Revised European Training Charter for Clinical Radiology

Curriculum for the Initial Structured Common Training Programme (Years 1–3)

Curriculum for Special Interest Subspecialty Training (Years 4–5)

Revised May 2012
By Birgit Ertl-Wagner,
ESR Education Committee Chairperson

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Preface

In 2005 the European Association of Radiology (EAR), in conjunction with the Radiology Section of the Union of European Medical Specialists (UEMS), elaborated on a revised charter for training to replace the previous charter of 2003. With the amalgamation of the EAR and the European Congress of Radiology (ECR) to form the European Society of Radiology (ESR) in March 2007, the revision and updating of this document became the responsibility of the ESR Education Committee.

The revision does not seek to fundamentally alter the original charter, but is intended to clarify and update certain areas, and incorporate new knowledge requirements within the radiology curriculum. The curriculum is a living document, and at any one time of publication there will be educational issues not yet fully dealt with, e.g. detailed matters of competence assessment and learning methodologies. However, publication of regular updates is essential so that major developments in the very rapidly increasing knowledge requirements for radiologists in training can be accommodated.

This process has been carried out in cooperation with all ESR subspecialty societies. Each society has reviewed and where necessary revised their recommended core subspecialty training curricula, and I am very grateful for their cooperation and enthusiasm. Input has also been sought from all members of the ESR Executive Council, the ESR Education Committee and its Board and many internationally recognised individual members of the ESR with specific expertise in newer areas of radiological knowledge. Their contributions and suggestions are greatly appreciated.

The document is divided into three sections:

- Part I (European Training Charter for Clinical Radiology) outlines the fundamental principles and concepts of radiology, specialty education, including training structures, required training facilities, staffing levels, core knowledge etc.

- Part II deals with a subject curriculum checklist (years 1 to 3) for radiology trainers and trainees, outlining a core curriculum that ensures that the broad areas of organ-based knowledge and competence are addressed and obtained.

- Part III deals with the knowledge requirements (years 4 and 5) for those wishing to bring a special knowledge base and expertise in a specific subspecialty to their clinical competence. The Society supports organ- rather than technology-based subspecialisation, but is cognisant that with increasingly sophisticated and complicated techniques, a "disease"-oriented educational matrix will inevitably be required in certain areas. The general radiologists undertaking training in areas of special interest in the latter part of their training may wish to use specific subspecialty society-authorised curricula, whilst recognising that this document is geared towards "special

interests" rather than full subspecialty practice, which will require formal fellowship training.

None of these sections is intended to stand alone, but should be considered as a continuum incorporating checklists for educators and trainees, whilst recognising that the detailed application of the principles and structures outlined will inevitably vary from country to country.

Health care systems in individual European countries differ for a variety of reasons, including administration, management, equipment, budgeting and tradition. In spite of these differences, recommendations for training facilities for specialisation in general radiology can be defined. It is accepted that detailed application of the following principles will be the responsibility of the respective countries. In producing the document the ESR is fully cognisant of these varying circumstances and the Society and the Education Committee remain available to give advice on the application of the curriculum to the local prevailing educational environment.

The ESR intends that this curriculum document will provide a template for radiology trainees and educators, with the long-term aim of harmonising radiology training and enhancing the quality of radiological care for patients throughout Europe. It is hoped that its existence will be helpful to national societies in their discussions with governments and other regulatory authorities. It is intended to assist individual national societies in their aims of promoting high-quality radiological education nationally, and in their efforts to ensure good radiological patient care through the encouragement of a structured clinical radiological training period of a minimum of five years throughout all European countries.

Éamann Breatnach,
Chairman,
ESR Education Committee

November 2010.

PART I

European Training Charter for Clinical Radiology

Duration of Training

Radiology is a medical specialty involving all aspects of medical imaging that provide information about the anatomy, pathological features, histopathology and function of disease states. The performance and reporting of radiological procedures is a clinical act, with all the associated responsibilities, implications and medico-legal consequences. Only appropriately trained medical personnel should carry out this duty.

The revised charter continues to outline a five-year (three + two) training period, including basic training over the first three years and flexible subspecialty interest training during the last two years.

Years 1–3

During the first three years of training, the fundamentals of undertaking and interpreting a wide range of imaging techniques and disease manifestations remain the essential curriculum component. Core knowledge to be learned at an early stage during this three-year period of training includes the fundamentals of organ-based clinical diagnostic radiology encompassing the relevant radiographic anatomy: during years 1–3 training should also include education in the principles of applied imaging technology, physics, radiation protection, principles of molecular medicine with regard to imaging, as well as the fundaments of clinical research and evidence-based medicine.

Years 4 and 5

The charter recognises that most European radiologists now work in teams, where individual members will have specific subspecialty skills. This increasing subspecialty is encouraged. However, the Society emphasises that during the fourth and fifth years a developing knowledge in general radiology as applied to the subspecialty interest should continue to be nourished. Subspecialty interest training during this period may apply to two subspecialties, but where these do not include general radiology rotations should be structured to continue parallel exposure to and knowledge development in general radiology. General radiology itself may be chosen as one of the subspecialty interest areas.

The term "special interest" is intended to distinguish subspecialty experience gained during the last two years of training from dedicated subspecialty "Fellowship" training after the initial five-year period. The latter may require total immersion in a single subspecialty and will require specific curricula that are beyond the scope of the present document.

Clinical training

Radiology is a clinical specialty, and while the timing of direct clinical exposure will vary from country to country, the charter promotes the concept that good clinical

competence is an essential component of radiology training. This experience is required to allow the radiologist to provide a safe medical environment for patients within the Imaging Department, and importantly will give training that ensures that the reporting of diagnostic imaging will have a clinically relevant and patient-focused emphasis.

Emergency radiology

Experience in emergency radiology is an integral component of radiology training, and must remain accommodated as a specific rotation and skill base within the training programme. A specific curriculum in emergency radiology is not included in this edition. This is the subject of deliberation under the auspices of a proposed new European Society of Emergency Radiology.

The implications of implementation of the "European Working Time Directive" for training are not yet clear. The ESR has concerns that the limitation of hours recommended by this legislation may have a deleterious effect on clinical confidence and the experience base for future radiologists; the Society will continue to monitor the situation.

Multidisciplinary conferencing

Multidisciplinary and clinico-radiology conferencing has become an integral component of medical care and decision-making. Frequently, such conferencing is conducted under the chairmanship of a radiologist and within a radiology department, emphasising the importance of training and direct experience of such meetings within the modern radiology curriculum.

Continuous medical education/continuous professional development

The recommendations of the charter are not an end in themselves, but should be interpreted in the context of understanding the seamless transition from training to lifelong continuous medical education (CME) and continuous professional development (CPD). An appreciation of this continuum should be instilled at an early stage of training.

Record of achievement and competence

A written or e-log book of activity during training should be maintained. This should provide a formal validated record of competencies achieved and examinations performed and should form an integral part of regular assessments of satisfactory training.

TRAINING PROGRAMMES – STRUCTURE AND CONTENT

Structure

The specialty of radiology involves all aspects of medical imaging that provide information about morphology, function, cell activity and those aspects of interventional radiology or minimally invasive therapy (MIT) that fall under the remit of the radiology department.

Trainees should participate in clinical radiology examinations and activities whose extent and complexity should gradually increase in line with experience. It is important that trainees systematically rotate through all sections of the radiology department at an early stage to become conversant with the principles of the main techniques and to gain a working knowledge of the following imaging methods:

- Conventional radiology
- Fluoroscopy
- Ultrasound
- Computed tomography
- Magnetic resonance imaging
- Radionuclide imaging, where possible

The precise structure of the system-based modules will vary a little from country to country and from department to department, but the time balance should reflect the importance of the system to the core of radiological practice. A detailed knowledge of normal imaging anatomy should be gained in the early stages of training. Early in this three-year period, trainees should acquire the necessary knowledge of basic sciences, the physical basis of image formation in all imaging techniques, picture archiving computer systems (PACS), radiology and hospital information systems, quality control, radiation protection, radiation physics, radiation biology, anatomy, physiology, cell biology and molecular structure, biochemistry and techniques related to radiological procedures; knowledge must also be gained of the pharmacology and application of contrast media and a basic understanding of computer science, as outlined in the core knowledge for general radiology.

Radiologists in training should undertake five years of full-time study dedicated to radiology. Arrangements may vary for those undertaking flexible training. For instance, rotations in other departments like clinical or pathological units can be embedded within the training programme. However, the total duration of training should be equivalent to the training period of a full-time trainee.

After a three-year period all radiology trainees should have knowledge of the gamut of available radiological techniques as well as of the main diagnostic features of the technique in question.

Training should be under the direction of the radiology department of a large teaching hospital, although models for clinic- and academy-based training also exist. Each training programme should outline the educational goals and objectives of the programme with respect to knowledge, skills and other attributes of residents at each level of training and for each major training task.

Most radiology training should be acquired at a single teaching institution where all or most subspecialty disciplines are available. However, several institutions can pool their resources in order to provide complete access to all techniques and specialties. Ideally, this department should be affiliated to a university, and should have full and close collaboration with a medical physics department. Ready access to university anatomy, biochemistry, statistics, legal physics and pathology departments should be available to all training centres. If at all possible, in-house physics training should be available. Teaching principles should include didactic lectures, tutorials etc., but there should also be a large component of one-to-one apprenticeship relations with the staff faculty.

The spectrum of patient and investigative material available during training should be sufficient to enable the trainee to gain experience in all fields of general radiology. When possible, training should ideally be integrated into a single department; however, attendees of a single-specialty institution may be required to ensure comprehensive training elsewhere.

Within each teaching department, a local tutor with direct responsibility for in-house training should be appointed to ensure that an appropriate proportion of service versus training time be maintained.

Regular assessments should be carried out on a yearly basis and easy access for trainees to local coordinators should be encouraged.

The trainee should be involved in the radiological examination and diagnosis of patients presenting in the emergency department and should be able to appropriately evaluate patients who are severely or critically ill. It is not anticipated that a trainee would enter into an emergency on-call rotation entailing clinical responsibility until the end of the first year of training.

All reporting should be supervised and all radiology reports checked up to the third year of training. Exposure to on-call and emergency work should be available, and participation in an on-call roster should take place after the first year of training.

The fully trained radiologist should be capable of working independently when solving most common clinical problems and those undertaking interventional procedures should also have sufficient clinical background knowledge to accept direct referrals and to clinically manage patients in the immediate time frame surrounding such interventions.

Staffing structure

The number of qualified radiologists with teaching functions in the department should be sufficient to fulfil all the needs of teaching in each major subspecialty area. The expertise of the teaching staff should cover a broad spectrum and include the subspecialties as outlined in the detailed curriculum for the initial structured common programme.

Departmental support should be given for modular training in neuroradiology and paediatric radiology for three months outside the base hospital, if necessary.

Teaching staff should be motivated and ideally several should be pursuing a university-based academic career pathway. In-house teaching should include didactic lectures, small tutorial groups and one-to-one apprenticeship experience. The teachers should ideally attend teacher-targeted training courses and should be fully integrated into the overall university educational process.

Where examinations are a feature of training all teachers should experience the appropriate practical examinations and participate as examiners.

Standard of equipment

Only departments with adequate imaging equipment and services should be approved for training. The equipment should comply with radiological safety standards and should be in good technical condition. Technical efficiency, security, electrical control, radiation safety and controls should be of an adequate standard and conform to agreed national quality control criteria. Radioprotection should be organised and radiation monitored according to European standards. The down-time of the equipment for repair should be minimal and should not interfere with training. The techniques for adequate radiological training will depend on local availability, but should include the following:

- Conventional radiography (including fluoroscopy)
- Mammography
- Angiography
- Ultrasound
- Computed tomography
- Interventional radiology
- Magnetic resonance imaging
- PET-CT (cooperation with other radiology departments and / or nuclear medicine departments may be necessary)
- Access to nuclear medicine

Reading facilities and teaching materials

Access to quiet reading areas with internet portals should be available to trainees within the department. Audio-visual equipment and rooms should be available in the radiology department, sufficient to enable the implementation of the teaching programme. An adequate supply of teaching materials should include text books (e.g. on neuroradiology, paediatric radiology, ultrasound, computed tomography, magnetic resonance imaging, mammography) and journals. Teaching facilities should include access to online medical publications, teaching aids (including EURORAD etc.) and a full radiology library. A wide range of e-learning facilities have now been developed within ESR, and are available on the website. Active in-house development of a teaching file represents a very valuable stimulus for trainees and is encouraged.

Trainee assessment

Formal trainee appraisal and assessment should take place at regular intervals (at least once a year). This should be conducted outside of the training department and coordinated by designated academic radiologists who are not directly involved with the scheme under evaluation. The process should preferably be coordinated through the

national society or training body, which can compare the various training facilities on a country-wide basis and with international standards.

In order to verify that appropriate modular training has been obtained, this assessment should include appraisal of the log book referred to above. Assessments should also cover clinical and technical competencies, including interpersonal skills and suitability as a clinically active doctor. As part of the assessment process, trainees should be given an opportunity to give their own observations on training facilities and teaching personnel on a confidential basis.

Accreditation of training departments

This should again be performed by a competent and independent authority coordinated through either the national society or a national authority with responsibility for training.

It is recommended that accreditation should be carried out every five years and should include the following:

- Number and type of basic radiological examinations (The spectrum of patient and investigative material available should be sufficient to enable the trainee to gain experience)
- Standards of equipment
- Trainee access to the full range of imaging techniques
- Adequacy of trainer–trainee ratios
- Teaching programmes available
- Teaching materials
- Research activity

The European Training and Assessment Programme (ETAP; **http://www.myesr.org/cms/website.php?id=/en/education_training/european_training_assessment_programme_etap_.htm**), which provides a formal evaluation of training programmes, is a programme within ESR and is available to all member national societies. For this purpose the programme will provide on-the-ground assessment and will also give advice on accreditation programmes to be run nationally.

Course participation

Attendance at outside courses and scientific congresses will depend on the stage of training and the relevance of the courses to the trainee's stage of training. Attendance at a minimum of two international and five national congresses or courses should be mandatory throughout the five years. Attendance at the relevant subspecialty interest and training scientific congresses should be encouraged during the fourth or fifth year. Presentation of original research at these scientific meetings should be emphasised. Such participation should be logged and recorded on an annual basis.

A spirit of benign competition between trainees in aiming to achieve academic excellence should be fostered within the department, including a pride in profiling the department's achievement at local, national and international scientific gatherings.

Knowledge assessment

On completion of the training period the radiologist is expected to be capable of working independently and unsupervised in a hospital or outpatient facility. Objective measurement of an achieved standard should be made by examination, thesis and/or a combination of both.

At the end of training an objective measurement of achieved standard should be made either by examination, thesis, and/or a combination of both depending on local custom and practice.

An ESR Coordinated Diploma in Radiology will shortly be available to supplement these evaluations. (See **http://www.myesr.org**.)

Relationship of training programme with regulatory authorities

This will vary greatly throughout Europe, but it is of importance that the central regulatory authorities cooperate and that easy cross-referencing takes place among the bodies responsible for radiological education and licensing regulatory authorities, teaching centres, local hospital administrations etc. Adequate educational funding budgets should be ring-fenced within health care structures.

Proportion of radiological training in university, teaching, non-university and/or private institutions

Rotations through small and specialist hospitals may frequently supplement basic radiological training and are to be recommended for limited periods (a maximum of three months). Such outside rotations may include paediatric radiology or neuroradiology for periods of up to three months during the first three years, but longer in the last two years depending on the subspecialty chosen. Ready access to university level physics and pathology departments should exist for all training centres. Ideally, in-house physics training should be available.

Part of training may be at accredited non-university hospitals or private practices, but this should only form a small proportion of the training time spent. Such facilities should have close working relationships with the main teaching institutions. The non-university component may supplement training in general radiology, primary care radiology or may target subspecialty exposure. The time proportion spent will be subject to locally assessed educational value.

All the university departments and training hospitals should be part of a coordinated national or federal training scheme. Training schemes should ideally be subject to single national organisations to standardise the educational experience and maximise efficiencies.

Nuclear medicine

Ideally, a three-month rotation in nuclear medicine should be available during basic training, either in the home department or in an adjacent or offsite nuclear medicine

teaching department in order to become familiar with basic methods in this specialty. Further training in nuclear medicine may be taken during years 4 and 5.

European School of Radiology

The European School of Radiology (ESOR) offers complementary and continuing education to residents and young radiologists through visiting schools, visiting seminars, scholarships, exchange programmes for fellowships, and tutorials, thus enhancing and ensuring the further development of young radiologists during their training.

The Education Committee encourages young radiologists to participate in the programmes and to benefit from internationally renowned faculties and/or training in pre-selected, highly esteemed reference training centres in Europe and beyond. (See **http://www.myesr.org**.)

PART II

KNOWLEDGE BASE YEARS 1–3

Introduction

It is recommended that a trainee should gain a general orientation in the working of a radiology department at the beginning of training. As an introduction to clinical radiology the trainee should have approximately one week's exposure to all of the major subspecialty areas available in a general university imaging department within the first three months.

Following this, rotations in clinical areas of radiology should be system-based, involving the use of all relevant techniques within the module and formulated into an integrated programme to cover most aspects of basic radiology.

Detailed knowledge should be gained in:

- Imaging anatomy and normal variants for each organ system
- The application of all imaging techniques to the system-based specialties, including the specific benefits of ultrasound, computed tomography, magnetic resonance imaging, and interventional procedures
- Techniques and indications for related interventional procedures including guided biopsy and drainage procedures
- The specific requirements of children via a specific three-month paediatric radiology rotation during the first three years
- The most common/severe clinical scenarios and the most apt imaging strategy required to elaborate

On completion of the first year, the trainee should be involved in the radiological examination and diagnosis of patients presenting in the emergency department and should be able to appropriately evaluate patients who are severely or critically ill.

An objective evaluation (examination) should take place at the end of the first year and satisfactory performance should be a prerequisite for unsupervised emergency room and/or supervised on-call duties.

An emphasis on patient safety specifically with reference to radiological practice should be thoroughly emphasised. Such safe radiology practice should include:

- Validation of any request for radiological examination with respect to:
    - Risk factors
    - Irradiation
    - Possible alternatives employing non-ionising radiation
- Safe and satisfactory performance of an examination adhering to the following principles:
    - Knowledge of the clinical history and the clinical questions to be answered

    - Knowledge of the protocol of the examination and any post-procedure patient care
- Competence in dealing with acute medical emergencies arising within the radiology department should be ensured

All technical performance and radiological reporting should be supervised by a staff radiologist during years 1–3.

Core knowledge

Basic sciences

- Radiation physics
- Radiobiology
- Molecular structure, pharmacology, classification dose and side effects of all radiographic, MRI and ultrasound contrast media should be known, to include emergency treatment for adverse reactions when required
- The physical basis of image formation including conventional X-ray, computed tomography, nuclear medicine, magnetic resonance imaging and ultrasound
- Quality control; radiation protection; including the ALARA principle (**A**s **L**ow **A**s **R**easonably **A**chievable)
- Anatomy, physiology, biochemistry and techniques relating to radiological procedures
- During training, an overview of molecular imaging should be attained. This need not be detailed, but an appreciation of the current possibilities in molecular imaging, including its potential application to oncology, cardiovascular imaging, neurology and drug delivery should be acquired
- Radiology training should ensure the understanding and implementation of the process of justification of requests and optimisation of investigation. Such an algorithmic approach to the use of various diagnostic radiology techniques is under constant revision, and at the time of writing a document outlining clinical guidelines and appropriateness criteria is under consideration by ESR in association with the World Health Organisation and other interested bodies
- At present, helpful guidelines are available through the Royal College of Radiologists (*Making Best Use of a Radiology Department*) and the American College of Radiology (*Appropriateness Criteria*), to include initiatives of the National Societies of Radiology
- The radiology training must ensure an understanding of the implementation of processes of justification and optimisation as laid down in the EURATOM directive 97/43. (See http://ec.europa.eu/energy/nuclear/radioprotection/doc/legislation/9743_en.pdf.)

Pathological sciences

Knowledge of pathological features and pathophysiology as related to diagnostic and interventional radiology.

Radiological reporting

The written radiological report is the most important means of communication between the radiologist and the referring doctor. It is part of the patient's permanent health record, and records the findings of each imaging investigation in an appropriate clinical context. The satisfactory construction, clarity and clinical focus of a radiological report are essential to high-quality patient care and learning how to construct a good report is essential for radiologists in training.

Elements include:

- Clinical referral
- Technique
- Findings
- Conclusion
- Advice

Clinical referral

This section should include a brief summary of the reason for referral, summarising the clinical problem. If insufficient clinical information is available for the radiologist to give a full interpretation, this should be stated in the report. When appropriate, the justification for radiation exposure should be given.

Technique

This section should include:

- A concise description of the investigation/procedure performed, with specific mention of any non-standard elements of the investigation, e.g. additional sequences
- A record of contrast medium administration, including route of administration, type and dose. Any adverse reaction must be recorded and the treatment described. All additional medications that were administered to the patient while in the imaging department (e.g. sedatives) should also be recorded
- A description of technically suboptimal features if they may have an impact on the accuracy of interpretation
- Patient dose where applicable

Findings

This section of the report should include:

- A targeted, systematic description of all abnormalities
- Observations should be described using accepted imaging terminology, and should be as precise as possible
- The description should be specific in giving the dimensions, signal intensity, attenuation, echogenicity or density of abnormalities. Specific positive or negative features that will affect interpretation of the abnormality/ies, such as clarity of margin, calcification or cavitation, should also be described

- The anatomical site of abnormalities should be clearly stated, together with their relationship with other structures where appropriate
- Negative findings pertinent to the clinical query should be included
- All incidental findings should be stated and analysed
- Where previous investigations have been performed, comparison with the current examination should be carried out and described in the report

Impression/conclusion

- The aim is to reach a precise diagnosis when possible, or an appropriately ranked differential diagnosis
- The conclusion should relate to the original presentation, e.g. "no cause of the left-hand side chest pain identified"
- This section is not a summary of the imaging findings already described in the "findings" section, but should be distilled into a clinical diagnosis. Conversely, it comprises an interpretation of the investigation, taking into account all the imaging features, together with relevant clinical information and laboratory findings to formulate an overall impression

Advice

The report may give suggestions for further action to be taken, e.g. referral for an urgent specialist opinion. More commonly, advice will be given on further investigations that will refine the diagnosis. If such an additional examination is recommended, the rationale should be briefly described.

Communication skills

Communication with patients

Clinical radiologists should appreciate the importance of relating to patients with respect, honesty and confidentiality. Appropriate training in these areas should cover issues regarding the communication of bad news, and the dangers of entering into detailed discussions with patients regarding further management in case this is not subject to direct supervision or organisation by the radiologists. Sensitivity regarding radiological reports should extend to the potential for patients to have access to the same.

Radiologists are clinical specialists. Direct patient contact is an increasing component of radiological practice. Learning of the principles of communication skills with patients should include the ability to explain tests and procedures to be performed, including hazards and benefits, the obtaining of informed patient consent and the explanation of examination results to patients when appropriate.

Communication with the patient is greatly enhanced by discussions between radiologists and referring clinicians: by this means the likelihood of a clear-cut unambiguous message been given to patients is enhanced. Examples include the recurrence/progression of a malignant disease, or communication with parents concerning their child's disease. This is especially true in situations of severe and/or chronic disease.

Communication with the referring doctor

The importance of timely communication with referring doctors with regard to imaging reports should be understood. The distinction between routine methods of communication, and the necessity for immediate reporting of emergency, life-threatening or unexpected findings should be appreciated. Unanticipated findings, which though non-urgent, but do require action, should also be communicated with priority.

Reporting terminology should also vary with the specific knowledge base and specialty of the referring clinician. When findings fall within a referring physician's specialty area, terminology specific to that specialty may be used, and in general, there is less risk of misinterpretation. Conversely, where the report is for a general practitioner appropriate and understandable terminology should be used. The principle of report communication is to ensure best patient care through the use of appropriate terminology to the skill set of the referring clinician.

Administration and management

Knowledge of the principles of administration and management as applicable to a clinical imaging department with multidisciplinary staff and high-cost equipment is required. With increasing costs, it is essential that the trainee radiologists are exposed to the procedures, legalities, critical evaluation processes and priorities required for systems purchase. This will vary from institution to institution and can best be achieved by stimulating attendance of scientific radiology meetings where equipment is exhibited, and exposure to decision-making purchase meetings within the department. The trainee should also become familiar with examples of cost–benefit and cost–efficiency studies in common imaging strategies.

The principles of teleradiology should be understood, including knowledge of communication resources, and the trainee should have the ability to discuss its potential role and legal implications.

Research

Knowledge of the basic elements of scientific methods and evidence-based medicine, including the statistics necessary for critical assessment and understanding of published papers and the promotion of personal research, should be acquired. Knowledge of research methods in radiology should include an understanding of design and data analysis for technical and diagnostic performance studies. Audit in radiology is also expected. Presentation of research projects at local, national and international scientific radiological meetings should be encouraged. Regular group meetings should take place within the department to encourage individual research projects, to share information and to ensure a balanced programme of presentation throughout the trainee cohort. There should be an active and ongoing research programme at the training department and trainees should be encouraged to participate. Presentation and attendance at international meetings, including those on funding, should be encouraged and supported. At least once a year, trainees should attend one national meeting and as a minimum every two years one major international meeting. Authorship of research publications and peer-reviewed journals should be encouraged and ongoing mentoring

in this area should be made available by more senior academic staff. Advice on research principles and protocols is freely available to ESOR members through the Research Committee of the ESR.

Evidence-based medicine

To improve understanding of the value and methods of evolving technologies, all trainees should receive basic instruction in reading critically medical literature, experimental design and biostatistics. Instruction should extend to focussed literature search, literature appraisal, appraisal and application as applied to diagnostic tests, interventional procedures and review articles.

Radiology audit and standards

An appreciation of the methodology and principles of the clinical audit should be learned. Trainees should understand the concept of measured performance, comparison with target standards, interpretation of such measurements, the process of implementing change and the re-measurement of performance. The application of the clinical audit to radiological organisations and its performance should be understood. Principles of the audit of structure, process and outcome should be attained on-site. The background principles of improving local practice through the application of such systems with honesty and integrity, full agreement and confidentiality should be appreciated. An understanding of the limitations of the selection of appropriate target standards and relevant country-specific legal implications of audits should be understood. The concepts of consensus statements from learning bodies and the methodology for sourcing them should be appreciated. Modules on the principles and application of the clinical audit in radiology of a minimum duration of two hours should be acquired during training.

Medico-legal issues

An understanding of the medico-legal implications of radiological practice should be attained.

Principles to be learned include:

- Perceptual errors
- Missed radiographic diagnosis
- Minimisation of radiological risk
- Knowledge of more common radiological pitfalls
- Concepts of uncertainty and error in radiological practice
- Hindsight bias
- Radiologist's responsibilities for communication of urgent findings
- Communication of significant but non urgent findings
- Comparison with previous examinations
- Informed consent
- Complications of diagnostic interventional procedures
- Responsibilities of the radiologist as a department chairperson
- Specific liabilities relating to screening

Years 1 to 3 – Subject Content

The following is a guideline for developing a core programme of knowledge for trainees in radiology, during the common trunk (the first three years of radiology training). It is clear that there is some overlap with some other sections in diagnostic radiology, but nevertheless it is important to define this common trunk programme.

The first three years of the five-year training programme should include the following elements:

- Breast radiology
- Cardiac, vascular and lymphatics
- Chest radiology
- Gastrointestinal and abdominal radiology
- Gynaecological and obstetric radiology
- Head and neck radiology
- Interventional techniques
- Musculoskeletal systems
- Molecular Imaging
- Neuroradiology
- Nuclear medicine as basic training
- Oncologic imaging
- Paediatric radiology
- Principles of imaging technology as applied to diagnostic radiology
- Urogenital radiology

Specific modular content for emergency and oncologic radiology is not formulated in this document. At present such curricula content is the subject of consideration by newer European societies dealing specifically with these subspecialty disciplines.

Breast Radiology

Introduction

The aim of this curriculum in breast imaging is to ensure that the trainee develops a core knowledge of breast disease that will form the basis for further training (if desired). It will also provide transferable skills that will equip the trainee for working as a specialist in any branch of radiology.

Physics and radiation protection are covered in separate courses and are not covered in detail unless specific to breast imaging.

Core knowledge

- Breast anatomy and associated structures and how they change with age
- Breast abnormalities and clinical practice relevant to breast imaging
- Physics of image production, particularly how they affect image quality
- Risk/benefit analysis associated with breast screening using ionising radiation compared with other techniques
- Radiographic techniques employed in diagnostic mammography
- Principles of current practice in breast imaging and breast cancer screening
- Proper application of other imaging techniques in this specific field, such as ultrasound, MRI, or radionuclide imaging
- Indications and contraindications for interventional breast procedures (fine needle aspiration, core biopsy, hook-wire)
- Appearance of cancer and common benign disease on:
    - Mammography
    - Ultrasound
    - Magnetic resonance imaging
- Principles of communication specifically related to the breaking of bad news and consent

Core skills

- Performing an ultrasound examination of the breast
- Supervising technical staff to ensure that appropriate images are obtained
- Understanding when to utilise ultrasound and other imaging techniques; to produce a report on mammographic and ultrasound breast imaging with respect to common breast disease
- Understanding when it is appropriate to obtain assistance in interpreting and reporting breast images
- Performing interventional breast procedures under ultrasound and X-ray control under supervision
- Communicating with patients explaining the nature of benign breast disease, giving and observing "bad news" being given

Cardiac, Vascular and Lymphatics

Core knowledge

- Normal anatomy of the heart and vessels including the lymphatic system as demonstrated by radiographs, echocardiography and Doppler, contrast-enhanced CT and MRI
- General principles and classification of congenital heart disease and the diagnostic features on conventional radiographs
- Natural history and anatomical deformities causing central cyanosis
- Radiological and echocardiographic features and causes of cardiac enlargement, including acquired valvular disease
- Diagnosis of ischaemic heart disease, including radionuclide imaging and the basics of coronary angiography
- Diagnostic features of vasculitis, atheroma, thrombosis and aneurysmal dilatation of arteries and veins
- Radiological and ultrasound diagnosis of pericardial disease

Core skills

- Reporting radiographs relevant to cardiovascular disease
- Performing ultrasound of arteries and veins
- Managing and reporting CT and MRI of the vascular system under supervision including image manipulation
- Diagnosing deep venous thrombosis on Doppler ultrasound
- Performing femoral artery and venous puncture techniques
- Diagnosing and treating femoral artery pseudoaneurysm

Chest Radiology

Core knowledge

- Anatomy of the respiratory system, heart and vessels, the mediastinum and the chest wall on radiographs, CT and MRI
- Significance of generic signs on chest radiographs and CT
- Features on radiographs and CT and the differential diagnosis of diffuse infiltrative and alveolar lung disease, airways and obstructive lung disease
- Solitary and multiple pulmonary nodules, benign and malignant neoplasms, hyperlucencies and their potential aetiology and evaluation
- Thoracic diseases in immunocompromised patients and congenital lung disease
- Disorders of the pulmonary vascular system and great vessels, including the diagnostic role of radiographs, radionuclides, CT and MRI in diagnosis
- Abnormalities of the chest wall, mediastinum and pleura

Core skills

- Managing and reporting under supervision radiographs, chest radiographs, ventilation/perfusion imaging, thoracic CT, high-resolution chest CT, and the CT pulmonary angiography (CTPA) technique and interpretation
- Positioning/views of chest radiographs and of chest CT examinations for adults, newborns, infants and children
- Knowing the mean exposure doses of chest radiographs and of chest CT examinations and techniques to reduce this dose
- Using ultrasound in the diagnosis and aspiration of pleural effusions
- Knowing the principles of digital imaging and image processing pertinent to chest radiology
- Protocolling CT examinations of the thorax, including appropriate application of intravenous contrast, high resolution, inspiration/expiration and reconstruction technique
- Recommending appropriate biopsy routes and techniques

Gastrointestinal and Abdominal Radiology

Core knowledge

- Clinical presentation and natural history of the most common and/or severe diseases of the abdomen, and the principles of their treatment
- Normal anatomy of the abdomen and the main variants including the internal viscera, abdominal organs, omentum, mesentery and peritoneum on CT, ultrasound, MRI and conventional radiology
- Normal post-procedure imaging related to previous treatment such as surgery or interventional radiology
- All situations in which imaging findings should lead to emergency management
- Features of abdominal trauma and acute conditions, including perforation, haemorrhage, inflammation, infection, obstruction, ischaemia and infarction on radiographs, ultrasound and CT
- Imaging features and differential diagnosis of primary and secondary tumours of the solid organs, oesophagus, stomach, small bowel, colon and rectum
- Imaging features of the stage and extent of tumours, including features that indicate non-resectability
- Technique and the role of associated examinations like endoscopy, endoscopic ultrasound and nuclear medicine (including SPECT, PET and hybrid imaging)
- Radiological manifestations of inflammatory bowel diseases, malabsorption syndromes and infection
- Aetiology and imaging signs of chronic liver diseases, including portal hypertension
- Main vascular lesions including fistulas, arterial diseases, arterial, portal or hepatic obstruction and their consequences
- Principles and the main applications of quantification and functional imaging in abdominal diseases, such as quantification of liver fat, iron or fibrosis, tumour perfusion and bowel inflammation
- Rationale and principles of diffusion-weighted imaging in abdominal diseases
- Principles and standards of post-therapy imaging evaluation (tumour, inflammation)
- Main indications and techniques of interventional radiology as applied to abdominal diseases

Core skills

- Reporting of abdominal radiographs, mainly in cases of acute abdomen
- Performing and reporting contrast medium examinations of the pharynx, oesophagus, stomach, and the small and large bowel, including small bowel enteroclysis
- Performing and reporting trans-abdominal ultrasound of the gastrointestinal system, abdominal viscera and their vessels, including performance of Doppler and contrast-enhanced studies
- Observing angiography and vascular and non-vascular-interventional techniques in gastrointestinal disease
- Protocolling and reporting CT of the abdomen, including adaptation to the specific situation (whether intravenous contrast medium or intraluminal contrast medium is required, whether an arterial phase or delayed imaging is necessary, CT

enterography), with a precise knowledge of the consequences of radiation dose for both patients and medical staff
- Protocolling and reporting under supervision of CT colonography, ensuring that a sufficient number of controlled teaching files have been read
- Protocolling and reporting MRI of the upper abdomen, including adaptation to the specific situation (whether intravenous contrast medium or intraluminal contrast medium is required, whether an arterial phase or delayed imaging is necessary, magnetic resonance cholangiopancreatography (MRCP), quantification of liver fat/iron)
- Protocolling and reporting MRI of the rectum and anal canal
- Protocolling and reporting MRI of the small bowel
- Performing common post-processing tasks, such as reformat, maximum intensity projection (MIP), minimum intensity projection (MinIP), vessels analysis and performing under supervision parametric imaging in functional studies like perfusion imaging
- Reporting of oncological studies according to international standards (RECIST, WHO) applicable to the specific situation

Gynaecological and Obstetric Radiology

Core knowledge

- Normal anatomy of the female reproductive organs and physiological changes affecting normal imaging anatomy
- Imaging features of disorders of the ovaries, uterus and vagina as demonstrated on ultrasound, CT and MRI
- Awareness of the applications of angiography and vascular interventional techniques
- Role and techniques of hysterosalpingography

Core skills

- Reporting CT and MRI examinations performed for gynaecological disorders, including tumours
- Performing and reporting transabdominal and, where possible, endovaginal ultrasound examinations in gynaecological disorders
- Reporting CT and MRI for gynaecological tumours
- Performing gynaecological examinations for infertility

Head and Neck Radiology

Core knowledge

- Normal anatomy and congenital lesions of the head and neck, including paranasal sinuses, the oral cavity, pharynx and larynx, the inner ear, orbit, teeth and the temporomandibular joint
- Manifestations of diseases and the investigation of the eye and orbit including trauma, foreign bodies, inflammation and tumours
- Diagnosis of facio-maxillary trauma and tumours and disorders of the teeth
- Diagnosis of lesions and abnormal function of the temporomandibular joint
- Diagnosis of disorders of the thyroid, parathyroid and salivary glands, including hypo- and hyperactivity and tumours, and awareness of the role of radionuclide imaging
- Imaging features of trauma, inflammation, infection and tumours of the paranasal sinuses, oral cavity, larynx and pharynx
- Role of ultrasound- and CT-guided puncture of salivary glands, lymph nodes and the thyroid gland
- Selective nuclear medicine studies in the functional evaluation of endocrine abnormalities

Core skills

- Reporting radiographs performed to show ear, nose and throat/dental disease
- Performing and reporting fluoroscopic examinations, including barium swallows, sialography and dacrocystography
- Performing and reporting ultrasound evaluation of the neck, including thyroid, parathyroid and salivary glands
- Managing and reporting CT and MRI of the neck, ear, nose, throat and skull base disorders
- Observing interventional techniques, e.g. fine needle aspiration biopsy of the thyroid gland

Interventional Techniques (Basic)

It is important for radiology trainees to develop a thorough knowledge of the performance and interpretation of diagnostic vascular techniques and a basic understanding of common interventional procedures, irrespective of whether they specialise in interventional radiology. Basic knowledge will allow the trainees to understand routine interventional procedures using imaging guidance throughout their careers. This can only serve to strengthen the specialty of radiology as a whole.

In order for the trainee to achieve core knowledge of interventional radiology (IR), six months of dedicated time and exposure to IR and IR-related imaging will be required during the first three years of common training in radiology.

Core knowledge

- Risk involved in common interventional techniques
- Use and administration of local anaesthetics
- Pharmacology, administration and patient supervision in relation to intravenous administration of sedation
- Techniques for emergency resuscitation
- Catheterisation techniques, principles of selective catheterisation and embolisation
- Indications for nephrostomy drainage, abscess drainage and pleural drainage

Core skills

- Under supervision carrying out basic catheterisation techniques, peripheral arteriography, abscess drainage and nephrostomy of dilated renal collecting systems
- Carrying out ultrasound-guided biopsy (at least of superficial structures)

Molecular Imaging

Core knowledge

- Cell biology (basic knowledge), including DNA and RNA activity, medical chemistry and physiology, as employed in molecular imaging
- Principles of the most common molecular imaging methods with gamma camera positron emission tomography (PET) and fluoro-deoxy-glucose, together with functional magnetic resonance imaging (fMRI)
- Imaging techniques useful for molecular imaging (micro-CT, micro-MRI, micro-PET)
- Advances in tracers and contrast agents
- Molecular targets for imaging

Core skills

- Imaging of biological processes (inflammation, apoptosis, hypoxia, signal transduction, gene expression)
- Applying molecular imaging techniques in the disease of cardiovascular and central nervous systems (basic knowledge)
- Understanding the potential of guiding therapy and the concepts of qualitative and quantitative image biomarker validation
- Understanding computer teleradiology and image post-processing, archiving and communication (basic)

Musculoskeletal Radiology

Core knowledge

- Musculoskeletal anatomy, normal skeletal variants that mimic disease and common congenital dysplasias
- Trauma involving the skeleton and soft tissue and the value of different imaging techniques
- Degenerative disorders and their clinical relevance
- Manifestations of musculoskeletal infection, inflammation and metabolic diseases, including osteoporosis and bone densitometry
- Radiographic features of the common bone tumours

Core skills

- Reporting of plain radiographs, radionuclide investigations, CT and MRI of common musculoskeletal disorders under supervision
- Managing and reporting of radiographs, CT and MRI of musculoskeletal trauma
- Recommending and guiding the most appropriate imaging technique for the clinical problem presented

Neuroradiology

Core knowledge

- Normal anatomy and normal variants of the skull, skull base, the brain, spine, spinal cord and nerve roots
- Rationale for selecting certain imaging techniques, and the use of contrast enhancement, in diagnosing diseases of the central and peripheral nervous system
- Imaging features on CT and MRI and differential diagnosis of stroke, haemorrhage and other vascular lesions of the brain and spinal cord; the application of CT and MR angiography
- Diagnosis of skull and spinal trauma and their neurological sequelae
- Imaging features and differential diagnosis of white matter disease, inflammation and degeneration
- Diagnosis of benign and malignant tumours of the skull, skull base, brain, spine, spinal cord and cranial and peripheral nerves
- Role of nuclear medicine, including PET, in neurological disorders

Core skills

- Reporting of radiographs of the skull and spine
- Managing and reporting of cranial and spinal CT and MRI
- Observing cerebral and spinal angiography and myelography
- Observing carotid ultrasound including Doppler of supra-aortic and intracranial vessels
- Performing and reporting of carotid ultrasound, including Doppler, and observation of Doppler studies of supra-aortic and intracranial vessels
- Applying interventional procedures

Nuclear Medicine

It is recommended that a three-month period of training in nuclear medicine should be a component of the radiology curriculum during the first three years in order to gain a familiarity with this specialty. Ideally, there should be continuous involvement in general radiology training during this period, and a skill base to include the integration of nuclear medicine techniques within the diagnostic imaging algorithms should be an educational priority.

Core knowledge

- Basic atomic and nuclear physics:
    - Basic atomic structure
    - Radioactivity to include alpha, beta, gamma
    - Radioactive decay including half life etc.
- Radiopharmaceuticals:
    - Production of radionuclides
    - Manufacturing of radiopharmaceuticals
    - Biological and effective half-life
    - Desirable characteristics
    - Physiological clearance
    - Standardised uptake value (SUV)
- Physical principles of nuclear medicine imaging technology:
    - Gamma camera
    - Single photon emission computed tomography (SPECT)
    - Positron emission tomography (PET)
    - Hybrid imaging to include PET-CT, SPECT-CT, and MR-PET. (See ESR/EANM hybrid imaging curriculum.)
- Evaluation of imaging performance parameters:
    - Uniformity of response
    - System sensitivity
    - Spatial resolution
    - Spatial linearity
    - Count rate performance
    - Image quality
- Safety issues:
    - Patient dosimetry
    - Staff dose
    - Contamination monitoring, including choice of equipment
    - Management of safety, quality control and legislative arrangements?
- Therapeutic nuclear medicine – a limited knowledge of the following areas should be acquired:
    - Radioactive iodine treatment of thyroid toxicosis and thyroid carcinoma
    - Yttrium-90 in inflammatory arthropathies
    - Zevalin immunotherapy in lymphoma

Core skills

- Experience in radiopharmaceutical administration and interpretation under supervision and incorporation with other imaging techniques of the following isotope imaging:
    - Bone
    - Renal
    - Ventilation/perfusion (V/Q)
    - Thyroid
    - Parathyroid
    - White cell
    - Cardiac
- Sentinel lymph node mapping
- Minimising radiation dose in specific clinical situations (e.g. pregnancy, lactating mothers, the paediatric population etc.)
- Correlating bone imaging findings in infection, fracture, primary and secondary tumours, stress fractures, identification of prostheses
- Applying isotope studies in thyroid toxicosis, Graves' disease, nodule evaluation, and in the diagnosis of parathyroid adenoma
- Applying ventilation perfusion studies, including mis-match and match defects
- Applying 99mTc-diethylenetriaminepenta-acetic acid (DTPA) in renal function and renal obstruction
- Applying 99mTc-2-3 dimercaptosuccinic acid (DMSA) imaging to the renal outline
- Applying liver colloid studies and focal nodular hypoplasia and haemangioma
- Applying meta-iodobenzylguanidine (MIBG) octeotide studies for diagnosis of neuroblastoma, phaeochromocytoma and carcinoid tumour (basic knowledge)

Oncologic Imaging

Core knowledge

- Basics of oncogenesis, including some elements of cell biology and genetics
- Principles of angiogenesis
- Principles of chemotherapy, including systemic, regional and targeted therapies, adjuvant and neoadjuvant therapies, and why imaging is critical to treatment planning
- Principle and organisation of screening
- Main techniques, doses and complications of radiation therapy, including conventional, local and stereotactic methods
- Why interventional radiology is an important tool for the treatment of patients with cancer
- Definitions of the following terms: baseline examination, nadir, tumour response, tumour progression, stable disease, target lesion, non-target lesions, new lesions
- TNM classification, its role in initial staging and treatment planning, and the principle of downstaging after treatment
- Importance of imaging for early tumour detection and the necessity of staging for appropriate therapy planning and correct estimation of prognosis
- Why imaging is critical in therapy monitoring, restaging and follow-up of most malignant tumours
- Main standards for tumour response evaluation, including RECIST and WHO criteria, the exact criteria for tumour response or progression and the advantages and limitations of each imaging method for this evaluation (ultrasound, CT, MRI, PET)
- Criteria for the evaluation of lymphoma and solid haematological tumours
- Basics of imaging beyond morphology, such as exploration of perfusion, structure and metabolism
- Main endpoints for evaluation of treatments like response rate, disease control rate, time to progression, disease-free and progression-free survival, best overall response

Core skills

- Explaining the main advantages and drawbacks of a screening programme, using the example of breast cancer
- Staging of most common tumours like lung, breast, colorectal, prostate, gynaecological and pancreatic cancers, using current staging systems
- Producing reports of treatment monitoring in a patient treated with chemotherapy for metastatic breast or colorectal cancer, using RECIST criteria, in a situation of tumour response, stable disease and tumour progression
- Attending multidisciplinary rounds for at least 20 patients and understanding why it is critical to examine the patient's file at the initial stage and in the case of recurrence, complication or when downstaging is expected
- Understanding the principles of communication with the patient, as described in part I of this document

Paediatric Radiology

In order to familiarise themselves with paediatric radiology (PR), residents should read and obtain as much information as needed and spend a two-month rotation in the paediatric radiology department during the first three years.

Core knowledge

- Normal paediatric anatomy and normal variants, with particular relevance to normal maturation and growth
- Disease entities specific to the paediatric age group and their clinical and radiological manifestations using all techniques
- Value of and indications for ultrasound, CT and MRI in children
- Disorders and imaging features of the neonate
- The ALARA principle and the special requirements for radiation safety and contrast material dosage in relation to body mass for the paediatric population
- Principles guiding the construction of a child-friendly environment

Core skills

At the end of this rotation, the resident should be able to perform and analyse:

- Ultrasound, to include:
    - Hip: congenital hip dysplasia and transient synovitis
    - Chest: pleural effusion, chest consolidation and normal thymus
    - Head: hydrocephalus, subependymal and intraventricular haemorrhage, periventricular leukomalacia and tumours
    - Neonates, including abdomen: hypertrophic pyloric stenosis, acute intestinal intussusception, acute appendicitis, intestinal obstruction and volvulus, inguinal hernia, abdominal and pelvic masses, uretero-hydronephrosis, urolithiasis and nephrocalcinosis and cystic disease of the kidney
- Conventional radiography:
    - Chest radiography: bronchiolitis, pneumonia, pleural effusion, pneumothorax, foreign body aspiration, thymus and variants, oesophagus atresia
    - Abdomen plain radiography: intestinal obstruction, urolithiasis, necrotising enterocolitis, pneumoperitoneum
    - Skeleton: fractures (accidental and non-accidental), bone dysplasia, tumours, osteomyelitis, joint effusion, Legg–Calvé–Perthes disease and slipped capital femoral epiphysis
    - Voiding cystourethrography: grade vesico-ureteral reflux and urethral anomalies
    - Upper gastrointestinal tract: gastro-oesophageal reflux, malrotation
    - Barium or equivalent: Hirschprung's disease, anal imperforation
- CT:
    - Head: trauma, intracranial hypertension
    - Chest: infiltrative diseases, complications of pneumonia, metastatic diseases, mediastinal masses
    - Abdominal CT: lesions in blunt trauma, complications of inflammatory bowel diseases, complicated obstruction, peritonitis, metastatic diseases

    - Skeletal CT: complex trauma, osteomyelitis, bone tumours
- MRI:
    - Central nervous system: main brain and spinal malformations, infection, haematoma and brain ischaemia, tumours, pituitary disease
    - Abdomen: work-up of tumours, MR cholangiopancreatography, urinary tract malformation
    - Osteoarticular: infiltrative bone marrow disorders, osteomyelitis, trauma, bone tumours
- Barium studies and voiding cystourethrography

Other skills:

- Reporting conventional radiographs in the investigation of paediatric disorders
- Performing and reporting routine fluoroscopic contrast medium studies of the gastrointestinal system and urinary tract
- Managing and reporting CT and MRI examinations
- Observing interventional techniques, e.g. management of intussusception

Principles of Imaging Technology as Applied to Diagnostic Radiology (Physics)

The aim of this module is to ensure that candidates have a strong foundation in radiation protection, patients and staff alike, with a good understanding of the interactions of X-rays with matter and of the delicate balance between diagnostic image quality and minimum patient effective dose.

Basic knowledge of the technology of each technique with an emphasis on dose and artefacts is expected as core knowledge for each technique.

Patient safety and factors affecting image quality are the two pillars underlying the principles of imaging technology as applied to radiology.

Core knowledge

- X-rays:
    - Concepts of electromagnetic waves
    - Mechanism of X-ray generators
    - X-ray production, with emphasis on the effects on dose and image quality of altering kV and mA and on the trade-off between diagnostic quality imaging and minimising the effective dose
    - Interaction between X-rays and matter
    - Filters, collimators and grids
- Digital radiography:
    - Principles of digital imaging
    - Radiographic image acquisition
    - Fluoroscopic image acquisition
    - Factors affecting image quality
- Computed tomography:
    - Principles of computed tomography, to include CT system design etc.
    - Principles of image acquisition
    - Sources of artefacts
    - Window centre and width
    - Reconstruction algorithms
- Magnetic resonance imaging:
    - Principles and main diagnostic applications of T1, T2, STIR, FLAIR, DWI, spin echo and gradient echo
    - Principles of pulse sequence and relaxation times
    - Biological effects of magnetism
    - Causation of imaging artefacts
    - MRI contrast agents, to include physical principles, gadolinium structure, biological effects, toxic reactions
    - Nephrogenic systemic fibrosis, high-risk groups and high-risk agents
- Diagnostic ultrasound:
    - Nature of ultrasound waves, their propagation, velocity, intensity and the equations that describe them
    - Acoustic impedance and tissue properties that determine it

    - Common artefacts, including reflection, diffusion and speckle
    - Frequency of transmission to achieve satisfactory imaging
    - Physical principles of the piezoelectric phenomenon
    - Factors that determine the resonance frequency of the piezoelectric element
    - Continuous and pulsed emission ultrasound
    - Factors that focus and unify the ultrasound beam
    - Principle differences between the A, B and TM modes of ultrasound
    - Principles of spatial and temporal resolution of ultrasound images as applied to good image formation
    - Principles of the Doppler effect and the application of angled beam and direction of flow
    - Application of pulsed and continuous wave Doppler and spectral waveform analysis
    - Principles of contrast ultrasound media and the relation between the ultrasound beam and microbubbles
    - Thermal and mechanical biological effects of ultrasound waves, including production of the cavitation phenomenon
- Dosimetry and radiation biology (linked with radiation protection, should be tested in all candidates)
- Radiation protection
- Intravenous contrast agents:
    - Ionic/non-ionic contrast agents, to include physiological principles, physical properties, toxic effects, anaphylactoid reaction and biological effects
- Mammography:
    - Principles of soft tissue imaging
    - Features of mammograms

Urogenital Radiology

Core knowledge (see also Gynaecology and Obstetrics)

- Normal anatomy of the kidneys, ureters, bladder and urethra, including normal variants
- Normal anatomy of the retroperitoneum, pelvis and genital tract
- Renal function, the diagnosis of renal parenchymal diseases, including infection and renovascular disease, including contrast medium management in renal failure
- Imaging features and appropriate investigation of calculus disease
- Investigation and features of urinary tract obstruction and reflux including radionuclide studies
- Imaging features and differential diagnosis of tumours of the kidney and urinary tract
- Imaging features and investigation of renal transplants
- Imaging features and differential diagnosis of prostate and testicular abnormalities, diagnostic features and imaging characterisation of common renal masses

Core skills

- Reporting of radiographs of the urinary tract
- Performing and reporting of intravenous urograms, retrograde pyelo-ureterography, nephrostograms, ascending urethrograms and micturating cysto-urethrograms
- Performing and reporting of transabdominal ultrasound imaging of the urinary tract and testis
- Managing and reporting of CT and MR imaging of the retroperitoneum, urinary tract and pelvis
- Observing and understanding of the application, hazards and roles of interventional techniques and nephrostomies

PART III

DETAILED CURRICULUM FOR SUBSPECIALTY INTEREST TRAINING

Detailed subspecialty interest knowledge base (years 4 and 5)

This curriculum outline should be interpreted as a continuum of training. It is envisaged that in years 4–5 subspecialty interest training will be encouraged. During these years the trainee should spend approximately 50% of the time in general radiology, with 50% exposure to a maximum of two subspecialty areas. One of these subspecialty areas may remain general radiology.

This programme should be seen as distinct from full subspecialty fellowship training, where the entirety of practice is devoted to a single, or a maximum of two subspecialties and which should include specific post five year Fellowship training in that area.

Breast Radiology

Introduction

The aim of subspecialised training in breast imaging is to prepare a radiologist for a career in which a significant portion of his/her time will be devoted to breast imaging and/or breast cancer screening with mammography. Such individuals will be expected to provide and promote breast imaging and interventional methods, as well as new imaging breast cancer screening procedures.

The aim of establishing a curriculum for subspecialty training in breast radiology is to ensure:

- An in-depth understanding of breast disease with particular knowledge of the nature of breast cancer in all its guises
- A clear understanding of the role of imaging in the early diagnosis of breast cancer
- Development of the necessary clinical and management skills to enable radiologists to become an integral part of a multidisciplinary breast team in symptomatic and/or population screening settings

Overview

Trainees will have obtained a basic knowledge of breast diagnosis in their initial training. The training outlined below will extend this to the practical role.

Trainees will acquire an extensive knowledge of the pathology and epidemiology of breast diseases, both female and male, and primary, of local recurrence, as well as distant disease. They should have at least a basic knowledge of the treatment of breast disease by surgery, radiotherapy and chemotherapy, and be aware of the diagnostic needs of their surgical, radiotherapy and oncology colleagues. It would therefore be helpful for trainees to spend time in breast clinics, operating theatres, as well as in radiotherapy and oncology departments.

Trainees must also develop skills in the use and interpretation of imaging techniques used in the diagnosis and treatment of the distant spread of a disease, e.g. plain radiographs, ultrasound, CT, and MR. They will receive training in communication with patients and colleagues and in "breaking bad news".

They must obtain extensive experience in all diagnostic procedures listed in the syllabus and will be expected to be familiar with the current breast imaging literature, both from standard textbooks and original articles.

As audit is an integral part of the process of breast imaging, particularly screening, trainees will have ready access to data to analyse the proficiency of his or her activities. Additionally, they will be expected to complete a focused audit and develop an understanding of the process of interval cancer review.

Trainees should participate in research and be encouraged to pursue a project up to and including publication. An understanding of the principles and techniques used in research, including the value of clinical trials and basic biostatistics, should be acquired.

They must attend regular multi-disciplinary conferences.

Core knowledge

Epidemiology and screening

In-depth knowledge and understanding of the national and regional epidemiological data regarding the breast:

- Major risk factors of breast cancer, including genetic risk; the indications for an oncogenetic consultation, definition of different risk levels, indications and principles of genetic screening
- Aims, objectives and principles of population screening
- Structure and management of a national screening programme (if it exists)
- Risks and benefits of screening to the population and the individual, including those related to age factors, family history and hormone replacement therapy
- European quality criteria for organised screening
- Principles and techniques used in audit, desirable goals for positive predictive value, percentage of stage 0 and stage I tumours, minimal carcinomas, node positivity, prevalent and incident cancer rates, recall rates, sensitivity, specificity and false-negative rate, importance of data collection
- Screening theory: lead time bias, length bias, survival rates, prevalence versus incidence screening, definition of lead time and interval cancer rate (in-depth knowledge)
- Controversies regarding screening and related research (in-depth knowledge)
- Legal liability

Radiation protection

- Current legislation governing the use of ionising radiation and of the responsibilities as defined in national and European legislation
- The need to minimise the radiation dose received by the patient/client
- Risk/benefit analysis associated with breast screening using ionising radiation compared with other techniques, e.g. ultrasound, MRI

Physics

For all imaging techniques:

- Physics of image production and how alteration of machine parameters affects the image
- Image recording and display systems and how alterations in machine parameters affect the image
- Quality assurance programmes and the impact that image quality has on clinical performance
- Artefacts, limitations of resolution and contrast agents

Anatomy and pathology

- Normal embryology, physiology and anatomy of the breast and associated structures; in particular changes due to age, lactation, hormonal status, surgery, radiotherapy etc.
- Normal anatomy, pathological conditions and pathophysiology of breasts and associated structures, including synchronous and metachronous disease
- Benign diseases of the breast (in-depth knowledge), and how these diseases manifest, both clinically and on imaging
- Atypical lesions of the breast, their clinical and pathological significance (in-depth knowledge)
- Malignant diseases of the breast and associated structures, genetic subtypes, histological prognostic factors and TNM classification; pathological reporting and radiologically relevant information (in-depth knowledge)
- Spread of breast carcinoma and the pathological features in other organs
- Radio-pathological correlation of imaging findings and biopsy results

Clinical training

- Clinical presentation of benign and malignant diseases of the breast
- Role of imaging in the management of benign breast disease (a clear understanding)
- Role of imaging in the early diagnosis of breast cancer (a clear understanding)
- Principles and contraindications for breast-conserving surgery and sentinel lymph node biopsy; role of radiology in the assessment of the extent of disease
- Indications for neoadjuvant chemotherapy, clinical and radiological evaluation of response to treatment
- Adjuvant therapy options for breast cancer and methods of surveillance after treatment
- Side effects of chemotherapy and radiotherapy, radiological findings associated with therapy, and the diagnostic needs of surgery and oncology colleagues
- Radiological methods for the staging of breast cancer, evaluation and minimally invasive therapy of distant metastases
- Radiological findings associated with reconstructive and cosmetic surgery
- Central role of the multidisciplinary team in planning investigations, treatment and in outcome review (a clear understanding)
- Current developments in clinical practice (detailed knowledge)
- Clinical management and radiological evaluation of patients presenting with a palpable breast mass, mastodynia, breast trauma, inflammatory findings, nipple discharge, nipple or skin retraction, nipple thickening and axillary adenopathy
- Imaging work-up and main pathological conditions that can be detected in male patients, children and adolescents, and in pregnant and lactating women

Imaging techniques

Trainees should understand the principles of all imaging methods including:

- Planning, implementation, supervision and accurate interpretation of all imaging techniques
- Relative indications and contraindications
- Complications
- Normal appearances, normal variations, benign and malignant processes, local recurrence and distant spread
- Limitations of individual techniques, examinations, sequences/views and the complementary nature of other techniques and the role of each technique in the investigation of breast disease
- How imaging findings influence decisions by others, e.g. surgeons, pathologists, oncologists etc.
- Advantages, limitations and potential indications of new technologies, such as CAD, tomosynthesis and other digital applications of mammography, elastography, diffusion-weighted MR imaging and MR spectroscopy, new contrast media
- Advantages and limitations of other imaging methods, e.g. PET-CT, scintimammography, breast CT

Team-work

- Roles and responsibilities of other members of the breast imaging team, e.g. clerical officers, radiographers, nurses, support staff, secretaries etc.
- Roles and responsibilities of other members of the multidisciplinary team
- How diagnosis affects the management pathway

Core skills

Clinical training

- Undertaking physical examination of the breast and associated structures
- Recognising the clinical priority of certain presentations and tailoring of the examination to the clinical indication

Interventional techniques

Trainees should understand the principles of all interventional methods including:

- Relative indications and contraindications
- Complications
- Advantages and disadvantages of different methods and guiding techniques
- Limitations of individual examinations, the complementary nature of other techniques and the role of each technique in the investigation of breast diseases
- How biopsy and interventional techniques influence decisions and treatment planning by others, e.g. surgeons, pathologists, oncologists
- Applicable procedures:
    - Cyst aspiration
    - Fine needle aspiration cytology (free-hand and/or image-guided)

- Mechanical and vacuum-assisted core biopsy (free-hand and/or image-guided)
- Image-guided localisation
- Abscess management
- MR-guided focused ultrasound and any other new therapeutic techniques

Communication

- Effective communication with both the patient and the members of the multidisciplinary team
- Breaking news and the psychosocial consequences of doing so improperly

Cardiac Radiology

Introduction

Cardiac radiology is an important and rapidly developing field in radiology. The use of non-invasive cardiac imaging has progressed over the last decade to involve virtually all techniques in diagnostic radiology. Interventional techniques in the heart have also progressed, and whether or not a radiologist is involved in cardiac intervention, it is important that there is an understanding of the clinical and diagnostic implications of these techniques. The heart is not an isolated organ, and it is equally important that the relationship between the heart and the cardiovascular and cardiopulmonary systems are understood. Incidental radiological findings that may have major clinical implications are an important aspect of cardiac imaging and radiologists are best equipped in these interpretations. No cross-sectional cardiac imaging studies should be performed or reported without the input of a supervising radiologist. Knowledge of the principles of radiation protection and their application to cardiac imaging is an essential component of training.

Core knowledge

The learning objectives for radiology trainees should include:

Background

- Cardiac anatomy by CT
- Common congenital and acquired cardiac conditions (basic understanding), in particular, atherosclerotic heart disease
- Role of alternative cardiac assessment tools (basic understanding, including radiological (MRI, SPECT) and non-radiological (stress test, echo)
- Cardiac CT image acquisition
- Cardiac CT image post-processing
- Cardiac CT clinical application and image interpretation

Image acquisition

- Patient preparation for cardiac CT including indications, venous access and beta-blocking
- Multidetector CT acquisition set-up for cardiac CT
- ECG gating for cardiac CT
- Contrast bolus timing as it pertains to cardiac CT

Image post-processing

- Axial, multiplanar reconstructions (MPR), maximum intensity projection (MIP) and volume rendering principles
- How to display the major coronary anatomy using 3D CT
- How to perform coronary calcification scoring

Clinical application and image interpretation

- Common congenital heart diseases
- Coronary artery disease
- Congenital anomalies
- Acquired atherosclerosis – coronary calcification and coronary CTA
- Pericardial disease
- Myocardial disease
- Valvular heart disease

Other knowledge

- Congenital and acquired cardiovascular disease (basic clinical, pathological and pathophysiological knowledge)
- Principles and practice of screening techniques and risk factors in cardiac disease
- Indications, contraindications and potential hazards (especially radiation hazards) of procedures and techniques relevant to cardiovascular disease
- Cardiovascular anatomy in clinical practice relevant to clinical radiology
- Normal variants of cardiac and coronary artery anatomy, in particular those that may mimic disease
- Manifestations of cardiovascular disease, including trauma, as demonstrated by conventional radiography, CT, MRI, angiography, radionuclide investigations and ultrasound
- Differential diagnosis relevant to clinical presentation and imaging features of cardiovascular disease
- Calcium scoring, imaging principles, techniques of measurement, limitations and the epidemiological implications
- Cardiac anatomy, and the relevant embryological principles
- Clinical aspects of cardiac disease including pathophysiological and biochemical correlates (working knowledge)
- Management of procedural complications in the diagnosis and treatment of cardiac disease
- Pathophysiology, differential diagnosis and treatment of pseudoaneurysm formation following invasive cardiac procedures
- Role of the varying treatments available for both congenital and acquired cardiac disease, including coronary artery disease

Clinical cardiac radiology

The general radiological training curriculum should include knowledge of the following disease categories:

- Coronary artery disease, including acute coronary syndromes:
    - Myocardial ischaemia
    - Myocardial infarction
    - Post-myocardial infarction syndrome
    - The radiological appearances of ventricular aneurysm
    - Coronary artery calcium scoring
    - Unusual causations of coronary artery disease, including various forms of arteritis
    - Hibernating/stunned myocardium

    - Disease patterns that are age- or gender-related, including sudden death syndrome in young men
- Valve disease:
    - Rheumatic or post-rheumatic valve disease
    - Stenosis and incompetence of cardiac valves
    - Endocarditis
    - Sub- and supravalvar disease
    - Subvalvar apparatus disease
    - The pericardium
- Cardiac tumours:
    - Working knowledge of clinical presentation
    - Intracardiac tumours, i.e. myxomas, haemangiomas and sarcomas
    - Primary tumours, i.e. myxomas, haemangiomas and sarcomas
    - Secondary tumours
    - Metastatic cardiac tumours
    - Cardiomyopathy:
        - Working knowledge of clinical manifestation
        - Acute myocarditis
        - Dilated cardiomyopathy
        - Restrictive and obstructive cardiomyopathy
        - Cardiomyopathy related to systemic disease
        - Infiltrative cardiomyopathy
    - Diabetic and renal cardiac disease
    - Athlete's heart
- Congenital heart disease (also under "*Coronary artery disease, including acute coronary syndromes*"):
    - Neonatal heart disease
    - Congenital disease in childhood
    - Adult congenital heart disease
- Major vessel disease:
    - Thoracic aneurysm
    - Classification of aortic dissection
    - Imaging findings of acute and chronic dissection
    - Clinical and radiological manifestations of Marfan's syndrome
    - Clinical and radiological manifestations of Takayasu's disease
    - Causes and radiological appearances of acute pericarditis
    - Causes and radiological appearances of chronic pericarditis
    - Malignant pericardial disease
- Expected imaging findings after:
    - By-pass grafts
    - Valve replacement
    - Aortic replacement
    - Ventricular surgery
    - Pericardiectomy
    - Principles, uses and limitations of nuclear cardiac imaging
    - Principles of intravascular imaging
- Stress testing:
    - Principles of exercise stress testing, uses and limitations
    - Methods of stress testing as applied to cardiac imaging
    - Patient management of stress testing for cardiac imaging

Molecular imaging

Principles of molecular imaging as applied to cardiac radiology include its role in:

- Myocardial ischaemia and viability
- Heart failure and heart graft rejection
- Cardiac stem cell and gene therapy

Core skills

- Supervising technical staff to ensure that appropriate images are obtained
- Discussing significant or unexpected radiological findings with referring clinicians and knowing when to contact a clinician
- Recommending the most appropriate imaging technique, appropriate to patients' symptoms or pathological features or a request from the referring clinician
- Developing skills in forming protocols, monitoring and interpreting cardiac studies appropriate to the patient's history and other clinical information
- Presenting effectively cardiac imaging in a conference setting
- Providing a coherent report on imaging studies of cardiovascular disease

Chest Radiology

Core knowledge

Normal anatomy

- Lobar and segmental bronchi
- Relationships of the hilar vessels and bronchi
- Secondary pulmonary lobule and its component parts
- Correct terminology for describing the site of mediastinal and hilar lymph nodes
- Normal variants of aortic arch branching, including the common origin of the brachiocephalic and left common carotid arteries ("bovine arch"), and separating the origin of the vertebral artery from the arches

Generic signs on chest radiographs

- The following structures on postero-anterior (PA) and lateral chest radiographs:
    - Right upper, middle and lower lobes; left upper and lower lobes; and lingula
    - Fissures – major, minor and azygos
    - Airway – trachea, main bronchi, posterior wall of the intermediate bronchus and lobar bronchi
    - Heart – position of the atria, ventricles, left atrial appendage and the location of the four cardiac valves
    - Pulmonary arteries – main, right, left and interlobar
    - Aorta – ascending, arch and descending aorta
    - Arteries – brachiocephalic (innominate), carotid and subclavian arteries
    - Veins – superior and inferior vena cava, azygos, left superior intercostal ("aortic nipple"), and left brachiocephalic (innominate) veins
    - Components of the thoracic skeleton
    - Mediastinal stripes and interfaces
    - Aortopulmonary window
    - Both hemidiaphragms
- Significance of the following chest radiography signs:
    - Silhouette sign – loss of the contour of the heart or diaphragm indicating an adjacent abnormality (e.g. atelectasis of the right middle lobe obscures the right-hand side of the heart's border)
    - Air bronchogram – indicates airless alveoli and, therefore, a parenchymal process as distinguished from a pleural or mediastinal process
    - Air crescent sign – indicates solid material in a lung cavity, often due to a fungus ball, or crescentic cavitation in invasive fungal infection
    - Cervicothoracic sign – a mediastinal opacity that projects above the clavicles, situated posterior to the plane of the trachea, while an opacity projecting at or below the clavicles is situated anteriorly
    - Tapered margins – a lesion in the chest wall, mediastinum or pleura may have smooth tapered borders and obtuse angles with the chest wall or mediastinum, while parenchymal lesions usually form acute angles
    - Gloved finger sign – indicates bronchial impaction, e.g. in allergic bronchopulmonary aspergillosis, or other chronic obstructive processes

    - Golden sign – indicates lobar collapse with a central mass, often due to an obstructing bronchogenic carcinoma in an adult
    - Deep sulcus sign on a supine radiograph – indicates pneumothorax
- Following structures on chest CT:
    - All pulmonary lobes and segments
    - A pulmonary lobule and associated structures
    - Fissures – major, minor, azygos and common accessory fissures
    - Extrapleural fat
    - Inferior pulmonary ligaments
    - Airway – trachea, carina, main bronchi, lobar bronchi and segmental bronchi
    - Heart – left and right ventricles, left and right atria, atrial appendages
    - Pericardium – including superior pericardial recesses
    - Pulmonary arteries – main, right, left, interlobar, segmental
    - Aorta – sinuses of Valsalva, ascending, arch and descending aorta
    - Arteries – brachiocephalic (innominate), common carotid, subclavian, axillary, vertebral, internal mammary arteries
    - Veins – pulmonary, superior vena cava, inferior vena cava, brachiocephalic, subclavian, internal jugular, external jugular, azygos, hemi-azygos, left superior intercostal, internal mammary
    - Oesophagus
    - Thymus
    - Normal mediastinal and hilar lymph nodes
    - Azygo-oesophageal recess
    - Inferior pulmonary ligaments
- Chest CT protocol optimised to evaluate each of the following, taking into account the patient's age:
    - Thoracic aorta and great vessels
    - Superior vena cava and brachiocephalic vein stenosis or obstruction
    - Pulmonary embolism
    - Diffuse lung disease
    - Tracheobronchial tree
    - Bronchiectasis
    - Small airway disease
    - Lung cancer staging
    - Oesophageal cancer staging
    - Superior sulcus tumour
    - Pulmonary metastases
    - Pulmonary nodule on a radiograph
    - Shortness of breath
    - Haemoptysis

Alveolar lung diseases and atelectasis

- The four common causes of segmental consolidation
- Five of the most common causes of adult (acute) respiratory distress syndrome
- The four predisposing causes of or associations with organising pneumonia
- Most common causes of bronchiectasis
- Centrilobular, paraseptal and panacinar emphysema and their patterns on chest radiographs and CT

- Imaging findings used to identify surgical candidates for giant bullectomy or lung volume reduction surgery

Solitary and multiple pulmonary nodules

- Definition of a solitary pulmonary nodule and a pulmonary mass
- Four most common causes of a solitary pulmonary nodule, cavitary pulmonary nodules and multiple pulmonary nodules
- Strategy for managing a solitary pulmonary nodule detected incidentally or at screening
- Role of contrast-enhanced CT and integrated PET-CT in the evaluation of a solitary pulmonary nodule
- Features that indicate benignity of a solitary pulmonary nodule and their limitations
- Complications of percutaneous lung biopsy and their frequency
- Indications for chest tube placement as a treatment for pneumothorax related to percutaneous lung biopsy

Benign and malignant neoplasms of the lung

- The four major histological types of bronchogenic carcinoma, and the difference in treatment between non-small-cell and small-cell lung cancer
- TNM classification for staging non-small-cell lung cancer, including the components of each stage
- Staging of bronchogenic cancer
- Abnormal contralateral mediastinal shift on a post-pneumonectomy chest radiograph and two possible aetiologies for the abnormal shift
- Acute and chronic radiographic and CT appearance of radiation injury in the thorax (lung, pleura, pericardium) and the temporal relationship with radiation therapy
- Roles of CT and MRI in lung cancer staging
- Role of positron emission tomography (PET) and integrated PET-CT in lung cancer staging
- Manifestations and the role of imaging in thoracic lymphoma

Thoracic disease in immunocompetent, immunocompromised and post-transplant patients

- Radiographic manifestations of pulmonary mycobacterial infections on a radiograph and CT
- Various types of pulmonary aspergillosis, understanding that they form part of a continuum, and recognising these entities on chest radiographs and chest CT
- Major categories of disease-causing chest radiography or chest CT abnormalities in the immunocompromised patient
- Two infections and two neoplasms in patients with AIDS and chest radiography or chest CT abnormalities
- Chest radiography and chest CT appearances of *Pneumocystis jiroveci* pneumonia
- The three most important aetiologies of hilar and mediastinal adenopathy in patients with AIDS

- Differential diagnoses for widespread consolidation in an immunocompromised host
- Chest radiography and chest CT findings of post-transplant lymphoproliferative disorders
- Chest radiography and chest CT findings of graft-versus-host disease

Congenital lung disease

- Components of pulmonary venolobar syndrome (scimitar syndrome) on a frontal chest radiograph, chest CT and chest MRI
- Signs of intralobar pulmonary sequestration and cystic adenomatoid malformation on chest radiographs and chest CT

Pulmonary vascular disease

- Five of the most common causes of pulmonary artery hypertension and signs on chest radiography and chest CT
- Role of CT pulmonary angiography (CTPA), MRI/MRA and lower extremity venous studies in the evaluation of a patient with suspected venous thromboembolic disease, including the advantages and limitations of each test

Pleura and the diaphragm

- Chest radiography and chest CT findings of malignant mesothelioma

Mediastinal and hilar disease

- The most common causes of an anterior mediastinal mass and localising a mass to the anterior mediastinum on chest radiographs, chest CT and chest MRI
- The three most common causes of a middle mediastinal mass and localising a mass to the middle mediastinum on chest radiographs, chest CT and chest MRI
- The most common cause of a posterior mediastinal mass and localising a mass to the posterior mediastinum on chest radiographs, chest CT and chest MRI
- The most common causes of bilateral hilar lymph node enlargement
- The most common causes of "egg-shell" calcified lymph nodes in the chest
- The most common causes of a mass arising in the thymus
- Imaging features and common associations of thymoma
- The three types of malignant germ cell tumour of the mediastinum
- Mechanisms and signs of pneumomediastinum

Thoracic aorta and the great vessels

- Normal dimensions of the thoracic aorta
- Stanford A and B classification of aortic dissection and the implications of the classification for medical versus surgical management
- Significance of a right aortic arch with mirror image branching versus an aberrant subclavian artery
- Advantages and disadvantages of CT, MRI/MRA and trans-oesophageal echocardiography in the evaluation of the thoracic aorta
- The terms "aneurysm" and "pseudoaneurysm"

Chest trauma

- The three common causes of abnormal lung opacity following trauma on chest radiographs or chest CT
- The three common causes of abnormal lung opacity following trauma on chest radiographs or chest CT
- The three most common causes of pneumomediastinum following trauma
- Monitoring and support devices – "tubes and lines"

Molecular imaging

Principles of molecular imaging as applied to chest radiology include its role in:

- Lung inflammatory diseases and lung transplants
- Chest tumours and lymphomas
- Gene therapies for tumours

Core skills

- Applying inspiratory and expiratory imaging, multiplanar reconstructions as applied to pulmonary disease
- Recognising the effects of various pathological processes on the component parts of the pulmonary lobule, as seen on high-resolution CT (HRCT)
- Identifying the pathophysiology of the following patterns:
    - Lung consolidation
    - Ground glass opacity, linear and reticular pattern
    - Honeycombing nodular pattern
    - Bronchiolar opacities ("tree-in-bud")
    - Air trapping
    - Cysts
    - Mosaic attenuation pattern
- Identifying thickening of the interlobular septa and the possible causes
- Making a specific diagnosis of interstitial lung disease (ILD) when HRCT appearances are characteristic
- Recognising the spectrum of changes of heart failure on chest radiographs, notably:
    - Pleural effusions
    - Vascular redistribution on erect chest radiographs
    - Features of interstitial and alveolar oedema
- Defining the terms "asbestos-related pleural disease" and "asbestosis", and identifying the imaging findings
- Recognising progressive massive fibrosis/conglomerate masses secondary to silicosis or coal worker's pneumoconiosis on radiography and chest CT

Differential diagnosis of diffuse infiltrative lung disease

The trainee radiologist should develop a differential diagnostic list for the following patterns, taking into account the anatomical and imaging distribution of the signs and the clinical information:

- On chest radiographs (according to whether the pattern is predominantly in the upper, mid or lower zone; or shows central or peripheral predominance):
    - Lung consolidation
    - Ground glass opacity
    - Nodular pattern
    - Reticular pattern
    - Cystic pattern
    - Widespread septal lines
- On HRCT (according to whether the pattern is predominantly in the upper, mid or lower zone; or shows perihilar or subpleural predominance; or shows a vascular or perivascular airway, a lymphatic or perilymphatic or an interstitial distribution:
    - Septal thickening/nodularity
    - Ground glass opacity
    - Reticular pattern
    - Honeycombing
    - Nodular pattern
    - Air space consolidation
    - Tree-in-bud pattern
    - Mosaic attenuation pattern
    - Cyst and cyst-like pattern

Alveolar lung diseases and atelectasis

- Recognising segmental and lobar consolidation
- Recognising partial or complete atelectasis of single or combined lobes on chest radiographs and listing the likely causes
- Recognising complete collapse of the right or left lung on a chest radiograph and listing the appropriate causes of the collapse
- Distinguishing lung collapse from massive pleural effusion on a frontal chest radiograph
- Recognising the halo sign and suggesting a diagnosis of invasive aspergillosis in an immunosuppressed patient
- Recognising the signs of bronchiectasis on chest radiographs and chest CT
- Recognising the HRCT signs of small airways disease and differentiating between the direct signs (tree-in-bud, centrilobar changes) of exudative bronchiolitis and the indirect signs (mosaic pattern, air-trapping) of obliterative bronchiolitis (bronchiolitis obliterans)
- Recognising the typical appearance of cystic fibrosis on chest radiographs and chest CT
- Recognising tracheal and bronchial stenosis on chest CT and naming the most common causes
- Recognising the signs of panacinar emphysema on chest radiographs and CT

Airways and obstructive lung disease

- Diagnosing bronchiectasis
- Identifying features of air trapping
- Recognising emphysema and the various patterns to include panacinar, bullus and paraseptal emphysema

- Understanding tracheal abnormalities, to include tracheomalacia, tracheal stenosis, and tracheobronchomegaly

Unilateral hyperlucent lung/haemothorax

- Recognising a unilateral hyperlucent lung on chest radiographs or chest CT and giving an appropriate differential diagnosis

Benign and malignant neoplasms of the lung

- Naming the four most common extrathoracic metastatic sites for non-small-cell lung cancer and for small-cell lung cancer

Congenital lung disease

- Recognising bronchial atresia on a chest radiograph and chest CT, and stating the most common lobes of the lungs in which it occurs

Pulmonary vascular disease

Recognising:

- Enlarged pulmonary arteries on a chest radiograph and distinguishing them from enlarged hilar lymph nodes
- Acute and chronic lobar and segmental pulmonary emboli on CT angiography
- Vascular redistribution seen in raised pulmonary venous pressure

Pleura and the diaphragm

Recognising:

- Typical chest radiography appearances of pleural effusion on erect, supine and lateral decubitus chest radiographs, and the four causes of a large unilateral pleural effusion
- Appearance of pleural effusion on ultrasound
- Pneumothorax on an upright and supine chest radiograph
- A pleural-based mass with bone destruction or infiltration of the chest wall on a radiograph or chest CT, and naming four likely causes
- Various forms of pleural calcification on a chest radiograph or chest CT and suggesting the diagnosis of asbestos exposure, or old TB, old empyema, or old haemothorax
- Unilateral elevation of one hemidiaphragm on chest radiographs and list five causes (e.g. subdiaphragmatic abscess, diaphragm rupture and phrenic nerve involvement with lung cancer, post-cardiac surgery, eventration)
- Tension pneumothorax
- Diffuse pleural thickening and four causes
- Split pleura sign in empyema

Mediastinal and hilar disease

Recognising:

- Normal vessels or vascular abnormality on chest CT and chest MRI that may mimic a solid mass
- Mediastinal and hilar lymphadenopathy on chest radiographs, chest CT and chest MRI
- Imaging signs of a benign cystic teratoma
- Signs of an intrathoracic thyroid mass
- Cystic mass and suggesting the possible diagnosis of a bronchogenic pericardial, thymic or oesophageal duplication cyst

Thoracic aorta and the great vessels

Recognising:

- Findings of, and distinguishing between, each of the following on chest CT and chest MRI:
    - Aortic aneurysm
    - Aortic dissection
    - Aortic intramural haematoma
    - Penetrating atherosclerotic ulcer
    - Ulcerated plaque
    - Ruptured aortic aneurysm
    - Sinus of Valsalva aneurysm
    - Subclavian or brachiocephalic artery aneurysm
    - Aortic coarctation
    - Aortic pseudocoarctation
    - Cervical aortic arch
- Two standard types of right aortic arch and a double aortic arch on chest radiographs, chest CT and chest MRI
- An aberrant subclavian artery on chest CT
- Findings seen in arteritis of the aorta on chest CT and chest MRI

Chest trauma

- Identifying a widened mediastinum on chest radiographs taken for trauma and stating the possible causes (including aortic/arterial injury, venous injury, fracture of sternum or spine)
- Identifying the indirect and direct signs of aortic injury on contrast-enhanced chest CT
- Identifying and stating the significance of chronic traumatic pseudoaneurysm on chest radiographs, chest CT or chest MRI
- Identifying fractured ribs, clavicle, spine and scapula on chest radiographs or chest CT
- Recognising an abnormally positioned diaphragm or loss of definition of a diaphragm on chest radiographs following trauma and suggesting the diagnosis of a ruptured diaphragm
- Recognising a pneumothorax and pneumomediastinum following trauma on chest radiographs

- Recognising a cavitary lesion following trauma on chest radiographs or chest CT and suggesting the diagnosis of laceration with pneumatocele formation, haematoma or abscess secondary to aspiration
- Recognising and distinguishing between pulmonary contusion, laceration and aspiration
- Identifying and stating the preferred placement of the following devices and lines; listing the complications associated with the malpositioning of each of the following:
    - Endotracheal tube
    - Central venous catheter
    - Swan–Ganz catheter
    - Nasogastric tube
    - Chest tube/drain
    - Intra-aortic balloon pump
    - Pacemaker and pacemaker leads
    - Implantable cardiac defibrillator
    - Left ventricular assistant device
    - Atrial septal defect closure device ("clamshell device")
    - Pericardial drain
    - Extracorporeal life support cannulae
    - Intra-oesophageal manometer, temperature probe or pH probe
    - Tracheal or bronchial stent
- Performing the following imaging-guided transthoracic interventions under appropriate supervision, and knowing the indications, contraindications, and management of complications:
    - Paracentesis and drainage of pleural effusions
    - Percutaneous lung biopsy
    - Paracentesis of mediastinal and pericardial fluid collections
    - Drainage of refractory lung abscess

Postoperative chest

Identifying normal postoperative findings and complications of the following procedures on chest radiographs, chest CT and chest MRI:

- Wedge resection mastectomy, lobectomy
- Pneumonectomy
- Coronary artery bypass graft surgery
- Cardiac valve replacement
- Aortic graft
- Aortic stent
- Transhiatal oesophagectomy
- Lung transplant
- Heart transplant
- Lung volume reduction surgery

Gastrointestinal and Abdominal Radiology

Introduction

Gastrointestinal and abdominal radiology include all aspects of medical imaging (diagnostic and interventional), thus covering information relative to the anatomy, pathophysiology and the various diseases that may affect the abdomen. This field of imaging includes various techniques (ultrasound, Doppler, conventional X-ray imaging, computed tomography, magnetic resonance imaging, angiography and other interventional procedures, and nuclear medicine) and various organs (pharynx, oesophagus, stomach, duodenum, small bowel, colon, rectum, anus, pancreas, liver, biliary tract, spleen, peritoneum, abdominal wall and pelvic floor).

Core knowledge

Imaging techniques – general requirements

- Indications and contraindications for the various imaging examinations in abdominal imaging
- Most appropriate imaging examination according to the clinical problem
- Best contrast material and its optimal use according to the imaging technique and the clinical problem
- Relative costs of the various imaging examinations in abdominal imaging
- Radiation burden and risks of different investigations
- Technique and indications for video-fluoroscopy of the swallowing mechanism
- Indications and contraindications for enema techniques and the optimal contrast material and technique to be used in each clinical situation
- Indications for and a contrast-enhanced ultrasound study of the liver
- Techniques for quantification of diseases using ultrasound, CT and MRI, and their clinical role and limitations.
- Retroperitoneal structures and the application and limitations of ultrasound in this area
- Strengths and limitations of endosonography
- Techniques for CT colonography, CT/MR enterography and CT/MR enteroclysis
- Techniques for post-processing images in view of obtaining reformat, MIP, MinIP, vessel analysis, 3D analysis, including endoluminal reconstructions, fusion images, as well as acquisition and treatment of functional studies
- Technique of PET-CT; the most important tracers (FDG, choline) and the development of new tracers; Se/sp of PET-CT in most common abdominal tumours, including liver metastases of extra-abdominal origin

Anatomy and physiology

- Principal aspects of embryology of the oesophagus, stomach, duodenum, small bowel, appendix, colon, rectum, anus, pancreas, liver, biliary tract and spleen
- Indication and techniques for interventional procedures within the abdomen, including hepatobiliary intervention and luminal stenting

- Anatomy of the pharynx, oesophagus, stomach, duodenum, small bowel, appendix, colon, rectum, anus, pancreas, liver, biliary tract, spleen, mesentery and peritoneum
- Anatomy of the pelvic floor and abdominal wall
- Arterial supply and venous drainage, including important variants, of the various portions of the gastrointestinal tract
- Lymphatic drainage of the relevant organs
- Main anatomical variants, and normal post-therapeutic imaging related to previous surgery, intervention or radiation therapy

Oesophagus

- Role of PET or PET-CT in the staging of oesophageal cancer
- Oesophageal perforation on plain films, and deciding if contrast studies or more likely CT should be performed for confirmation and better evaluation
- Oesophageal cancer, diverticulum, extrinsic compression, submucosal masses, fistulae, sliding and para-oesophageal hiatus hernia, oesophageal varices, benign strictures, benign tumours, varices, different forms of oesophagitis on a contrast-enhanced examination of the oesophagus
- Significance of Barrett's oesophagus and the manifestations of this disease
- Appearance of common motility disorders
- Basic surgical techniques in oesophageal surgery and post-surgical appearances on imaging examinations
- Oesophageal cancer on CT and the criteria for non-resectability and lymph node involvement
- Use of endoscopic ultrasound in the staging of oesophageal cancer and the technique of endoscopic ultrasound-guided biopsy

Stomach and duodenum

- Most appropriate imaging examination and contrast medium use in suspected perforation of the stomach and postoperative follow-up; the limitations of each examination for these specific conditions
- Role of endoscopic ultrasound and PET or PET-CT in the staging of gastric cancer
- CT protocol for gastric cancer staging
- Surgical procedures for the treatment of obesity and the radiological postoperative appearance and complications
- Imaging features (on barium studies and CT) of a variety of conditions such as benign and malignant tumours, infiltrative disorders, e.g. linitis plastica, gastric ulcers and positional abnormalities, including gastric volvulus
- Duplication cysts of the upper gastrointestinal tract on CT
- Appearance of gastroduodenal disease on ultrasound
- Rotational abnormalities of the duodenum and also the appearance of annular pancreas, submucosal tumours, papillary tumours, inflammatory disease including ulceration

Small bowel

- Most appropriate imaging examination in the following cases: small bowel obstruction, inflammatory disease, infiltrative disease, small bowel perforation

and ischaemia, cancer, lymphoma, carcinoid tumour and post-operative follow-up; the limitations of each examination for these specific cases
- Lymphoid hyperplasia of the terminal ileum on small bowel series; the most common mid-gut abnormalities (malrotation, internal hernia)
- MRI and CT techniques of enterography and enteroclysis
- Indications for capsule endoscopy; the limitations and potential complications of the examination
- Features of small bowel abnormalities on small bowel imaging, including stenosis, fold abnormalities, nodules, tumours, ulcerations, wall thickening, marked angulation, extrinsic compression and fistula
- On a small bowel series, identifying the following diseases: adenocarcinoma, polyposis, stromal tumour, lymphoma, carcinoid tumour, Crohn's disease, mesenteric ischaemia, haematoma, Whipple's disease, amyloidosis, radiation-induced injury, malrotation, Meckel's diverticulum, coeliac disease, diverticulosis, systemic sclerosis and chronic pseudo-obstruction
- Main principles of the interpretation of CT examination of the small bowel; findings in the various diseases of the small bowel, and, in particular, a halo sign and a target sign; a transitional zone in the case of small bowel obstruction; a small bowel tumour; mural pneumatosis, vascular engorgement, increased density of the mesenteric fat, peritoneal abnormality and malrotation
- Causes of small bowel obstruction on CT (adhesion, band, strangulation, intussusception, volvulus, internal and external hernias, tumours) and their complications; criteria for emergency surgery
- Main principles of the interpretation of MRI of the small bowel, especially in cases of inflammatory bowel disease

Colon and rectum

- Optimal imaging examination and detailed technique for study of the colon according to the suspected disease (obstruction, volvulus, diverticulitis, benign tumour, inflammatory disease, cancer, lymphoma, carcinoid tumour, stromal tumour, perforation, postoperative evaluation) and the limitations of each technique
- Rotational abnormalities of the colon
- Normal appendix on CT and ultrasound; the various features of appendicitis on CT and ultrasound
- Different features of colon tumours, diverticulitis, inflammatory diseases, colon ischaemia and radiation-induced colitis
- Megacolon, colonic diverticulosis, specific and non-specific colitis, colonic fistula, carcinoma, polyps and postoperative stenosis on an enema
- Colonic diverticulosis, diverticulitis, tumour stenosis, ileocolic intussusception, colonic fistula, paracolic abscess, epiploic appendicitis, intra-peritoneal fluid collection, colonic pneumatosis and pneumoperitoneum on CT
- Current indications for CT colonography, including its potential role in colorectal cancer screening, and reporting on CT colonography
- Appearances and differential diagnosis of retrorectal cysts and techniques for surgical treatment
- Available therapies (including surgical) for the treatment of recurrent colorectal cancer and the use of pre-operative imaging to guide such therapies
- Anatomy of the rectum, perirectal tissues and of the anal sphincters

- Appearance of the anal sphincter complex on endoanal ultrasound and the major pathological proof, including sphincter tears and perianal sepsis
- Various diseases of the rectum and the anus and the most frequent operative techniques that may be used to treat them
- Diagnosis of functional and anatomical disorders on both fluoroscopic and MR proctography and the appearance of pelvic floor muscle tears and atrophy depicted using MRI
- CT features of colon cancer; criteria for local extent (enlarged lymph nodes, peritoneal carcinomatosis, hepatic metastases and obstruction)
- TNM classification of colon cancer and its prognostic value; the technique and value of endosonography, MDCT and MRI in the staging of rectal cancer
- Rectal cancer, tumour recurrence after surgery and a pelvic fistula on CT and on MRI; the value of PET-CT; criteria that may help in differentiating between postoperative fibrosis and tumour recurrence
- Basic MRI technique that is used to search for a pelvic/perianal fistula; the appearance of fistulae on MRI
- Basic MRI technique for rectal cancer and staging the tumour according to the tumour proximity with the mesorectal fascia and distance to the sphincter; the potential limitations of MRI for N staging

Peritoneum and abdominal wall

- Normal features of the peritoneum on ultrasound, CT and MRI; the various findings that can be seen in cases of peritoneal disease (nodules, thickening, fluid collection)
- Various types of abdominal wall hernias (inguinal, umbilical, parastomal, postoperative) on CT; an abdominal wall hernia on ultrasound; a hernial strangulation on CT and on ultrasound
- Mesenteric tumour and its location on ultrasound/CT/MRI
- Features of a mesenteric cyst on ultrasound/CT/MRI
- Ascites on ultrasound, CT and MRI; the features of loculated ascites
- Following peritoneal diseases on CT/MRI: peritonitis, peritoneal carcinomatosis, peritoneal tuberculosis, mesenteric lymphoma, mesenteric and greater omental infarction

Vessels

- Basic principles of Doppler ultrasound and superior mesenteric artery stenosis or occlusion; use of Doppler to assess the patency of and the direction of flow in the portal and hepatic veins
- Respective roles of angiography and CT angiography in acute gastrointestinal haemorrhage; fluoroscopic and CT appearances of acute haemorrhage; advantages and limitations of the techniques
- Small bowel infarction on CT
- Angiographic study of the mesenteric vessels and occlusion, stenosis and aneurysms of the superior mesenteric artery

Liver

Knowledge base should include:

- In detail, liver anatomy and segmentation and vessel anatomy (hepatic artery, portal vein, hepatic veins, inferior vena cava), including variants in arterial distribution and in portal vein anatomy that may affect surgical planning
- Most common surgical procedures for hepatectomy and liver transplantation
- Appearance of vascular diseases of the liver (such as Budd–Chiari Syndrome, Osler–Weber disease, portal thrombosis, veno-occlusive disease)
- Appearance of a typical biliary cyst on ultrasound, CT and MRI
- Appearance of hydatid cysts
- Differences between amoebic abscess and pyogenic abscess of the liver (appearance, evolution, treatment, indication for drainage)
- Appearance of liver haemangioma on ultrasound (including ultrasound contrast agents), CT and MRI including typical and atypical cases (i.e. giant and "flash-filling" haemangioma)
- Usual appearance of focal nodular hyperplasia and liver cell adenoma on ultrasound, including Doppler ultrasound, and ultrasound contrast agents, CT and MRI
- Appearance of fatty liver, homogeneous and heterogeneous, on ultrasound, CT and MRI (including imaging quantification)
- Natural history of hepatocellular carcinoma (HCC), the major techniques and indications for treatment (surgical resection, transplantation, chemotherapy, chemo- or radioembolisation, percutaneous ablation, liver transplantation)
- Appearance of HCC on ultrasound (including Doppler), CT and MRI; staging of the lesion in order to discuss indications for treatment
- Usual appearance of liver metastases on ultrasound (including Doppler and ultrasound contrast agents), CT and MRI, including MRI with hepato-specific contrast agents, and the sensitivity and specificity of each
- Imaging findings in intrahepatic cholangiocarcinoma, including staging and consequences on treatment possibilities (surgery, palliation)
- Most common morphological changes associated with liver cirrhosis: lobar atrophy or hypertrophy, regeneration nodules, fibrosis; the main causes of liver cirrhosis; principles and methods for fibrosis quantification using ultrasound and MRI
- Rare tumours of the liver and their radiological appearance
- Appearance and quantification of liver iron overload
- Technique for percutaneous-guided liver biopsy and its most common indications; also the complications with a precise evaluation of the occurrence of morbidity and mortality
- Role of liver-specific contrast media

Biliary tract

- Sensitivity and specificity of imaging methods for the detection of gall bladder and common bile duct stones
- Common appearance of acute cholecystitis on ultrasound (including Doppler), CT and MRI; unusual features like gangrenous, emphysematous and acalculous cholecystitis
- Main causes of gallbladder wall thickening on ultrasound

- Appearance of gallbladder cancer on ultrasound, CT and MRI; staging of the tumours and differentiating cancer from chronic cholecystitis on ultrasound and CT
- Appearance of cholangiocarcinoma of the liver hilum (Klatskin's tumour) and performing tumour staging, with regard to treatment options (resectability, indication for palliation)
- Appearance of an ampullary carcinoma on ultrasound, CT and MRI, including magnetic resonance cholangiopancreatography (MRCP) and endoscopic ultrasound
- Common appearance of sclerosing cholangitis on ultrasound, CT and MRI, including MRCP; know the natural history and possibility of associated cholangiocarcinoma and indications for treatment; indications for biliary tract opacification
- Main techniques for surgery of the bile duct and its common complications; biliary leaks on specific contrast-enhanced MRI examinations

Pancreas

- Natural history of chronic pancreatitis; the common causes
- Pancreatic calcifications on plain films, ultrasound and CT
- Anatomical variants of the pancreatic duct (i.e. pancreas divisum) and the imaging methods used to diagnose it
- Indications and rationale for functional examinations of the pancreas (e.g. MRCP following secretin stimulation)
- Clinico-biological (Ranson score, APACHE II) and CT (Balthazar's CT severity score) methods for the grading of acute pancreatitis
- Common appearance of extra-pancreatic fluid collections and phlegmons in the case of acute pancreatitis
- Most common appearance (nodular, infiltrating) on ultrasound, CT, MRI and endoscopic ultrasound of pancreatic adenocarcinoma, and performing tumour staging
- Usual appearance of cystic tumours of the pancreas, mainly serous and mucinous cystadenoma, intraductal mucinous tumours and rare cystic tumours; the initial indication for tumour characterisation
- Main techniques for pancreatic surgery and their usual complications

Spleen

- Optimal imaging examination for the spleen according to the indication (e.g. trauma, staging of lymphoproliferative disorders, investigation of a focal lesion etc.)
- Causes and appearances of focal splenic abnormalities, including infection and both benign and malignant masses
- Causes of splenic calcification
- Causes of splenic enlargement

Molecular imaging

- See section on molecular imaging and understand the main applications for abdominal diseases including quantification of chronic processes (fibrosis, fat,

iron) and evaluation of the response to treatment (tumours, inflammatory diseases), liver cirrhosis

Core skills

Imaging techniques – general requirements

- Evaluating the quality of the imaging examinations in abdominal imaging

Imaging techniques – specific requirements

Plain abdominal radiograph

- Diagnosing pneumoperitoneum, mechanical obstruction and pseudo-obstruction, toxic dilatation of the colon, gas in the small and large bowel wall indicating ischaemia and necrosis, pancreatic and biliary calcifications and aerobilia on plain abdominal films

Contrast studies of the upper gastrointestinal tract

- Performing a contrast study of the upper gastrointestinal tract and determining the most appropriate contrast material
- Performing both single and double contrast studies as well as motility assessments; understanding the principles and limitations of these studies and their advantages and disadvantages compared with endoscopy
- Performing small bowel follow-through and enteroclysis, including catheter placement beyond the ligament of Treitz; appreciating the importance and degree of filling and distension of small bowel loops
- Interpreting a small bowel series; recognising the various segments of the small bowel and normal findings

Radiological examination of the lower gastrointestinal tract

- Performing a double contrast barium enema, a motility assessment barium study and a single contrast enema
- Catheterising a stoma for colon opacification and performing pouchograms and loopograms
- Interpreting an enema; recognising the anatomical components of the rectum and colon and normal findings

Ultrasound

- Performing an ultrasound examination of the liver, gall bladder, biliary tree, pancreas and spleen
- Performing a duplex Doppler study of the abdominal vessels; recognising the normal findings of the duplex Doppler study of the hepatic artery, superior mesenteric artery, portal vein and hepatic veins
- Performing an ultrasound study of the gastrointestinal tract and identifying the various portions (stomach, duodenum, small bowel, appendix and colon)

- Performing an ultrasound examination of the abdomen in patients with suspected inflammatory bowel disease

Computed tomography

- Performing and protocolling a CT examination of the abdomen and tailoring the protocol to the specific organ or clinical situation to be studied; determining the optimal protocol for the injection of contrast material (rate of injection, dose, delay); knowing the various phases (plain, arterial-dominant, portal-dominant, late phase) and their respective values according to the clinical problem
- Performing and interpreting CT colonography
- Experiencing the use of workstations for MPR and 3D reconstruction based around volume datasets
- Staging abdominal tumours on CT
- Performing a CT examination of the small bowel, with or without enteroclysis

Magnetic resonance imaging

- Performing and reporting of an MRI examination of the liver, the biliary tract and the pancreas; tailoring the protocol to the specific organ to be studied; determining if intravenous administration of a contrast material is needed; determining the optimal protocol for the injection (rate of injection, dose, delay); knowing the various phases (plain, arterial-dominant, portal-dominant, late phase) and their respective values according to the clinical problem
- Performing and reporting of an MRI examination for abdominal masses
- Performing and interpreting MRI enterography/enteroclysis
- Performing MRI of the rectum, anal canal and pelvic floor

Abdominal intervention

- Performing liver biopsy under ultrasound or CT guidance
- Performing biopsy of abdominal tumours with an easy access route under ultrasound or CT guidance
- Draining abdominal abscesses with an easy access route under ultrasound or CT guidance
- Performing percutaneous cholecystostomy
- Technique of interventional radiology in colon cancer, especially of colonic stent placement in the case of colonic obstruction; indications and contraindications for this technique
- Technique of percutaneous gastrostomy under image guidance
- Techniques of percutaneous biliary intervention
- Technique of radiologically guided stenting of the biliary system and gastrointestinal system, using polytetrafluoroethylene and expandable metal stents
- Main indications, contraindications and basic technique for ablation of liver tumours using ultrasound and/or CT guidance
- Technique of trans-jugular liver biopsy
- Basic principles of balloon angioplasty and stenting of the superior mesenteric artery for the treatment of stenosis and aneurysms of the superior mesenteric artery
- Technique, principle and results of transarterial chemoembolisation

- Rationale and technique for radio-embolisation
- Detecting a pancreatic pseudocyst and discussing the advantages and limitations of different treatments (follow-up, interventional procedure, percutaneous or endoscopic surgery) according to practical cases
- Performing a reconstruction of abdominal vessels with CT post-processing and the optimised protocol for CT angiography

Head and Neck Radiology (including Maxillofacial and Basic Dental Radiology)

Introduction

The head and neck imaging curriculum describes the following:

- The knowledge-based objectives for general head and neck radiology and maxillofacial and dental radiology
- The appropriate technical and communication skills

Core knowledge

Normal anatomy

- Temporal bone
- Facial skeleton, skull base and cranial nerves
- Orbit and visual pathways
- Sinuses
- Pharynx
- Oral cavity
- Larynx
- Neck
- Mandible, teeth and temporomandibular joints
- Salivary glands
- Deep spaces of the face and neck
- Thoracic inlet and brachial plexus
- Thyroid gland and parathyroid glands

Pathological features

Temporal bone

- Pathological conditions defining deafness
- On CT and MRI:
    - Temporal bone inflammatory disease
    - Temporal bone fractures
    - Tumours of the temporal bone and cerebellopontine angle
- Vascular tinnitus

The facial skeleton, skull base and cranial nerves

- On CT and MRI:
    - Inflammatory conditions
    - Tumours and tumour-like conditions
    - Trauma and resulting complications
    - Major pathological conditions involving the cranial nerves

Orbit and visual pathways

- Orbital pathological conditions
- Pathological features of the visual apparatus

Sinuses

- Anatomical variations and congenital anomalies of the paranasal sinuses on CT
- Inflammatory conditions, tumours and tumour-like conditions on CT and MRI
- Common techniques (functional endoscopic sinus surgery)
- Paranasal sinuses after surgery

Pharynx

- Pathological conditions of the nasopharynx, oropharynx and hypopharynx on ultrasound, CT and MRI

Oral cavity

- Pathological conditions of the oral cavity on ultrasound, CT, MRI and videofluoroscopy

Larynx

- Pathological conditions of the larynx on CT and MRI

Neck

- On ultrasound, CT and MRI:
    - Embryology and congenital cystic lesions
    - The clinical significance of lymph nodes, metastatic, inflammatory and infectious disease
    - Non-nodal masses of the neck
- Vascular diseases on ultrasound, CT, CT angiography, MRI, MRI angiography and conventional angiography

Mandible, teeth and temporomandibular joints

- Pathological conditions of the mandible on orthopantomography (OPM), CT, MRI and dental radiographs
- Dental implants and dental CT programmes
- Pathological conditions of the temporomandibular joint
- Orthopantomography

Salivary glands

- Inflammatory disorders and tumours on ultrasound, CT, MRI and MR sialography
- Vascular malformations on ultrasound, Doppler ultrasound, CT and MRI
- Periglandular lesions on ultrasound, CT, MRI

Deep spaces of the face and neck

- Anatomy of the deep cervical fascia and the most common pathological conditions involving the different spaces of the supra- and infrahyoid neck

Thoracic inlet and the brachial plexus

- On CT and MRI the most common pathological conditions of the thoracic inlet and brachial plexus

Thyroid gland and the parathyroid glands

- On ultrasound, Doppler ultrasound, CT and MRI:
    - Congenital lesions
    - Inflammatory lesions
    - Benign thyroid masses
    - Malignancies of the thyroid gland
    - Pathological conditions of the parathyroid glands
- The most important findings of Tc-99m-scintigraphy in specific diseases of the thyroid gland

Molecular imaging

Principles of molecular imaging as applied to head and neck radiology include its role in:

- Head and neck tumours
- Gene therapies for tumours

Core skills

At the end of the fourth year the resident should be able to carry out or supervise the following techniques to a level appropriate to practice in a general hospital. This competence should include the ability to evaluate and justify referrals for the purpose of protection of the patient:

- Radiography of the skull, sinus, skull base, and facial bones including special views
- Imaging of swallowing, including dynamic functional studies
- Ultrasound of the neck, tongue, thyroid and salivary glands
- Percutaneous biopsy, guided by ultrasound, CT and/or MRI in straightforward/technically easy cases
- Fine needle aspiration biopsy in easy cases
- Doppler ultrasound
- CT of the face, skull base and neck
- MRI of the face and neck
- Angiography, including digital subtraction or CT angiography
- Dental radiology, including the use of CT
- Lymph node aspiration biopsies

At the end of his/her training the resident should be able to recommend the appropriate use of imaging studies of head and neck disease to the referring clinician

Interventional Radiology

Introduction

Diagnostic radiology involves interventional techniques and minimally invasive therapy involving image-guided systems. The ESR supports the development of interventional radiology as a subspecialty within diagnostic radiology, and requires background training in the specialty of diagnostic radiology as a foundation. This is in agreement with the recent adoption of interventional radiology as a subspecialty of general radiology within the European Union of Medical Specialists radiology section.

It is expected that, by years 4 and 5 of training, the trainee will have a thorough knowledge of the performance and interpretation of diagnostic vascular techniques and a basic understanding of common interventional procedures, including:

- Indications and contraindications for the common interventional radiology procedures
- Non-invasive imaging studies to determine that the requested procedure is appropriate
- Appropriateness of patient selection for a requested interventional procedure through a review of available history, imaging, laboratory values, and proposed or expected outcomes of the procedure
- Agents used for conscious sedation and analgesia during interventional procedures; risk factors that may indicate potential risks of conscious sedation
- Radiation safety in the interventional radiology suite
- Methods used to reduce accidental exposure to blood and body fluids in the interventional radiology suite

Core knowledge

Non-invasive vascular imaging

Doppler ultrasound

The trainee should demonstrate a thorough understanding and be able to perform and interpret the following:

- Duplex ultrasound, including both arterial and venous examinations
- Normal and abnormal Doppler waveforms
- Common Doppler examinations, such as carotid Doppler, hepatic and renal Doppler studies and lower extremity venous duplex examinations
- Diagnosis of atherosclerotic disease, vasculitis, aneurismal disease, thrombosis, embolism and other vascular pathological conditions

CT angiography

The trainee should have a thorough understanding of:

- Basic physics of helical and multidetector CT
- CTA protocols, including contrast materials used and reconstruction techniques

- Radiation doses for CTA and methods of reducing these
- Advantages and disadvantages of CTA versus other techniques
- Diagnosis of atherosclerotic disease, vasculitis, aneurismal disease, thrombosis, embolism and other vascular pathological conditions

MR angiography

The trainee should be familiar with:

- MR physics and MR angiography (MRA) techniques
- Advantages and disadvantages of different contrast materials used for MRA
- Differences between time-of-flight, phase contrast, and contrast-enhanced techniques pertaining to MRA
- Advantages and disadvantages of MRA compared with other techniques
- Nephrogenic systemic fibrosis
- Diagnosis of atherosclerotic disease, vasculitis, aneurismal disease, thrombosis, embolism and other vascular pathological conditions

Diagnostic angiography/venography

In general, the trainee should be familiar with:

- The basic chemistry of the different iodinated contrast materials used, and the advantages/disadvantages of each for angiography
- Mechanisms to minimise nephrotoxicity in at-risk patients, such as patients with diabetes or renal impairment
- Treatment of both minor and major allergic reactions to iodinated contrast materials

Arterial and venous puncture technique

The trainee should have a thorough knowledge of:

- Standard groin anatomy, including the position of the inguinal ligament and the femoral nerve, artery and vein
- Seldinger technique of arterial and venous puncture
- Mechanisms for guidewire, sheath and catheter insertions into the groin
- Mechanisms of puncture site haemostasis, including manual compression and common closure devices
- Alternative sites of arterial puncture, such as brachial, axillary and translumbar

The trainee should have knowledge of:

- Guidewires, sheaths and catheters used for common diagnostic angiographic procedures
- Digital subtraction angiography techniques, bolus chase techniques, road mapping and pixel shift techniques
- Standard arterial and venous anatomy and variations in anatomy throughout the body
- Peripheral vascular angiography

- Mesenteric, coeliac and renal angiography
- Abdominal aortography
- Thoracic aortography
- Carotid, vertebral and subclavian angiography
- Venous venography
- Diagnosis of atherosclerotic disease, vasculitis, aneurismal disease, thrombosis, embolism and other vascular pathological conditions
- Complication rates for common diagnostic procedures
- Post-procedural care regimens for standard diagnostic vascular procedures
- Corticosteroid prophylaxis
- Treatment of both minor and major allergic reactions to iodinated contrast materials

Diagnostic angiography

The trainee should be familiar with:

- Guidewires, sheaths and catheters used for common diagnostic angiographic procedures
- Digital subtraction angiography techniques, bolus chase techniques, road mapping and pixel shift techniques
- Standard arterial and venous anatomy and variations in anatomy throughout the body
- Peripheral vascular angiography
- Mesenteric and renal angiography
- Abdominal aortography
- Thoracic aortography
- Carotid, vertebral and subclavian angiography
- Diagnosis of atherosclerotic disease, vasculitis, aneurismal disease, thrombosis, embolism and other vascular pathological conditions
- Complication rates for common diagnostic procedures
- Post-procedural care regimens for standard diagnostic vascular procedures

Vascular intervention

The trainee should be familiar with common vascular interventional procedures, such as:

Angioplasty

- Medical risk factors for atherosclerotic diseases
- Clinical symptoms of peripheral arterial disease
- Indications for endovascular treatment
- Consent procedures
- Pre-procedure coagulation tests and correction of abnormalities
- Angioplasty balloon dynamics, mechanism of action of angioplasty
- Indications for angioplasty
- Complications and results in different anatomical areas
- Drugs used during angioplasty
- Intra-arterial pressure studies
- Common angioplasty procedures, such as renal, iliac and femoral angioplasties

- Groin closure techniques and post-procedural care
- Groin complications and how to deal with them
- Post-procedural care and medical treatment

Arterial stenting

- Basic mechanisms for stent deployment and materials used for stent construction
- Indications for stent placement versus angioplasty
- Complications and results
- Post-procedural care

Venous intervention

Venous access

The trainee should be familiar with the various forms of venous access including:

- Peripherally inserted central catheter (PICC) lines, Hickman catheters, dialysis catheters and ports
- Indications for use of the above venous access catheters
- Technique of access to jugular and subclavian veins
- Haemodialysis shunt interventions
- Results and complications

Venoplasty and stenting

The trainee should be familiar with:

- Techniques of venoplasty and stenting
- Success rates and complications
- Post-procedural care

Caval interruption

The trainee should be familiar with:

- Indications for caval filter placement
- Different filter types available, including retrievable filters
- Success rates and complications
- Post-procedural care

Embolisation

The trainee should be familiar with:

- Indications such as acute bleeding, tumour therapy, AVM treatment
- Selective angiography
- Embolisation materials and their specific use
- Catheters and microcatheters
- Endpoints of embolisation

- Risks of embolisation and specific embolisation materials
- Treatment of post-embolic pain and post-embolic syndrome

Transjugular intrahepatic portosystemic shunt

- The trainee should be familiar with indications for transjugular intrahepatic portosystemic shunt (TIPS), the technique and complications

Non-vascular intervention

Trainees should have a thorough understanding of basic non-vascular interventional techniques, such as biopsy, abscess drainage, transhepatocholangiography and nephrostomy

Biopsy

The trainee should be familiar with:

- Consent procedures
- Pre-procedure coagulation tests and correction of abnormalities
- Differences in imaging techniques used for guiding biopsy, including CT and ultrasound
- Needles used for biopsy procedures, including fine gauge needles, large gauge needles and trucut biopsy
- Planning a safe access route to the lesion to be biopsied
- Complication rates associated with individual organ biopsy
- Indications for fine needle biopsy versus large gauge or core biopsy
- Post-procedural care for chest and abdominal biopsy
- Algorithms for treatment of common complications, such as pneumothorax and haemorrhage

Fluid aspiration and abscess drainage

The trainee should be familiar with:

- Commonly used chest tubes and abscess drainage catheters
- Indications for chest drainage, fluid aspiration and abscess drainage
- Imaging techniques used for guidance
- Interpretation of Gram stain results
- Methods of chest tube placement
- Underwater seal drainage systems
- Fibrinolytic agents used in patients with loculated or complex empyemas
- Planning a safe access route for abscess drainage
- Antibiotic regimens used before abscess drainage
- Trocar and Seldinger techniques for catheter placement
- Situations where more than one catheter is required
- Various approaches to pelvic abscess drainage
- Post-procedural care including catheter care, ward rounds and when to remove catheters

Hepatobiliary intervention

The trainees should have knowledge of basic hepatobiliary intervention, such as transhepatocholangiography and basic percutaneous biliary drainage (PBD).

The trainee should be familiar with:

- Biliary anatomy that may influence biliary drainage
- Pre-procedure work-up, including antibiotic regimens, coagulation screening and intravenous fluid replacement
- Integration of ultrasound, CT and MRCP to plan an appropriate drainage procedure
- Performance of transhepatocholangiography
- One-stick needle systems and needle and guidewire for biliary drainage
- Catheters used for biliary decompression
- Complications of biliary procedures
- Aftercare, including knowledge of complications, catheter care and ward rounds

Genitourinary intervention

The trainee should be familiar with:

- Renal and calyceal anatomy that may influence nephrostomy drainage
- Indications for percutaneous nephrostomy
- Integration of ultrasound, CT and urographic studies to plan an appropriate nephrostomy
- Pre-procedural work-up including coagulation screens and antibiotic regimens
- Ultrasound/fluoroscopic guidance mechanism for percutaneous nephrostomy
- Catheters used for percutaneous nephrostomy
- Placement of percutaneous nephrostomy tubes
- Complications of percutaneous nephrostomy
- Aftercare, including catheter care and removal

Core skills

The goals of basic training in interventional radiology are as follows:

- Demonstrating an understanding of the history or physical findings that would require pre-procedure assistance from other specialty disciplines, such as cardiology, anaesthesia, surgery or internal medicine
- Obtaining informed consent after discussion of the procedure with the patient, including a discussion of risks, benefits and alternative therapeutic options
- Being familiar with monitoring equipment used during interventional radiology procedures and recognising abnormalities and physical signs or symptoms that need immediate attention during the procedure
- Understanding and identifying risk factors from the patient's history, physical or laboratory examinations that indicate potential risk of bleeding, nephrotoxicity, cardiovascular problems, breathing abnormalities, or adverse drug interactions during or after the procedure

Molecular imaging

Principles of molecular imaging as applied to interventional radiology include its role in:

- Atherosclerosis
- Vascular thrombosis
- Tumour growth and regression
- Monitoring of therapies
- Intravascular gene therapy
- Gene therapies for tumours

Molecular Imaging

Introduction

Trainees who would like to orient towards research in molecular imaging in academic centres should develop a deeper understanding and knowledge of the principles, techniques and methods required for development of this research field, as well as main applications with a translational perspective, during a two-year programme. These candidates would spend 50% of the time in molecular imaging and 50% of the time in conventional clinical subspecialties of radiology.

The first year will serve as a central core for all possible applications in the different organs, and consist of deeper involvement into biological processes, specific probes development, specific imaging techniques devoted to animal models and methods of quantification of these processes. This first year should serve as the equivalent of a master's degree in molecular imaging.

The second year will be devoted to applications of these techniques in specific pathological domains, depending on the trainees' orientation and preferences. One or two domains could be covered. Each application should cover the different approaches of imaging the biological process, including different imaging techniques and for each technique, the different possible probes.

Core knowledge

Principles of advanced imaging techniques and contrast agents

- PET:
    - Radiolabelling with fluorine 18 or carbon 11
    - Micro-PET and micro-SPECT
    - Imaging protocols for pharmacokinetics studies in rodents
    - PET image analysis and data processing
- MRI:
    - Dynamic contrast-enhanced (DCE) MRI
    - Diffusion-weighted imaging (DWI)
    - Spectroscopy using ^{1}H, ^{31}P, ^{13}C
    - Targeted contrast agents
    - fMRI (BOLD)
- CT:
    - Principles of perfusion imaging with CT
    - Dual-source imaging
- Optical imaging:
    - Theory of light propagation, absorption, emission, fluorescence, bioluminescence, linear and non-linear phenomena
    - Spectroscopy
    - Microscopy:
        - Normal
        - Fluorescence
        - Confocal
        - In vivo microscopy
    - Bioluminescent imaging

- Ultrasound imaging with contrast agents:
    - Acoustic response of the contrast agent (resonance, harmonics, destruction)
    - Techniques of detection
    - Relationship between response and concentration
    - Limiting tissue-based non-linear wave propagation, probe concentration variations, attenuation bias
    - Quantification of the response
    - Kinetic modelling
    - Different types of targeted contrast agents
    - Bio-effects and safety
- Basics in chemistry and probe design:
    - Basic principles of probe design
    - Bio-conjugate chemistry
    - Nano-sized systems in chemistry
    - Basics of molecular recognition
    - Gadolinium complexes, chemical exchange saturation transfer (CEST) agents, lanthanide complexes, iron oxide particles, PET-SPECT labelling
    - Cell-labelling techniques
- Fundamentals of pharmacokinetics:
    - Routes of administration: intravascular bolus kinetics or constant rate input
    - Absorption
        - Concepts and kinetics
        - Factors influencing drug absorption
    - Biodistribution
        - Volume of distribution and transport systems
        - Multiple dose regimens
        - Mean residence time
        - Drug receptors
        - Drug metabolism
        - Drug-metabolising enzymes
        - Hepatic metabolism of drugs
        - Other sites of drug metabolism
        - Variability and pharmacogenomics
    - Excretion
        - Clearance (blood vs organ clearance)
        - Extraction fraction
        - Integration of concepts
        - Non-linear pharmacokinetics and multi-compartment kinetics
        - Pharmacokinetics–pharmacodynamics modelling (PK–PD)

Biology

- Basics of molecular biology:
    - DNA, RNA, protein
    - Transcription, translation, post-translational modifications, protein folding
- Targets:
    - Ways of signalisation in biology:
        - Cellular compartments and interactions
        - Protein–protein interaction
        - Nature of the biological membrane
    - Main molecular targets for imaging:
        - Extracellular/vascular targets:
            - Vascular
            - Extracellular space (pH, extracellular matrix)

        - Cellular targets
            - Receptors (neurotransmitters, trophic factors, others)
        - Transporters: metabolites (osides, nucleosides, amino acids), peptides, viruses
        - Enzymes (energetic metabolism, proteins, ways of synthesis, ways of reproduction)
        - Ionic channels
    - Limitation to probe delivery:
        - Sequestration
        - Degradation
        - Barriers
- Vectorisation:
    - Physicochemical bases of passage and diffusion
    - Formulation:
        - Lipophilicity
        - Ligands
        - Transfectants
    - Small molecules targeting transporters:
        - Peptides
        - Proteins
        - Viral envelopes
    - Viral vectors
    - Complex constructions (nanoparticles)
- Genetic engineering:
    - Gene transfer
    - Recall in genetics (sexual reproduction, gene structure, regulation of gene expression)
    - Transfection and homologous recombination
    - Reporter genes:
        - Beta-galactosidase
        - Luciferase
        - GFP
        - TK
    - Expression control:
        - Promoters
        - Transcription factors
        - Conditional expression
    - Limits, leakage, lack of expression
    - Virus:
        - Adenoviruses
        - Retroviruses
    - Antisense, siRNA and other regulators (miRNA) of gene expression
    - Turnover, stabilisation, degradation of mRNA
    - Strategies/gene therapy:
        - Gene replacement
        - Symptomatic
        - Gene repair
        - Silencing

Signal processing

- Basics in signal processing
- Linear systems:
    - Convolution

    - Fourier transform
    - Nyquist
    - Image restoration
    - Deconvolution
- Image display
- Image quality:
    - Noise
    - Contrast
    - Resolution
    - Noise amplification during processing
- Quantification:
    - ROI
    - Time–activity curves
    - Factorial analysis
- Image processing:
    - Edge
    - Detectors
    - Smoothing
    - Segmentation
    - Image reconstruction
    - Image fusion
    - Registration
    - Display
- Basics in Matlab

Laboratory animal science

- European legislation regarding laboratory animals
- Animal handling and use in biomedical research:
    - Legislation
    - Ethics
    - Husbandry
    - Hygiene
    - Health management
- Transgenesis and species-specific behaviour
- Anaesthesia, analgesia and euthanasia
- Overview of current animal models, their use, their relevance and possible alternatives

Core skills

Principles of advanced imaging techniques and contrast agents

- MRI:
    - Hyperpolarised techniques
    - Chemical exchange saturation transfer (CEST)
- CT with targeted contrast agents
- Optical imaging:
    - Spectroscopy
    - Fluorescence activated cell sorting (FACS)
    - Optical tomography
    - Modern biophotonics imaging
- Ultrasound imaging with contrast agents:
    - Targeted therapy with ultrasound agents
    - Ultrasound vehicles

- Basics in chemistry and probe design:
    - Synthesis and functionalisation of imaging probes
    - Peptide synthesis and conjugation to probes

Industrial context

- Molecular imaging – medical needs
- Industrial perspectives
- Patenting
- Bioethics
- Barriers to clinical translation

Main experimental models

These items should be modulated according to the field of interest of the trainees (cardiovascular, neurological etc.). Oncological imaging will cover many of the areas listed below and can be considered a separate topic.

- Cardiovascular:
    - Development of atherosclerosis
    - Aneurysms
    - Myocardial ischaemia
    - Experimental thrombosis
    - Experimental myocarditis
- Neurology:
    - Development of tumour models
    - Cerebral ischaemia
    - Experimental degenerative diseases
    - Experimental encephalitis
- Chest:
    - Development of tumour models
    - Emphysema
    - Fibrosis
- Urogenital:
    - Development of urogenital tumour models (kidney, prostate)
    - Acute and chronic experimental nephropathies
    - Urinary obstruction
    - Kidney transplantation
- Digestive:
    - Development of digestive tumour models (liver, pancreas, colon)
    - Acute and chronic experimental hepatopathies
    - Biliary obstruction
    - Liver and pancreatic transplantation
- Skeletal:
    - Development of bone tumour models (primary and secondary)
    - Experimental inflammatory and infectious arthropathies
    - Experimental degenerative arthropathies

Molecular imaging of main biological processes

Each item includes: development of the biological process, description of the different targets, description of the different specific probes used, according to each imaging technique, and illustration by examples of application.

- Inflammatory process:
    - Platelet activation
    - Endothelial dysfunction
    - Integrin expression
    - Macrophage and leukocyte trafficking (adhesion and invasion; cell labelling and antibody-based)
    - Oxidised lipoprotein uptake into macrophages
- Immune response:
    - T-cell trafficking (cell labelling and antibody-based)
    - Dendritic cell trafficking
- Extracellular matrix changes:
    - MMP activity
    - Cathepsin activity
    - MPO activity
    - Metabolism activity of ECM (PET probes)
- Hypoxia
- Cell stress and cell death:
    - Apoptosis
    - Necrosis
- Thrombotic process:
    - Thrombus formation (fibrin)
    - Thrombus stabilisation
    - Activated coagulation factors (XIII)
- Vascular remodelling and angiogenesis:
    - Vascular smooth muscle cells proliferation
    - Neo-vessel proliferation
- Tissue repair:
    - Fibrosis and scarring
- Organ function:
    - Neurotransmitters
- Cell-based therapies:
    - Labelled cell- or reporter gene-based approaches
    - Stem cell migration
    - Stem cell differentiation
- Monitoring gene therapies:
    - Gene expression (enzyme- or receptor-based strategies)

Applications in the different organ systems

These items should be modulated according to the field of interest of the trainees (cardiovascular, neurological etc.)

- Cardiovascular system:
    - Atherosclerosis
    - Vascular thrombosis
    - Myocardial ischaemia

    - Myocardial viability
    - Heart failure
    - Heart graft rejection
    - Stem cell therapies into the myocardium and the vessels
    - Cardiac gene therapy
    - Intravascular gene therapy
- Neurological system:
    - Degenerative diseases
    - White matter inflammatory diseases
    - Psychiatric diseases
    - Brain ischaemia
    - Brain tumours
    - Stem cell therapies into the brain
    - Gene therapy into the brain
- Musculoskeletal system:
    - Rheumatoid arthritis
    - Osteoarthritis
    - Pain and related inflammation
    - Musculoskeletal tumours
    - Stem cell therapies of cartilage
    - Gene therapy into the musculoskeletal system
- In the body:
    - Cirrhotic liver
    - Nephropathies
    - Lung inflammatory diseases
    - Renal and liver fibrosis
    - Renal, liver and lung transplants
    - Pancreatic cell transplants
    - Body tumours
    - Body lymphomas
- Oncology:
    - Tumour phenotypes
    - Tumour angiogenesis
    - Tumour metabolism
    - Tumour hypoxia
    - Monitoring of therapies
    - Gene therapy for tumours

Genes and drug delivery

- Vehicles: cells, liposomes, nanovehicles, microbubbles, polymers
- Content: drugs, peptides, DNA, siRNA
- Administration routes: intravenous, intra-arterial, intraperitoneal, intramuscular, inhaled
- Overcoming biological barriers:
    - Cell membrane (electroporation, sonoporation)
    - Blood–brain barrier
- Monitoring of drug release:
    - Light
    - Heat

    - Ultrasound
- Safety and toxicity

Musculoskeletal Radiology

Introduction

Musculoskeletal imaging involves all aspects of medical imaging that provide information about the anatomy, function, disease states and those aspects of interventional radiology or minimally invasive therapy pertaining to the musculoskeletal system. This will include imaging in orthopaedics, trauma, rheumatology, metabolic and endocrine disease, as well as aspects of paediatrics, emergency radiology and, to a lesser extent, oncological imaging. Imaging of the spine is included within both the musculoskeletal and the neuroradiological fields.

Core knowledge

- Basic clinical knowledge, i.e. medical, surgical and pathological conditions as well as pathophysiology related to the musculoskeletal system
- Current good clinical practice
- Indications, contraindications and potential hazards (especially radiation hazards) of procedures and techniques relevant to musculoskeletal disease and trauma
- Management of procedural complications
- Musculoskeletal anatomy in clinical practice relevant to clinical radiology
- Normal skeletal variants that may mimic disease
- Manifestations of musculoskeletal disease and trauma (see list below), as demonstrated by conventional radiography, CT, MRI, arthrography, radionuclide investigations and ultrasound
- Differential diagnosis relevant to clinical presentation and imaging appearance of musculoskeletal disease and trauma, as listed below

The following manifestations of musculoskeletal disease and trauma must be covered during the general radiological training. This should include formal teaching and exposure to clinical case material.

Trauma (acute and chronic)

Fractures and dislocations

- Types and general classifications
- Features in the adult skeleton
- Features in the immature skeleton* (including normal development)
- Articular (chondral and osteochondral, including osteochondritis dissecans)
- Healing and complications:
    - Delayed union/non-union
    - Avascular necrosis
    - Reflex sympathetic dystrophy
    - Myositis ossificans
- Stress (fatigue and insufficiency)
- Avulsion
- Pathological, and non accidental injury*

Specific bony/joint injuries

- Skull and facial bone fractures
- Spinal fractures (including spondylolysis)
- Shoulder girdle:
    - Sternoclavicular and acromioclavicular dislocations
    - Clavicular fractures
    - Scapular fractures
    - Shoulder dislocation/instability
- Upper limb:
    - Humeral fractures
    - Elbow fractures/dislocations
    - Proximal and distal forearm fractures/dislocations
    - Wrist joint fractures/dislocations
    - Hand fractures/dislocations
- Pelvic fractures/dislocations (including associated soft tissue injuries)
- Lower limb:
    - Hip fractures/dislocations
    - Femoral fractures
    - Tibial and fibular fractures (including the ankle joint)
    - Hindfoot fractures
    - Tarso-metatarsal fractures/dislocations
    - Forefoot fractures/dislocations

Soft tissues

- Shoulder:
    - Rotator cuff
    - Glenoid labrum
    - Biceps tendon
- Wrist:
    - Triangular fibrocartilage complex
- Knee:
    - Menisci
    - Cruciate ligaments
    - Collateral ligaments
- Ankle:
    - Principal tendons and ligaments

Infections

- Acute, subacute and chronic osteomyelitis:
    - Spine
    - Appendicular skeleton
- Post-traumatic and postoperative osteomyelitis
- Tuberculosis
- Spine
- Appendicular skeleton
- Rarer infections (e.g. leprosy, brucellosis – main manifestations only)
- Commoner parasites worldwide (e.g. echinococcus)
- Soft tissue infections

- HIV-associated infections

Tumours and tumour-like lesions

Bone

- Principles of tumour characterisation and staging, and bone-forming:
    - Osteoma and bone islands
    - Osteoid osteoma and osteoblastoma
    - Osteosarcoma (conventional and commoner variants)
- Cartilage-forming:
    - Osteochondroma
    - Enchondroma
    - Chondroblastoma
    - Chondromyxoid fibroma
    - Chondrosarcoma (central and peripheral)
- Fibrous origin:
    - Fibrous cortical defect/non-ossifying fibroma
    - Fibrous dysplasia
    - Fibrosarcoma/malignant fibrous histiocytoma
- Haematopoietic and reticuloendothelial:
    - Giant cell tumour
    - Langerhans cell histiocytosis
    - Malignant round cell (Ewing 's sarcoma, lymphoma and leukaemia)
    - Myeloma and plasmacytoma
- Tumour-like:
    - Simple bone cyst
    - Aneurysmal bone cyst
- Metastases
- Recognition of "don't touch" lesions
- Others:
    - Chordoma
    - Adamantinoma

Soft tissue

- Fat origin:
    - Lipoma
    - Liposarcoma
- Neural origin:
    - Neurofibroma
    - Schwannoma
- Vascular origin:
    - Haemangioma
- Soft tissue sarcomas

Haematological disorders

- Haemoglobinopathies:
    - Sickle cell disease

    - Thalassaemia
- Myelofibrosis

Metabolic, endocrine and toxic disorders

- Rickets* and osteomalacia
- Primary and secondary hyperparathyroidism (including chronic renal failure)
- Osteoporosis (including basic concepts of bone mineral density measurements), and fluorosis

Joints

- Degenerative joint disease:
    - Spine (including intervertebral disc and facet joints)
    - Peripheral joints
- Inflammatory joint disease:
    - Rheumatoid arthritis
    - Juvenile rheumatoid arthritis*
    - Ankylosing spondylitis
    - Psoriatic arthritis
    - Enteropathic arthropathies
    - Infective (pyogenic and tuberculous)
- Crystal arthropathies:
    - Pyrophosphate arthropathy
    - Hydroxyapatite deposition disease
    - Gout
- Masses:
    - Ganglion
    - Synovial chondromatosis
    - Pigmented villonodular synovitis
- Neuroarthropathy:
    - Diabetic foot
    - Charcot's joints
    - Pseudo-Charcot (steroid-induced)
- Complications of prosthetic joint replacement (hip and knee)

*Congenital, developmental and paediatric**

- Spine:
    - Scoliosis (congenital and idiopathic)
    - Dysraphism
- Shoulder:
    - Sprengel's deformity
- Hand and wrist:
    - Madelung's deformity (idiopathic and other causes)
- Hip:
    - Developmental dysplasia
    - Irritable hip
    - Perthes disease
    - Slipped upper femoral epiphysis

- Femoroacetabular impingement
- Ankle and foot
- Congenital disorders
- Tarsal coalition
- Bone dysplasias
- Multiple epiphyseal dysplasia
- Achondroplasia
- Osteogenesis imperfecta
- Sclerosing (osteopetrosis, melorheostosis and osteopoikilosis)
- Tumour-like (diaphyseal aclasis and Ollier's disease)
- Neurofibromatosis

Miscellaneous

- Paget's disease
- Sarcoidosis
- Hypertrophic osteoarthropathy
- Transient or regional migratory osteoporosis
- Osteonecrosis
- Characterisation of soft tissue calcification/ossification

*These topics may or may not be covered in the paediatric component of the radiologist's training. It is the responsibility of the director of each training scheme to ensure that the topics are adequately covered in either the paediatric or the musculoskeletal component.

Core skills

- Supervising and reporting of plain radiographic examinations, CT, MRI and ultrasound relevant to the diagnosis of disorders of the musculoskeletal system, including musculoskeletal trauma (to include provision of on-call service)
- Communicating with patients and taking history relevant to the clinical problem
- Using all available data (clinical, laboratory, imaging) to find a concise diagnosis or differential diagnosis

Optional experience:

- Reporting radionuclide investigations of the musculoskeletal system, particularly skeletal scintigrams
- Being aware of the role and, where practicable, the observation of discography, facet joint injections and vertebroplasty
- Observing image-guided bone biopsy and drainage of the musculoskeletal system
- Interpreting bone densitometry examinations
- Performing under supervision of all of the above

Molecular imaging

Principles of molecular imaging as applied to musculoskeletal imaging include its role in:

- Rheumatoid arthritis

- Osteoarthritis
- Pain and related inflammation
- Musculoskeletal tumours
- Stem cell therapies of cartilage
- Gene therapy in the musculoskeletal system

Neuroradiology

Introduction

The aim of this core training is for the trainees to familiarise themselves and gain core competence in the basics of neuroradiology including interventional neuroradiology as well as to develop enough understanding of neuroradiology so as to be able to recognise that there is an abnormality and to know where and when to seek help. It should be undertaken in an established neuroradiology department. Arrangements should be made within the training scheme for secondment to neurology and neurosurgery departments. Exposure to all imaging and interventional techniques used in neuroradiology should be achieved.

Core knowledge

Normal anatomy

- Normal results on X-ray, ultrasound, CT and MRI
- Neuroanatomy and clinical practice relevant to neuroradiology – the skull, skull base, brain, spine, spinal cord and nerve routes
- Manifestations of CNS disease as demonstrated on conventional radiography, CT, MRI and angiography
- Following structures on plain X-rays:
    - Skull
    - Skull base
    - Skull–cervical junction
    - Vertebral bodies
    - Vertebral canal
    - Intervertebral joints
    - Sacro-iliac joints
- Following structures on CT:
    - Brain CT – grey matter, basal ganglia, ventricular system, cisterns, white matter
    - Spine CT – vertebral bodies, joints, vertebral canal, intervertebral discs, dural sac, spinal cord
- Following structures on MRI:
    - Brain MRI – grey matter, basal ganglia, ventricular system, cisterns, white matter
    - Spine MRI: vertebral bodies, joints, vertebral canal, intervertebral discs, dural sac, spinal cord, spinal grey and white matter
- Following structures on angiography:
    - Aortic arch, carotid and vertebral arteries, intracranial arteries and the Willis polygon, spinal and spinal cord vascularisation

Pathological conditions

- Indications for a diagnostic neuroradiological examinations
- Applications, contraindications and complications of invasive neuroradiological procedures
- Application of:

    - CT and MR angiography in neuroradiology
    - Radionuclide investigations in neuroradiology (PET, SPECT)
- Trauma:
    - Skull and facial injury
    - Intracranial injury, including child abuse and the complications
    - Spine and spinal cord injury
- Developmental anomalies:
    - Anomalies of the skull and brain
    - Anomalies of the spine and spinal cord
    - Tumours of the brain, skull, skull base, orbit, spine and spinal cord
    - Vascular disease including congenital and acquired malformations
    - Degenerative and inflammatory diseases of the brain
    - Hydrocephalus

Core skills

- Basic experience of MRI and CT including CT angiography/venography, MR angiography/venography, CT perfusion, MR perfusion, MR spectroscopy, functional MRI, MR tractography and related advanced techniques
- Performing:
    - Cerebral angiograms and their reporting
    - Myelographic examinations and their reporting
    - Cranial Doppler ultrasound examinations and their reporting
- Participating at least as second operator in the following imaging-guided interventions:
    - Vascular interventional procedures and follow-ups
    - Spinal interventional procedures and follow-ups
- Reporting plain radiographs in the investigation of neurological disorders
- Supervising, reporting and documenting (in a log book) a minimum of 500 cranial and spinal CT and spinal MRI, 100 cranial and spinal angiographies, and 100 cranial and Doppler ultrasounds
- Supervising technical staff to ensure appropriate images are obtained
- Discussing significant or unexpected radiological findings with referring clinicians and knowing when to contact a clinician
- Describing indications
- Deciding when it is appropriate to obtain help from supervisory faculty in interpreting radiographs
- Understanding the clinical indications for obtaining chest radiographs and when further views or a chest CT or MRI might be necessary
- Developing skills in protocolling, and monitoring of imaging, appropriate to patient history and other clinical information
- Demonstrating the ability to effectively present neuroimaging in a conference setting
- Recommending the appropriate use of imaging studies to referring clinicians
- Correlating pathological and clinical data with imaging findings
- Optional experience includes PET and SPECT

Paediatric Radiology

Years 4 and 5 special interest training in paediatric radiology will involve at least 50% of the time allocated to a special paediatric unit. This unit should serve a comprehensive gamut of general paediatrics, medical and surgical conditions. It is anticipated that after this training a certain number of radiologists will go on to specialise fully in the subject through stages that will involve a full-time education in the subject within specialised paediatric units. These have previously been standalone, but are more and more frequently incorporated within a tertiary institution where certain services are shared with adult patient populations.

Core knowledge

- Principles guiding the construction of a child-friendly environment
- ALARA principle and dose consideration and their application in paediatric patients
- Imaging guideline algorithms specific to children
- Childhood developmental anatomy
- Medical and surgical diseases of childhood
- Embryology as applied to paediatric diseases
- Comprehensive knowledge of contrast media within the paediatric population including neonates

Core skills

- Ultrasound of the abdomen, hip, thorax and brain in neonates
- CT of the head, thorax, abdomen and skeleton
- MRI of the central nervous system, skeleton, thoraco-abdominal masses and uro-MRI
- Barium studies and voiding cystourethrography

Residents should be able to diagnose correctly:

- On ultrasound:
    - Abdomen:
        - Hypertrophic pyloric stenosis
        - Acute intestinal intussusception
        - Acute appendicitis
        - Intestinal obstruction and volvulus
        - Inguinal hernia
        - Abdominal and pelvic masses
        - Uretero-hydronephrosis
        - Urolithiasis
        - Nephrocalcinosis
        - Cystic diseases of the kidney
    - Hip:
        - Congenital hip dysplasia
        - Transient synovitis
    - Head:
        - Hydrocephalus

        - Subependymal and intraventricular haemorrhage
        - Periventricular leukomalacia
        - Tumour
    - Pleural:
        - Effusion
        - Chest consolidation
        - Normal thymus
- On conventional radiography:
    - Chest radiography:
        - Bronchiolitis
        - Pneumonia
        - Pleural effusion
        - Pneumothorax
        - Foreign body aspiration
        - Thymus and variants
        - Oesophageal atresia
    - Abdomen plain X-rays:
        - Intestinal obstruction
        - Urolithiasis
        - Necrotising enterocolitis
        - Pneumoperitoneum
    - Skeleton:
        - Fractures (accidental and non-accidental)
        - Bone dysplasia
        - Tumours
        - Osteomyelitis
        - Joint effusion
        - Legg–Calvé–Perthes disease
        - Slipped capital femoral epiphysis
    - Voiding cystourethrography:
        - Grade vesico-ureteral reflux
        - Urethral anomalies
    - Upper gastrointestinal tract:
        - Gastro-oesophageal reflux
        - Malrotation
    - Barium or equivalent:
        - Hirschprung's disease
        - Anal imperforation
- On CT:
    - Head CT:
        - Trauma
        - Intracranial hypertension
    - Chest CT:
        - Infiltrative diseases
        - Complications of pneumonia
        - Metastatic diseases
        - Mediastinal masses
    - Abdominal CT:
        - Lesions in blunt trauma
        - Complications of inflammatory bowel diseases

        - Complicated obstruction
        - Peritonitis
        - Metastatic diseases
    - Skeletal CT:
        - Complex trauma
        - Osteomyelitis
        - Bone tumours
- On MRI:
    - Central nervous system:
        - Main brain and spinal malformations
        - Infection
        - Haematoma
        - Brain ischaemia
        - Tumours
        - Pituitary disease
    - Abdomen:
        - Work-up of tumours
        - MR cholangiopancreatography
        - Urinary tract malformation
    - Osteoarticular:
        - Infiltrative bone marrow disorders
        - Osteomyelitis
        - Trauma
        - Bone tumours

Molecular imaging

Principles of molecular imaging as applied to paediatric radiology include its role in:

- Apoptosis in paediatric cancer
- Inflammation in Crohn's disease and ulcerative colitis
- Cell tracking in inflammation and monitoring of cellular therapies
- Graft versus host disease
- Angiogenesis

Urogenital Radiology

Core knowledge

Renal physiology and kinetics of contrast agents

- Physiology of renal excretion of contrast medium
- Enhancement curves within renal compartments after injection of contrast agents
- Concentrations and doses of contrast agents used intravenously
- The following aspects of contrast media (both iodinated and gadolinium-based ones):
    - Definition of contrast media nephrotoxicity
    - Risk factors of contrast media nephrotoxicity
    - How to identify patients at risk of contrast media nephrotoxicity
    - Measures to reduce the risk of contrast nephrotoxicity
    - Precautions in diabetics taking metformin and requiring intravascular administration of contrast media
- The following aspects of nephrogenic systemic fibrosis (NSF):
    - Definition of NSF and knowledge of its clinical features
    - Risk factors for NSF
    - How to identify patients at risk of NSF
    - Use of Gd-based contrast media in patients at risk

Normal anatomy and variants

Retroperitoneum

- Retroperitoneal spaces and pathways

Kidney

- Triple obliquity of the kidney
- Criteria of normality of the pyelocaliceal system on intravenous urography (IVU)
- Normal variants, such as junctional parenchymal defect, column of Bertin's hypertrophy, fetal lobulation, or lipomatosis of the sinus
- Main renal malformations, such as horseshoe kidney, duplications, ectopia, or fusions

Bladder and urethra

- Anatomy of the bladder wall and the physiology of micturition
- Segments of the male urethra and the location of the urethral glands

Prostate

- Zonal anatomy of the prostate
- Prostatic zones with ultrasound and MRI

Scrotum

- Ultrasound anatomy of intra-scrotal structures (testicular and extratesticular)
- Doppler anatomy of the testicular and extratesticular vasculature

Gynaecological

- Anatomy:
    - Main normal dimensions of the uterus and ovaries with ultrasound
    - Variations of the uterus and ovaries during genital life
    - Variations of the uterus and ovaries during the menstrual cycle
    - Normal pelvic compartments
    - Normal pelvic organs and boundaries on CT and MRI
    - Role of the levator ani in the physiology of the pelvic floor
    - Imaging techniques that can be used to visualise the pelvic floor
    - Factors responsible for urinary incontinence
- Pathological conditions:
    - Uterus
        - Congenital anomalies
        - Tumours (benign and malignant)
    - Myometrium
    - Endometrium
    - Cervix
        - Inflammation
        - Adenomyosis
        - Functional disorders
    - Ovaries
        - Cysts
        - Tumours
        - Functional disorders, e.g. precocious puberty, polycystic ovaries
        - Endometriosis
    - Tubes
        - Inflammatory disorders
        - Tumours
    - Pelvis
        - Prolapse
        - Infertility

Core skills

These include the ability to perform the following techniques:

- Ultrasound of the urinary tract:
    - Choosing the appropriate transducer according to the organ imaged
    - Optimising imaging parameters
    - Recognising the criteria for a good ultrasound image
    - Recognising and explaining the main artefacts visible in urinary organs
    - Obtaining a Doppler spectrum on intrarenal vessels (for resistive index measurement) and on the entire course of the proximal renal arteries for velocity calculation

    - Knowing the indications for the use of ultrasound contrast media in the study of kidneys, urinary tract and male genital organs, and performing such studies
- Intravenous urography:
    - Listing the main indications for intravenous urography
    - Knowing the main technical aspects:
        - Choice of the contrast agent
        - Doses
        - Film timing and sequences
        - Indications for ureteral compression
        - Indications for furosemide
- Cystourethrography:
    - Listing the main indications for cystourethrography
    - Knowing the main technical aspects:
        - Choice of technique: trans-urethral, transabdominal
        - Choice of the contrast agent
        - Film timing and sequences
        - Remembering the aseptic technique
- CT of the urinary tract:
    - Defining the normal level of density (in HU) of urinary organs and components
    - Knowing the protocol for:
        - A renal and an adrenal tumour
        - A urinary obstruction (including stones)
        - A bladder tumour
- MRI of the urinary tract:
    - Knowing the appearance of urinary organs on T1- and T2-weighted images
    - Knowing the protocol for:
        - A renal and adrenal tumour
        - A urinary obstruction
        - A bladder tumour
        - A prostatic tumour

Recognising the following pathological conditions:

- Kidney and ureter:
    - Congenital – covered under "*Normal anatomy and variants*" above
    - Obstruction
    - Calculus
    - Infection
    - Tumours
    - Cystic diseases
    - Medical nephropathies
    - Vascular
    - Renal transplantation
    - Trauma
- Bladder:
    - Congenital – covered under "*Normal anatomy and variants*" above
    - Obstruction

    - Inflammatory
    - Tumours
    - Trauma
    - Incontinence and functional disorders
    - Urinary diversion
- Urethra:
    - Congenital – covered under "*Normal anatomy and variants*" above
    - Strictures
    - Diverticula
    - Trauma
- Prostate and seminal vesicles:
    - Congenital – covered under "*Normal anatomy and variants*" above
- Benign prostatic hypertrophy
- Inflammatory
- Tumours
- Testis and scrotum:
    - Congenital – covered under "*Normal anatomy and variants*" above
    - Inflammatory
    - Torsion
    - Tumours
- Penis:
    - Impotence
    - Trauma
    - Peyronie's disease
    - Priapism
    - Tumours
- Adrenal:
    - Benign tumours
    - Malignant tumours
    - Inflammations
    - Cysts
    - Insufficiency
    - Trauma
    - Incidentally discovered lesions: principles of differential diagnosis

Interventional

Under supervision, the following:

- Verifying indications, satisfactory blood count and coagulation status
- Explaining the procedure and follow-up to the patient
- Identifying what equipment is required
- Identifying what aftercare is required
- Performing ultrasound-guided biopsies/cystic drainage, e.g. kidney mass, prostate
- Performing CT-guided biopsies
- Performing percutaneous nephrostomy

Gynaecological imaging

Ultrasound examination

- Explaining the value of an ultrasound examination
- Performing and interpreting an ultrasound examination of the female pelvis and to explaining its value
- Explaining the advantages and limitations of the abdominal vs the transvaginal approach
- Knowing the indications and contraindications for hysterosonography

Hysterosalpingography

- Describing the procedure
- Knowing the possible complications of hysterosalpingography
- Knowing the contraindications for hysterosalpingography
- Explaining the choice of contrast agent
- Knowing the different phases of the examination
- Explaining the technique of a pelvic CT
- Knowing the possible complications of CT
- Knowing the contraindications for CT
- Knowing the irradiation delivered by a pelvic CT
- Knowing the required preparation of the patient and the choice of technical parameters (slice thickness, Kv, mA, number of acquisitions etc.) depending on indications
- Explaining the technique of a pelvic MRI
- Knowing the contraindications for MRI
- Knowing the required preparation of the patient and the choice of technical parameters (slice thickness, orientation, weighting etc.) depending on indications

Angiography

- Knowing the main indications for pelvic angiography in women
- Knowing how to perform a pelvic angiography

Molecular imaging

Principles of molecular imaging as applied to urogenital radiology include its role in:

- Nephropathies
- Renal fibrosis
- Renal transplants
- Urogenital tumours and lymphomas
- Renal stem cell and gene therapy
- Gene therapies for tumours