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Clinical Radiology
The Royal College of Radiologists

Recommendations for cross-sectional imaging in cancer management, Second edition

General techniques for examinations discussing CT, biopsy and MRI

Faculty of Clinical Radiology

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Computed tomography (CT)

Patient preparation

It is helpful for patients to receive general information about the scan before their attendance in the department, and this is best achieved in leaflet or booklet form. Up-to-date versions of these documents should also be available via the department's website with links to other resources as appropriate. The information should include a brief description of CT scanning, the specific preparation that will be required, the time taken for the examination, including waiting time in the department, and a statement about to who and when the report will be sent. The use of intravenous contrast medium for the majority of CT examinations should also be included.

At the time of attendance, it is useful to check that outpatients have an appropriate clinic appointment.

For abdomino-pelvic examinations it is usual to ask the patient to fast for four hours.

It is important to be aware of patients with renal impairment and to take measures to minimise contrast medium nephrotoxicity (CMN). Patients at risk should receive a small dose of either non-ionic iso-osmolar dimeric or non-ionic low osmolar monomeric contrast medium and intravenous fluid. Intravenous infusion (1 ml/kg patient body weight/h) of 0.9% saline for at least six hours before and after contrast injection is effective in reducing the incidence of CMN.[1]

Patient positioning

Patients are usually scanned supine with their arms raised above the head for CT of the torso. Any variations are detailed in the text.

Contrast medium

Bowel opacification

Bowel contrast medium is generally given in the form of water-soluble iodine or a diluted barium-based agent. For general abdomino-pelvic CT examinations, one litre of dilute oral contrast medium is recommended. This is given in divided doses commencing an hour before the scan with the last dose of approximately 150–200 ml being given immediately before the patient is positioned on the scanner. A smaller volume of contrast medium is required for limited upper abdominal studies (approximately 500 ml).

Contrast opacification of the colon and rectum can be improved by administration of a small dose of oral contrast medium 4–12 hours before the examination. For outpatients, this can be achieved by sending a small vial of contrast through the post with the appointment letter and information leaflet; 5 ml of contrast taken in 150–200 ml of water is effective, if taken last thing at night for morning examinations or after breakfast for afternoon appointments.

Some inpatients receive their oral contrast on the ward. Effective administration is encouraged by liaison between skilled radiographic helpers and ward staff. Some patients prefer flavourings in the contrast medium. The radiologist/radiographer should ensure that these flavourings do not result in precipitation of the contrast medium within the bowel lumen.

Rectal contrast medium is not mandatory but may assist in the delineation of disease within the pelvis. If used, 100 ml is suggested followed by 50 ml of air which helps to push the contrast medium into the sigmoid colon.

Water and carbon dioxide granules may also be used as oral contrast agents (particularly for staging examinations of the stomach and oesophagus – see sections on Oesophagus and stomach cancers and Colon, rectum and anal canal cancer).

If bowel opacification is suboptimal, then delayed scans, with or without additional oral contrast medium, or scans with the patient in the decubitus or prone position, may be useful.

Before an abdominal CT, it is important to check that the patient has not had a recent barium study since retained, radiographically dense barium will degrade the images by streak artefacts.

Intravenous contrast medium

The use of intravenous contrast medium (IVCM) is an important component of the CT examination. Each intravenous injection should be planned to maximise positive information from the scan and minimise risk and discomfort to the patient.

The information to be derived from the CT examination should determine the intravenous technique to be used. Contrast medium should be given as a rapid intravenous bolus via an intravenous (IV) cannula using a pump injector. It is advisable that CT departments adhere to established protocols, and radiographic staff should make themselves familiar with them. With appropriate training and supervision, placement of the IV cannula, injection of contrast and aftercare management of the cannula site can all be delegated to radiographic and/or nursing staff.

Multislice (multidetector) CT (MSCT or MDCT) gives great flexibility in terms of anatomical coverage, enhancement phase, slice thickness and image reformatting. A typical single breathhold general examination of the abdomen and pelvis typically employs 100 ml of 350 mg iodine strength contrast medium administered at 3–4 ml/sec, beginning in the portal venous phase 65 seconds after commencement of the injection. When the chest is examined, a first breathhold acquisition at 25–30 seconds after commencement of injection is followed by the abdomino-pelvic acquisition in a second breathhold. Bolus tracking techniques can be used where variations in cardiac output between patients might compromise optimum enhancement. For general examinations of the torso, slice thicknesses of 2–5 mm are typical. Details of slice thicknesses and contrast protocols which differ from these general statements are indicated in the relevant sections.

For examination of the brain, 50–100 ml of 300 mg iodine strength contrast medium should be administered; the rate of injection and the timing of the scan in relation to the injection are less critical than for body CT unless angiographic or perfusion information is specifically required.

A key principle to the use of contrast media is to use the minimal dose that provides optimal contrast enhancement, but also minimises risks of contrast-induced nephropathy. This may be facilitated by the use of certain software packages available on modern contrast injectors.

Imaging parameters for MDCT

Using MDCT, there is a trade-off between volume and speed of coverage and contrast and spatial resolution in terms of collimation and dose of ionising radiation. For example, in breathless or restless individuals, large volumes of coverage can be achieved which would previously have been impossible or exquisite anatomical detail of a region of interest can be obtained.

MDCT allows near isotropic imaging and with selection of appropriate imaging parameters, high-quality multiplanar reconstructions (MPR) and 3D renderings are possible. Data can be reconstructed at different slice thicknesses from 1–10 mm. Overlapping reconstructions of data further improve image quality and, for most available machines, 2–3 mm overlapping reconstructions of the abdomen and pelvis result in high-quality renderings.

Radiation protection for the patient in CT

Notwithstanding the undoubted role of properly directed CT scanning in the clinical management of cancer patients, the levels of potentially harmful radiation delivered to the patient can be relatively high when compared with many other types of diagnostic X-ray examination.[2] There is consequently a need to balance the benefits and risks from CT within the broad context of a patient's health, both present and future, through active management of patient dose.[3] In principle, this means the elimination of all unnecessary radiation exposure. In practice, it requires the prior clinical justification of all CT examinations and the use of optimal scanning techniques that result in the lowest patient dose to meet each particular clinical purpose. These guiding principles for radiation protection are enshrined in European and UK legislation.[4,5]

Once duly authorised by the practitioner or operator,[5] each CT examination should be conducted by the application of protocols developed for specific clinical purposes by the radiographer and radiologist (in close collaboration with the medical physics expert when needed). Such protocols should reflect

good scanning practice, with active management of technique including:

- Tube current
- X-ray beam collimation
- Pitch
- Length of each scan sequence
- Number of such sequences.

Attention to these factors will limit the patient dose to the minimum level commensurate with providing the diagnostic information required. While significant reductions in dose can be achieved utilising automatic exposure control (AEC) technology to modulate tube current according to patient anatomy,[6] with MDCT the understanding of some parameters is not intuitive and the selection of image quality parameter values in AEC systems is not entirely straightforward. Scanning protocols should not simply be transferred between scanners from different manufacturers and should be determined for each MDCT.[7]

Many scanner models also display values of the two practical dose quantities – volume CT dose index (CTDIvol) and dose-length product (DLP), which have been defined for the purpose of promoting the use of good technique. Levels of such doses should be assessed for each protocol and, as an initial step in the process of optimisation, compared against relevant national reference doses that are published by the Radiation Protection Division of the Health Protection Agency (formerly the National Radiological Protection Board), following periodic reviews of national practice.[8] The 2003 national reference values for CTDIvol are summarised for various scan regions and patient groups in the Appendix. These doses are intended to represent levels to trigger the investigation of potentially unacceptable practice. Consequently, any local levels of dose above the relevant national reference dose should be reviewed for potential changes in technique that could lead to dose reduction without compromising clinical requirements.

Since children are potentially more susceptible to radiation effects, special attention should be given to the justification and optimisation of paediatric CT scanning. Particular regard should be given to the use of size-specific scan protocols and dose reduction software, where this is available.

Biopsy

If CT is the preferred technique for guiding the biopsy, good practice dictates that prior to beginning the biopsy procedure:

- Informed consent is obtained
- The possibility of a bleeding diathesis is excluded or corrected
- Provision is made for aftercare; for example, a day-care bed
- There is liaison with colleagues in the histopathology/cytology departments so that preservation and storage of tissue are appropriate or a member of the cytology department is present at the procedure to assess the adequacy of the material obtained from a fine-needle aspiration
- A diagnostic CT scan is undertaken with intravenous contrast medium to assess both the vascularity of the lesion and its relationship to adjacent vessels. This scan is also useful for planning the patient position, determining lesion choice and biopsy route.

To formalise aspects of best practice and act as a safeguarding measure, The Royal College of Radiologists has collaborated with the National Patient Safety Agency (NPSA) to produce a specific checklist adapted for radiological interventions, based on the World Health Organization (WHO) Surgical Safety Checklist.[9]

Where possible, a needle-core biopsy should be obtained. Use of 18G needles is usually sufficient. It should be remembered that sampling errors, although small, are not insignificant. If the clinical features are overwhelmingly those of malignancy, but this is not supported by the histopathology, the biopsy should be repeated, perhaps from a different anatomical location or the patient referred for surgical biopsy. Only a biopsy result positive for cancer is reliable in the short term; negative biopsies only being corroborated by follow-up.

Radiation protection for patients and staff during CT biopsy procedures

Needle guidance during biopsy may be undertaken using conventional CT imaging or CT fluoroscopy (CTF).[10] The latter technology provides real-time images, although there is potential for significantly higher doses to the patient from continuous localised exposure and to staff (particularly in relation to eyes, thyroid and hands) from their close proximity to the X-ray beam during needle manipulation.[11]

There is a particular need for active dose management during CTF to limit screening times and tube currents to the minimum values necessary and, when manipulating the needle during real-time imaging, to keep hands away from the X-ray beam. The use of special needle holders and lead sheets placed over the patient can help reduce hand exposures. Doses to both patients and staff are also reduced when CTF is used intermittently as a series of very short exposures in a ‘quick-check’ mode between needle manipulations, rather than in ‘real-time’ mode with simultaneous needle manipulation and CTF.[12]

Magnetic resonance imaging (MRI)

Patient preparation

All patients should be sent an information leaflet or booklet at the time of booking their appointment. The booklet should include a brief description of the MRI scanner and of the need to place coils closer to the body to improve the pictures obtained. Patients should be made aware of the loud noise which occurs during scanning and earplugs should be available. The use of intramuscular and intravenous injections should be mentioned as well as the expected overall duration of the examination. Booklets should also include a list of absolute contraindications to MRI in a language style appropriate to patients. This information should also be available on the imaging departments website, with links to other resources where appropriate. Patients should be provided with a telephone number to discuss possible concerns about safety aspects. When there are concerns for intraocular or other relevant metallic fragments, the patient may need to attend in advance of the MRI appointment for radiographs/limited CT scans.

Concerns about claustrophobia can be addressed by encouraging the patient to visit the MRI unit before the study is undertaken so that fears relating to the examination can be allayed as far as possible. Approximately 1–2% of patients are unable to proceed due to claustrophobia and some patients may require sedation. Sedation should always be given in accordance with RCR guidelines,[13] and be organised in advance of the appointment to enable the procedure to be conducted in a relaxed and orderly manner. Sedation can be by oral premedication or by intravenous injection. There must be appropriate monitoring equipment and aftercare for sedated patients, and national guidelines as well as local rules must be followed in this regard.

On arrival in the department, the scanning procedures should be explained to the patient by a specialist radiographer. This should include a discussion on the use of various coils and whether an intravenous injection will be required for the study.

The patient should be asked about any contraindications to MRI and about the possibility of pregnancy; a checklist is recommended which the patient is then asked to sign.

Patient handling

Patients are usually scanned in the supine position, but in those patients who are claustrophobic, the prone position has been found to be helpful. The patient's arms are usually placed by their side and quiet respiration is permitted for all examinations except those where breathhold techniques are used. An intramuscular or intravenous bowel relaxant (Hyoscine-N-Butyl Bromide [Buscopan] or Glucagon) may be required for some abdominal/pelvic MRI examinations to reduce bowel peristalsis.

Sequences

Although there are a large number of different sequences used for MRI examinations and different manufacturers use different terminology for the same sequences, discussion of all these different approaches is considered inappropriate in this document. In general, T1-weighted (T1W) and fast/turbo spin-echo T2-weighted (T2W) sequences are used for the evaluation of tumours. Fat suppression either using a frequency selective saturation pulse or short tau inversion recovery (STIR) is also valuable. Gradient-echo sequences may be employed for in- and opposed-phase imaging and to obtain rapid data acquisition, particularly when using three-dimensional (3D) and breath-hold contrast-enhanced techniques. Diffusion-weighted imaging (DWI) is increasingly used to aid tumour evaluation at a number of body sites.[14]

Respiratory compensation, navigator assistance and pre-saturation pulses for abdominal imaging are all helpful when used appropriately. Cardiac gating is also valuable for both chest and abdominal studies to reduce pulsatile motion artefact.

Supervision of oncological MRI examinations by a trained MR radiologist or radiographer is vital to

ensure that adequate image quality and satisfactory diagnostic information are obtained.

Field of view/matrix

The field of view and matrix size are interrelated, as the matrix size used varies according to the field of view used. The aim is to produce high-resolution images with adequate signal-to-noise ratio of the organ or area of interest and these parameters will depend upon the equipment used as well as other factors such as the size of the primary tumour or organ being studied. High-resolution, small field of view T2W images in two planes are required for most pelvic examinations. Some organs such as the prostate gland have predictable orientation; others such as the uterus and cervix show a greater variation in anatomical position and therefore require prescription of oblique planes to ensure maximal diagnostic information.

Coils

While the body coil is suitable for imaging large areas of the body, such as for survey of the whole abdomen or pelvis or for localisation of organs prior to detailed examination, local tumour staging should be undertaken using surface or endocavitary coils.

A wide range of these coils is available with modern MRI machines, including dedicated coils for examination of the breast, neck and pelvis. These coils enable improved image quality by increasing the signal-to-noise ratio, but many have a limited field of view.

Contrast medium

Bowel opacification
Bowel contrast media for use with MRI are now commercially available, but have not as yet gained widespread acceptance as part of oncological staging studies. A number of naturally occurring substances such as cranberry and pineapple juice have also proved effective as contrast agents. Oral contrast agents are of two types: those which produce delineation of the bowel by shortening T1 relaxation time (best evaluated on T1W images resulting in increased signal intensity – positive agents), and those which shorten T2/T2* relaxation time (best evaluated on T2/T2*-weighted sequences as negative agents).

Intravenous contrast medium (IVCM)
IVCM may be given as an extracellular agent, for example, Gadopentetate dimeglumine (also called gadolinium-DTPA) or as an organ-specific agent; that is, a liver-specific contrast agent. Extracellular IVCM for MRI has been generally considered to be extremely safe, however, since 2006 exposure to some gadolinium-based contrast media has been linked to the development of nephrogenic systemic fibrosis (NSF), a severe delayed fibrotic tissue reaction.[15]

Patient-related risk factors for the development of NSF are:

- Renal impairment (GFR<60 ml/min/1.73m^2) including patients on dialysis
- Liver transplant patients who have had or who are awaiting transplantation where there is any degree of renal impairment
- Age under one year, because of immature renal function.

The agents associated with the development of NSF appear to be the less stable linear chelates (gadodiamide [Omniscan], gadopentetate dimeglumine [Magevist] and gadoversetamide [OptiMARK]).

No cases of NSF have been reported in patients with a GFR >60ml/min/1.73m^2. Screening for renal dysfunction with serum creatinine/estimated GFR is therefore mandatory if considering the use of gadolinium-based contrast media linked to the development of NSF. High stability chelates have not been implicated in the development of NSF and can be used in either at risk groups or as an alternative or as a firstline agent when renal function is not known.

Extracellular agents
IVCM for opacification of vessels and for evaluation of the extravascular phase is an important component of many MRI examinations. The use of IVCM should be planned according to examination protocols, but on occasion its use will be determined after review of the initial unenhanced sequences.

IV extracellular CM may be given as:

- A rapid bolus injection combined with a rapid T1W dynamic scanning (gradient echo) technique (often using a mechanical injector), or
- A bolus by hand injection followed by a routine non-dynamic T1W sequence.

The dose of IVCM is usually 0.1 mmol/kg patient body weight although agents with higher relaxivity are usually given at lower doses.

Organ-specific agents
The role of tissue-specific contrast agents continues to evolve.

- Liver-specific contrast agents have been developed and are broadly divided into two major groups: those which are taken up by the hepatocytes (for example, gadoxetete [Primovist]) and those which are taken up by the reticuloendothelial system (that is, super paramagnetic iron oxide or SPIO particles). Many studies have shown that liver enhancement using these agents is more sensitive in the detection of focal liver lesions than unenhanced MRI and such agents can also be used for lesion characterisation.16 For a variety of commercial reasons, the SPIO agents have been gradually withdrawn from the marketplace and should be noted to have a differing adverse effects profile from that of gadolinium-based contrast media.
- Lymph node-specific contrast agents for detection of metastases use ultrasmall super paramagnetic iron oxide particles (USPIO), which are taken up by the reticuloendothelial system. They remain under investigation, but are not currently commercially available.

Biopsy

Open magnetic systems which permit interventional techniques have been installed in a few centres in the United Kingdom. In general, biopsy under MRI guidance is a limited resource and, in most centres, biopsy continues to be undertaken under ultrasound or CT guidance. Specialised breast coils for breast biopsy are increasingly used. Special needles are available for biopsy of other regions.

Display of CT and MR imaging

Multislice CT and MRI examinations produce a large number of images, particularly those examinations where dynamic scanning is employed. Review and reporting of the examination should be conducted on a PACS workstation with reformatted images or reformatting facilities being available. Some studies, particularly where more quantitative dynamic analysis or other software tools not available through the standard PACS portal, will require dedicated console workstation review. Systems should be in place within networks to allow secure transfer of images and reports for MDT purposes.

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References

1. Stacul F, van der Molen AJ, Reimer P *et al.* Contrast induced nephropathy: updated ESUR Contrast Media Safety Committee guidelines. *Eur Radiol* 2011; **21:** 2527–2541.

2. The Royal College of Radiologists. *iRefer: Making the best use of clinical radiology*, 7th edn. London: The Royal College of Radiologists, 2012. (www.irefer.org.uk)

3. ICRP. Managing patient dose in computed tomography. ICRP Publication 87. *Ann ICRP* 2000; **30**(4).

4. European Commission. European Commission Council Directive 97/43/EURATOM of 30 June 1997 on health protection of individuals against the dangers of ionising radiation in relation to medical exposure. *Off J Eur Commun* 1997; **L180:** 22–27.

5. *The Ionising Radiation (Medical Exposure) Regulations 2000. SI (2000) No.1059*. London: TSO, 2000.

6. Keat N. *CT scanner automatic exposure control systems. MHRA Evaluation Report 05016*. London: Medicines and Healthcare products Regulatory Agency, 2005.

7. ICRP. Managing Patient Dose in Multi-Detector Computed Tomography (MDCT). ICRP Publication 102. *Ann ICRP* 2007; **37**(1).

8. Shrimpton PC, Hillier MC, Lewis MA, Dunn M. *Doses from computed tomography (CT) examinations in the UK – 2003 review*. Chilton: NRPB, 2005. http://www.hpa.org.uk/Publications/Radiation/NPRBArchive/NRPBWSeriesReports/2005nrpbw067/

9. The Royal College of Radiologists. *Standards for the NPSA and RCR safety checklist for radiological interventions*. London: The Royal College of Radiologists, 2010.

10. Prosch H, Stadler A, Schilling M *et al.* CT fluoroscopy-guided vs. multislice CT biopsy mode-guided lung biopsies; accuracy, complications and radiation dose. *Eur Radiol* 2012; **81**(5): 1029–1033.

11. Buls N, Pages J, De Mey J, Osteaux M. Evaluation of patient and staff doses during various CT fluoroscopy guided interventions. *Health Physics* 2003; **85:** 165–173.

12. Paulson EK, Sheafor DH, Enterline DS, McAdams HP, Yoshizumi TT. CT fluoroscopy-guided interventional procedures: techniques and radiation dose to radiologists. *Radiology* 2001; **220:** 161–167.

13. The Royal College of Radiologists. *Safe Sedation, Analgesia and Anaesthesia within the Radiology Department*. London: The Royal College of Radiologists, 2003.

14. Koh DM, Collins DJ. Diffusion-weighted MRI in the body: applications and challenges in oncology. *Am J Roentgenol* 2007; **188:** 1622–1635.

15. The Royal College of Radiologists. *Gadolinium-based Contrast Media and Nephrogenic Systemic Fibrosis*. London: The Royal College of Radiologists, 2007.

16. Ba Ba-Ssalamah A, Uffmann M, Saini S, Bastati N, Herold C, Schima W. Clinical value of MRI liver-specific contrast agents: a tailored examination for a confident non-invasive diagnosis of focal liver lesions. *Eur Radiol* 2009; **19:** 342–357.

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