous medical training. As detailed in the Specialty Training Curriculum for Clinical Radiology, the anatomy module forms part of the evidence that trainees have met CiP 7 (Appropriately select and tailor imaging to patient context and the clinical question(s)) and CiP 8 (Provide timely, accurate and clinically useful reports on imaging studies).

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Learning outcomes

Candidates should be able to:

1. Describe and recognise the bony and soft tissue anatomy visible on radiographs, including common normal variants for adults and children of all ages.
2. Describe and recognise the radiological anatomy visible on CT, including multiplanar and surface shaded reformats. This will include solid organs such as the heart and lungs in addition to bones, vessels and muscles
3. Describe and recognise the radiological anatomy visible on ultrasound imaging. This will include solid viscera such as the liver and spleen, bones, vessels, major ligaments and tendons. Transrectal and transvaginal ultrasound may be included
4. Describe and recognise the radiological anatomy of MRI, including solid viscera such as the brain, thoracic and abdominal organs, bones, joints, muscles and vessels
5. Describe and recognise the radiological anatomy of fluoroscopic studies of the gastrointestinal, biliary, genito-urinary and vascular systems

NB: Nuclear medicine, including positron emission tomography, is excluded from the anatomy curriculum.

Table 1 provides a guide to the topics through which the learning outcomes may be examined. It is intended as a guide and general indication to the breadth of the topics that may appear in the examination questions. It is not an exhaustive list or teaching plan and the points do not relate to equal amounts of study time.

Table 1: Topics for the First FRCR (Anatomy) module

System/Area	Further guidance
1. Head & Neck	
1.1 Brain	<ul style="list-style-type: none">▪ Ventricles and CSF spaces▪ Arteries and venous sinuses▪ Basal nuclei and major white matter tracts▪ Cerebrum and cerebellum▪ Cranial nerves▪ Pituitary and juxtaseellar structures
1.2 Skull	<ul style="list-style-type: none">▪ Calvaria and base of skull



System/Area	Further guidance
1.3 Face and neck	<ul style="list-style-type: none">Arteries and veinsSinusesOrbit and contentsFacial skeletonTongue and oral cavityLymph node groupsLarynx and pharynxThyroid and parathyroidSalivary glands
2. Thorax	
2.1 Cardiovascular	<ul style="list-style-type: none">Mediastinum, pericardium and lymph node groupsCardiac chambers, valves, arteries and veinsGreat vessels and azygous/hemi-azygous system
2.2 Bronchopulmonary	<ul style="list-style-type: none">Trachea, lobar and segmental bronchiPulmonary vasculaturePleura and fissures
2.3 Chest wall and diaphragm	
2.4 Breast and axilla	
3. Abdomen and Pelvis	
3.1 Bowel	<ul style="list-style-type: none">Oesophagus and stomachDuodenum, small bowel and appendixColon, rectum and anus
3.2 Upper Abdominal Viscera	<ul style="list-style-type: none">Liver segments and blood vesselsBiliary tree and gall bladderPancreas, adrenals and spleen
3.3 Abdominal wall	
3.4 Spaces and planes	<ul style="list-style-type: none">Perirenal and pararenal spaces and fasciaePeritoneal reflections and spacesMesentery and omentum



System/Area	Further guidance
3.5 Genitourinary tract	<ul style="list-style-type: none">▪ Kidneys and pelvicalyceal systems▪ Ureters and bladder▪ Prostate, seminal vesicles and urethra▪ Testes and epididymides
3.6 Gynaecology	<ul style="list-style-type: none">▪ Ovaries and fallopian tubes▪ Uterus and cervix▪ Vagina
3.7 Vascular supply	<ul style="list-style-type: none">▪ Portal venous system▪ Aorta and major branches▪ IVC and tributaries▪ Azygous system
3.8 Lymph node groups	
4. Musculoskeletal system	
4.1 Spine	<ul style="list-style-type: none">▪ Vertebrae, sacrum and joints▪ Paraspinal muscles and ligaments▪ Spinal cord, cauda equina and nerve roots
4.2 Upper Limb	<ul style="list-style-type: none">▪ Bones and joints, including shoulder▪ Muscles and nerves▪ Blood vessels
4.3 Lower Limb	<ul style="list-style-type: none">▪ Bones and joints, including pelvis▪ Muscles and nerves▪ Blood vessels

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First FRCR Examination (Scientific Basis of Imaging)

The first FRCR examination (Scientific Basis of Imaging) assesses the knowledge of those physical, cellular and molecular principles that underpin the generation of radiological studies.

The purpose of the examination is to assess whether those undertaking specialty training in clinical radiology have an appropriate knowledge of the scientific principles that underpin all radiological imaging, including radiography, fluoroscopy, angiography, computed tomography (CT), ultrasound imaging, radionuclide imaging and magnetic resonance imaging (MRI). This will allow trainees to choose and rationally apply appropriate imaging techniques to clinical problems, based upon understanding of the scientific basis of each modality, and to describe how the concepts of risk, safety and quality apply in these imaging modalities. It will also assist trainees in selecting optimal operating factors and help them to interpret the images produced.

Complete understanding of the principles underlying the imaging process will form the basis of radiologists updating their knowledge throughout their careers, enabling them to remain current as new imaging techniques are introduced and clinical pathways evolve. This should build on basic knowledge of physics, cell biology and mathematics, which is assumed.

Learning outcomes

Candidates should be able to:

1. Describe the structure and properties of matter, the phenomena of radioactivity and magnetism, the nature of ionising radiation, radiofrequency radiation, optical imaging and ultrasound and how they interact with matter and the differences between ionising and non-ionising radiation
2. Distinguish and compare between different types of diagnostic medical image and understand how such images are created, reconstructed, processed, transmitted, stored and displayed
3. Describe the construction and function of medical imaging equipment including the radiation, optical or ultrasound source, image-forming components and image or signal receptor and detectors used for QA and monitoring. Given the overwhelming use of digital imaging (CR or DR) film-screen applications will not be examined
4. Indicate how imaging equipment is operated and describe the imaging techniques that are performed with such equipment
5. Identify and compare the type of information contained in images from different modalities
6. Distinguish between different indices of image quality, explain how they are inter related and indicate how they are affected by changing the operating factors of imaging equipment
7. Identify agents that are used to enhance image contrast and explain their action
8. Explain how the performance of imaging equipment is measured and expressed
9. Describe the principles of quality assurance and outline how quality control tests of imaging equipment are performed and interpreted



10. Recognise artefacts in medical images and identify how they are removed or their impact is reduced
11. Recognise the hazards and risks to patients, members of staff and members of the public associated with medical imaging and describe how their impact is reduced without compromising diagnostic image quality
12. Identify the major pieces of UK legislation and guidance that affect the practice of medical imaging and interpret their requirements
13. Describe how functional and molecular imaging can be used to probe biological processes in disease
14. Understand the concepts relevant to improving patient related outcomes

Table 2 provides a guide to the topics through which the learning outcomes may be examined. It is intended as a guide and general indication to the breadth of the topics that may appear in the examination questions. It is not an exhaustive list or teaching plan and the points do not relate to equal amounts of study time.

Table 2: Topics for the First FRCR (Scientific Basis of Imaging) module

Topic area	Examples of expected knowledge
1. Matter and radiation	
1.1 Structure of matter, the atom and the nucleus	<ul style="list-style-type: none">▪ Basic atomic structure, including electron shells & energies
1.2 Interaction of electrons and photons with matter	<ul style="list-style-type: none">▪ Nature and properties of charged particles and electromagnetic radiation▪ Interaction of ionizing radiation with atoms and molecules, especially those in human tissuesInteraction of photons with matter over energy range 10 keV to 1 MeV▪ Photoelectric and Compton interactions, including the likelihood depending on photon energy and the atomic number of the atoms in the matter:▪ Electron energy in solids▪ How electron energy is dependent on the elements of matter and the physical form of that matter
1.3 Filtration of x-ray beams	<ul style="list-style-type: none">▪ Spectrum of energies in x-ray production and how and why the energy distribution might be changed by materials placed in the primary beam in order to improve image quality and/or reduce patient radiation exposure



Topic area	Examples of expected knowledge
1.4 Nuclear stability	<ul style="list-style-type: none">How the combination of protons and neutrons affects whether a nucleus is stable and how that relates to radioactive decay
1.5 Mechanisms of radioactive transformation	<ul style="list-style-type: none">Isomeric transitionElectron captureBeta emissionAlpha emissionGamma ray emissionCharacteristic x-rays
1.6 Nuclear energy states and gamma emission	<ul style="list-style-type: none">Energy levels within nuclei and the implications for the energies of gamma rays emitted by clinically used radionuclides
1.7 Activity and radioactive decay	<ul style="list-style-type: none">The definition of activity and how it is measuredPhysical, biological and effective half-lives and how these factors relate to patient doseBackground sources of radiation
1.8 Artificial radionuclides and their production	<ul style="list-style-type: none">How radionuclides are produced using the following<ul style="list-style-type: none">CyclotronsFission productsGenerators and elution
1.9 Radiopharmaceuticals and their production	<ul style="list-style-type: none">How radionuclides are incorporated into clinically useful molecules; shelf life; quality assurance
2. Common themes for multiple imaging modalities	
2.1 Structure of images	<ul style="list-style-type: none">Pixels and voxelsBit depth, windowing and dynamic rangeGreyscale and colour imagesMultimodal images and colour overlays



Topic area	Examples of expected knowledge
2.2 Image quality	<ul style="list-style-type: none">▪ Signal to noise ratio (SNR)▪ Contrast▪ Resolution (spatial/temporal)▪ Artefacts, including geometrical inaccuracies; causes and potential fixes▪ Differences between acquired spatial resolution and reconstructed spatial resolution, and common reasons for this▪ How different acquisition parameters are interrelated and how changing one impacts on others, e.g. in MR how SNR, spatial resolution and acquisition time are interrelated▪ Changes in image quality that do not affect patient dose
2.3 Signal processing, image reconstruction and reformatting	<ul style="list-style-type: none">▪ Basic understanding of data sampling and processing including, the Nyquist criterion, bit depth and frequency analysis.▪ Basic understanding of image registration and post-processing including concepts of<ul style="list-style-type: none">– Multiplanar reformats– Curvilinear reconstructions– Maximum intensity projections– Minimum intensity projections– Surface and volume rendering
2.4 Quality assurance	<ul style="list-style-type: none">▪ The role of acceptance testing of new imaging equipment, technology and software, including artificial intelligence▪ The importance of quality assurance as part of an imaging service and any regulatory implications▪ Quality assurance recommendations from manufacturers and professional bodies guidance▪ Accreditation schemes such as 'Quality Standard for Imaging' (QSI)



Topic area	Examples of expected knowledge
2.5 Management of radiological imaging	<ul style="list-style-type: none">▪ Concepts of DICOM and image metadata▪ Image compression (lossless and lossy) and implications of this▪ anonymisation & encryption▪ Image consistency between different display units▪ Display monitor requirements for viewing diagnostic images▪ Radiation Dose Structured Report (RDSR)▪ PACS (Picture Archiving and Communications Systems)▪ RIS (Radiology Information System)▪ Teleradiology
3. Radiography & Fluoroscopy	
3.1 Construction, function and operation of computed and digital radiographic systems	<ul style="list-style-type: none">▪ Physical and engineering components and processes involved in the production of radiographic images▪ Impact of changing basic exposure factors – kVp, mA, time, mAs – on the x-ray beam, the patient dose and image quality
3.2 X-ray tube and x-ray beam	<ul style="list-style-type: none">▪ Why specific components are used in the production of x-rays (dependent on the radiographic modality) and how the primary beam is delineated▪ How heat is generated and dissipated from the ray anode and the limitations in clinical imaging▪ Effects of filtration on the X-ray beam, image quality and patient dose▪ Common filtration materials used and the reasons for their selection
3.3 Image receptors for computed and digital radiography	<ul style="list-style-type: none">▪ Materials, structure and function of the image receptors▪ How a latent image is produced and retrieved for computed radiology and the device in which the image is first held▪ How the image is read and initially stored by digital radiology systems



Topic area	Examples of expected knowledge
3.4 Scatter rejection	<ul style="list-style-type: none">How grids, x-ray energy, air gaps can reduce the impact of scattered radiation in imagesPractical use and construction of grids, including: moving or stationary, grid ratio, grid lines per cm and materials usedHow to use kV/mA dose curves, the grid, collimation, magnification and/or compression in order to reduce the effect of scatter on image quality
3.5 Contrast media – iodinated, barium and air	<ul style="list-style-type: none">Physical nature of contrast materials and their interaction with x-raysSafety considerations of contrast media
3.6 Dual energy radiography	<ul style="list-style-type: none">How energy spectra are created and used
3.7 Mammography	<ul style="list-style-type: none">Anode angles, anode materials, filtration, grid, exposure settings and collimation, etc. used to gain the maximum contrast within radiation sensitive soft tissue
3.8 Radiographic tomography and tomosynthesis	<ul style="list-style-type: none">How these systems can increase soft tissue contrast
3.9 Construction, function and operation of a fluoroscopy system	<ul style="list-style-type: none">C-arm (or equivalent), automatic brightness control and automatic exposure control (with kV/mA dose curves)kV/mA dose curve selection and settingDifference between fluoroscopy and fluorography and the image quality/dose implicationsHow automatic brightness control works and how best to use the system with and without contrast or in the presence of bone and/or soft tissue
3.10 Image receptor – image intensifier and flat panel detector	<ul style="list-style-type: none">Basic principles of image receptors used for fluoroscopyHow the imaging chains affect the image quality



Topic area	Examples of expected knowledge
3.11 Image digitisation	<ul style="list-style-type: none">▪ Specific implications of digitisation on:<ul style="list-style-type: none">– Applied dose per frame– Artefacts▪ Data storage
3.12 Angiography with contrast media, including digital subtraction techniques	<ul style="list-style-type: none">▪ How images are obtained and how multiple images during injection of contrast materials can be used to increase contrast
4. Radionuclide imaging	
4.1 Construction, function and operation of a gamma camera/scanner	<ul style="list-style-type: none">▪ Understand how the gamma camera is operated in planar mode▪ Patient positioning, body contouring, mechanical safety
4.2 Imaging collimators	<ul style="list-style-type: none">▪ How they are made, significance of the dimensions and shapes of the holes and how to assess which are suitable for each clinical application▪ How the physical dimensions of the collimator holes and septa affect sensitivity and spatial resolution▪ Storage and handling requirements
4.3 Image receptor – scintillation detector	<ul style="list-style-type: none">▪ Factors relevant to the care and maintenance of the detector, temperature and mechanical safety
4.4 Scatter rejection	<ul style="list-style-type: none">▪ Pulse height analysis, rejection of scatter and effects on sensitivity
4.5 Mechanisms and quantification of radiopharmaceutical localisation	<ul style="list-style-type: none">▪ Use of regions of interest▪ Use of activity time curves and their analysis
4.6 Static, whole-body, dynamic and gated imaging	<ul style="list-style-type: none">▪ Different modes of data acquisition and how these impact on setting PHA window, collimation choice, and acquisition duration
4.7 Radiation safety and factors affecting radiation dose	<ul style="list-style-type: none">▪ Choice of radionuclide, radiopharmaceutical, administered activity and administration method.▪ CT image quality requirements of localisation and attenuation imaging, effects on dose (kV, mA, etc.) and z-axis range.



Topic area	Examples of expected knowledge
4.8 Construction, function and operation of a rotating multi-head gamma camera	<ul style="list-style-type: none">▪ How gamma camera gantry operates in SPECT mode▪ Patient contouring and safety▪ Step and shoot versus continuous rotation▪ How the camera and CT gantries are located in the system
4.9 SPECT/CT	<ul style="list-style-type: none">▪ CT for localisation or attenuation correction▪ Correct image registration
4.10 Image reconstruction, scatter and attenuation corrections	<ul style="list-style-type: none">▪ Filtered back projection and iterative techniques▪ Time-of-flight in PET▪ The selection of pixel size, field of view, reconstruction filters▪ Other forms of data analysis based on time activity curves, gated acquisition, etc.▪ Understand the impact of X-ray contrast agents on attenuation correction in radionuclide imaging, e.g. PET-CT
4.11 Construction, function and operation of a multi-detector PET-CT ring system	<ul style="list-style-type: none">▪ Layout of a typical PET-CT gantry, in particular, the locations of the annihilation photon detectors and their collimation
4.12 Data acquisition	<ul style="list-style-type: none">▪ 3D & 2D acquisition
4.13 Standardised uptake value (SUV) and quantification	<ul style="list-style-type: none">▪ Definition, factors affecting and harmonization between scanners
4.14 PET/CT	<ul style="list-style-type: none">▪ Impact of CT for attenuation correction in SUV and artefacts, e.g. movement
5. Radiation Safety	
5.1 Radiation safety and factors affecting radiation dose	<ul style="list-style-type: none">▪ Absorbed dose, equivalent dose and effective dose▪ How equivalent and effective doses of staff and patients are estimated in clinical practice.▪ Radiation risk▪ Stochastic and deterministic effects for different exposures occurring in clinical practice.▪ Typical annual background dose rate and the population doses received from common x-ray and nuclear medicine procedures



Topic area	Examples of expected knowledge
5.2 Statutory Legislation	<ul style="list-style-type: none">▪ Hierarchy of recommendations, legislation and guidance▪ 'Ionising Radiations Regulations 2017' and 'Approved Code of Practice & Guidance (L121)' including:<ul style="list-style-type: none">– Risk assessment, restriction of exposure and dose monitoring– Duty holders such as Radiation Protection Adviser and Radiation Protection Supervisor– Designation of working areas, Local Rules and Systems of Work– Dose limits, dose constraints and classification of employees– Requirements relating to pregnant staff– Training requirements▪ 'Ionising Radiation (Medical Exposure) Regulations 2017' and guidance June 2019 including:<ul style="list-style-type: none">– Justification, optimisation and dose limitation– Requirements for carers and comforters– Employer's procedures– Diagnostic reference levels– Notification and reporting of radiation incidents– Duty holders and their training and responsibilities▪ Environmental regulations, including variations within UK regions.▪ Exposures for research, health screening and medico-legal purposes
5.3 Practical management of radiation doses to patients, staff and the general public	<ul style="list-style-type: none">▪ Radiation detectors and dose meters▪ Measurement of absorbed dose and dose rate in air▪ Use of personal protective equipment and radiation shielding
5.4 Practical management of radiation doses in radiology	<ul style="list-style-type: none">▪ Typical dose-area products, entrance surface doses and effective doses in radiography and fluoroscopy▪ Detector dose indicators▪ Factors affecting radiation dose▪ Time, distance and shielding for dose reduction▪ Children, staff and pregnant patients



Topic area	Examples of expected knowledge
5.5 Practical management of radiation doses in nuclear medicine	<ul style="list-style-type: none">Contamination and environmental dose rate monitoringActivity measurement with radionuclide calibratorTypical activities and effective dosesFactors affecting radiation doseTime, distance and shielding for dose reductionChildren and conception, pregnancy and breast-feeding in patientsStorage, handling and transportation of radioactive substancesStorage and disposal of radioactive waste'Administration of Radioactive Substances Advisory Committee' and 'Notes for Guidance'
6. Computed tomography	
6.1 Construction, function and operation of a CT scanner	<ul style="list-style-type: none">Basic construction of a CT scannerCooling of the x-ray tube and how it may impact on acquisitionHow the scanner is controlled from the workstation and acquisition parametersz-axis collimation, filtration and field of viewTable motion and linear projection for aligning prior to scanningkV and mA settingsmA modulation techniques (x, x-y axis) and the effect on patient dose and image qualityScout images
6.2 Axial and helical scanners	<ul style="list-style-type: none">Geometry of axial and helical scanning and the effect on acquisitionUnderstand pitch and the impact on image reconstruction process, IQ and patient dose
6.3 Multi-slice scan acquisition	<ul style="list-style-type: none">Multi-slice acquisition process and how it has impacted on CT technology developments and current CT scanners (e.g. offering wider or narrower detector banks)Overview of modern CT multi-slice technology



Topic area	Examples of expected knowledge
6.4 Image reconstruction	<ul style="list-style-type: none">▪ Filtered back projection, iterative reconstruction and the implications for patient dose and image quality▪ The z-axis collimation and the reconstructed slice width▪ Digital filtering of the images during reconstruction
6.5 Advanced CT imaging techniques	<ul style="list-style-type: none">▪ CT angiography, CT fluoroscopy and gated imaging▪ CT perfusion and physiological principles underpinning functional assessment▪ Dual energy CT, dual source CT
6.6 Radiation dose to patients, staff and the public	<ul style="list-style-type: none">▪ Dose metrics (CTDI, and Dose Length Product)▪ Protocol settings (kV, detector configuration, collimation, beam filtration, and impact on patient dose and image quality)▪ How to approach technique optimisation / dose reduction▪ How patient dose is estimated from dose metrics provided by the scanner▪ Typical radiation dose rates to staff and how these are managed▪ The definition of 'Controlled Area' and how it is physically defined and managed▪ IRMER duty holders in CT – roles, responsibilities and training▪ The role of the radiation protection supervisor in CT
6.7 Radiation safety and factors affecting radiation dose	<ul style="list-style-type: none">▪ Distance to source, duration of exposure to radiation exposure, and shielding when staff are near to the primary or secondary sources of radiation (gantry, patient, walls, etc)



Topic area	Examples of expected knowledge
7. Magnetic resonance	
7.1 Creation, detection and spatial localisation of the MR signal	<ul style="list-style-type: none">▪ Nuclear magnetic resonance▪ Precession about magnetic fields (B_0 and B_1)▪ Equilibrium magnetisation (M_0) and dependence on the strength of the static magnetic field, B_0▪ Longitudinal (M_z) & transverse magnetisation (M_{xy})▪ Magnitude and phase of transverse magnetisation▪ Overview of MR hardware▪ Slice selection▪ k-space:<ul style="list-style-type: none">– Relationship between k-space and MR image– Frequency-encoding– Phase-encoding– Awareness of different k-space trajectories and their advantages/disadvantages▪ 2D versus 3D sequences
7.2 Basic contrast mechanisms	<ul style="list-style-type: none">▪ T1. Understand the concept of MR signal saturation▪ T2 and T2*▪ Impact of relaxivity of gadolinium-based contrast agents on T1-weighted and T2*-weighted MR images▪ Difference between a contrast-weighted MR image and a quantitative image (map)▪ Extension of T2*-weighted MRI to susceptibility-weighted imaging (SWI)
7.3 Basic MRI sequences & common variants	<ul style="list-style-type: none">▪ Spoiled gradient echo, spin echo▪ Multiple echo variants (TSE/FSE, EPI)▪ Single shot versus multi shot▪ Pulse sequence diagram▪ Basics of steady-state sequences
7.4 Frequency-dependent techniques	<ul style="list-style-type: none">▪ Understanding of chemical shift: fat & water▪ Fat saturation▪ In-phase & out-of-phase TEs, Dixon▪ Awareness of MR spectroscopy (MRS) and appropriate TEs for particular clinical questions



Topic area	Examples of expected knowledge
7.5 T1-dependent techniques	<ul style="list-style-type: none">▪ Inversion recovery (IR)▪ Suppression: STIR & FLAIR. The role(s) of TR (and T1) in determining null point▪ Increased T1-weighting e.g. MPRAGE▪ Phase-sensitive IR
7.6 Diffusion MRI	<ul style="list-style-type: none">▪ Diffusion weighting, relationship with underlying cellularity▪ b-values, ADCs and calculated b-values▪ Potential perfusion contribution to ADC▪ Diffusion anisotropy
7.7 Acceleration techniques	<ul style="list-style-type: none">▪ Acceleration techniques, their impact on image quality and potential artefacts:<ul style="list-style-type: none">– Zero-filling (interpolation)– Half-Fourier– Parallel imaging– Simultaneous multislice (multiband)– Compressed sensing– Temporal sharing (TWIST/TRICKS)
7.8 Flow-related MR techniques	<ul style="list-style-type: none">▪ Dynamic contrast-enhanced (DCE)▪ Perfusion MRI<ul style="list-style-type: none">– Dynamic susceptibility contrast (DSC)– Awareness of arterial spin labelling (ASL)– DCE for myocardial perfusion, oncology▪ MR angiography (MRA) techniques,<ul style="list-style-type: none">– Time of flight– Contrast-enhanced– Phase contrast▪ Other non-contrast enhanced MRA options



Topic area	Examples of expected knowledge
7.9 MR artefacts and artefact reduction techniques	<ul style="list-style-type: none">▪ Causes and potential solutions for artefacts found in MRI, including:<ul style="list-style-type: none">– Motion artefacts, respiratory gating, navigated sequences, saturation bands, radial-type k-space acquisitions– B0 inhomogeneities, e.g. air/tissue interfaces or metal implants– B1 inhomogeneities, especially at 3T– RF interference: instantaneous (RF spikes); continuous RF interference– Phase wrap– Truncation artefact (Gibb's ringing)– Chemical shift, receiver bandwidth– Fat-water swaps in Dixon MRI– Poor geometry-factor with high acceleration factors in parallel imaging
7.10 MR safety	<ul style="list-style-type: none">▪ MHRA guidelines as the primary MR safety reference for UK▪ MR safety framework, definitions, roles & responsibilities<ul style="list-style-type: none">– MR Responsible Person and MR Safety Expert– MR Authorised Persons– MR Environment and MR Controlled Access Area– MR Safe/ MR Conditional/ MR Unsafe/ MR Unlabelled▪ Safety issues, particularly with regards implanted devices and emergency situations, including<ul style="list-style-type: none">– Attraction, torque– RF heating: SAR and B1+rms– Magnet quench▪ Safety issues associated with gadolinium-based contrast agents<ul style="list-style-type: none">– Linear versus Macrocylic-based agents– Nephrogenic systemic fibrosis (NSF)– Gadolinium deposition/retention▪ Recommendations for scanning patients with implanted devices without the device manufacturer's approval, e.g. 'off-label'



Topic area	Examples of expected knowledge
7.11 Quality assurance	<ul style="list-style-type: none">Importance of quality assurance in MR to identify failing elements in phased array coilsQuality assurance to help establish reproducibility of quantitative MR techniques
8. Ultrasound	
8.1 Nature and properties of ultrasound waves	<ul style="list-style-type: none">Non-ionising mechanical wave; define wavelength, speed, elasticity, density, impedance, energy and power
8.2 Propagation and interaction of ultrasound waves with matter	<ul style="list-style-type: none">Absorption - individual relaxations, frequency dependencyReflections / transmission; relation to wavelength and impedance relations and organ boundary delineationScatter – Rayleigh scattering and relation of particle size to wavelengthSpeckle; Doppler implicationsRefraction – speed of sound variation; implications for artefactsDiffraction – Sidelobes / grating lobes; implications for artefactsAttenuation; dB scale / frequency / depth dependence
8.3 Basic design and construction of ultrasound transducers	<ul style="list-style-type: none">Production and detection of ultrasoundParts of a transducer and implications for imaging performanceContinuous waves and pulsesBacking layer for axial resolutionMatching layers for energy transferLens for out of plane focus
8.4 Beam shapes and focusing from transducers arrays	<ul style="list-style-type: none">Influence of beam shape and focusing on lateral / axial and out of plane resolution from 1D, 1.5D, 2D arraysHow to produce a representation of the beam thickness



Topic area	Examples of expected knowledge
8.5 Image acquisition, reconstruction and imaging modes	<ul style="list-style-type: none">▪ Pulse echo principle▪ Scanned and non-scanned modes▪ TGC and relationship to tissue attenuation▪ Transmit and receive focusing▪ Apodisation
8.6 Scanner functionality and image optimisation	<ul style="list-style-type: none">▪ Output Power, depth, gain, dynamic range, focus(s)▪ Harmonic Imaging, compound imaging, line density, persistence▪ Post processing – gamma correction, mapping, edge detection
8.7 Doppler ultrasound	<ul style="list-style-type: none">▪ Basic principles – Doppler equation, CW operation, PW operation, Nyquist limit, gate size and position, Doppler angle▪ Advantages / disadvantages of CWD, PWD, CFD, PD
8.8 Advanced techniques and their clinical uses e.g. contrast ultrasound, tissue optimisation, elastography, 3D	<ul style="list-style-type: none">▪ CEUS; basic properties; principles behind wash-out curves; clinical uses in liver and kidney▪ Harmonics; production & propagation; influence on image quality with reference to beam shapes, clutter artifact, tissue type etc.▪ Tissue optimisation – speed of sound adjustment; clinical uses in breast▪ Strain, shear wave, ARFI; clinical uses in liver, breast, thyroid▪ Basic principles and clinical advantages / disadvantages



Topic area	Examples of expected knowledge
8.9 Clinical artefacts and how to overcome them.	<ul style="list-style-type: none">▪ Enhancement▪ Shadowing▪ Reflection▪ Mis-registration▪ Refraction▪ Grating lobes▪ Reverberation▪ Comet trail▪ Aliasing▪ Colour bleed▪ Flash▪ Mirror
8.10 Safety, physical effects, safety indices, safety guideline	<ul style="list-style-type: none">▪ Basics on types of energy transfer to tissue▪ Heating, streaming, cavitation and mechanical damage▪ Thermal and mechanical indices; definitions and links to physical effects and scan modes▪ Overview of British Medical Ultrasound Society guidelines