CLARK'S POSITIONING IN RADIOGRAPHY

13TH EDITION

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Section 1

Basic Principles of Radiography and Digital Technology

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Introduction

The patient journey

Successful radiography is dependent on many factors but uppermost is the patient's experience during their short journey and encounter with the Diagnostic Imaging Department (see Fig. 1.3). The radiographer has a duty of care to the patient and must treat them with respect and ensure their dignity is maintained. It is essential that the radiographer establishes a rapport with the patient and carers. The radiographer must introduce themselves to the patient/carer and inform them of their role in the examination. They must make sure the request form is for the patient being examined and that the clinical details and history are accurate. The radiographer must request consent from the patient and the patient must give consent for the examination before the radiographer starts the examination.

The flow chart demonstrating a systematic way of undertaking an X-ray examination is on page 7. The purpose of the flow chart is to ensure that the patient journey is patient focussed and mistakes are eliminated. The key aspects are:

- Effective communication with patients and carers.
- The ability to follow a logical framework in order to be able to perform the X-ray examination proficiently and effectively.
- Efficient use of technology to produce diagnostic images at the first attempt.
- Evaluation of the radiographic image using the 10-point plan.

Whilst there are several 'main headings' to the algorithm it is essential to emphasise that the primary focus is the patient and their interaction within the process. Effective communications encompasses a myriad of interactions, which include being 'open and friendly' to the patient, telling them who you are, what you are intending to do, gaining consent and also inviting and answering any questions they may have about the examination.

Stages of an X-ray examination

There are 3 stages to undertaking an X-ray examination, preparation, the radiographic procedure itself and follow up from the examination undertaken. Each of these stages can be further subdivided as shown below:

Preparation for the examination:

- The request form.
- The X-ray room.
- The patient, including consent for the examination and identity checks.

Undertaking the examination:

- Patient care.
- Radiographic procedure.
- Radiation protection.

Post-examination and aftercare:

- Image quality.
- Patient aspects.
- Imaging informatics.

Preparation for the examination

The request form

- Ensure the examination requested is authorised and signed with a suitable rationale.
- Make sure the examination is justified using the IR(ME)R 2000 regulations[1] and the request card has a justifiable clinical reason for the X-ray, e.g. history of injury and pain in the metacarpal region ?fractured foot.
- Any examination using X-rays must affect the management of the patient.
- Check the protocol for the examination.
- Make sure you know which projections are required, e.g. DP and oblique foot.

Preparation of the X-ray room

- Make sure the X-ray room is clean, safe and tidy, ensure that the floor is clear and the X-ray tube is not in a position where the patient can walk into it.
- Set a preliminary exposure for the examination, i.e. X-ray tube focus size, mAs and kV.
- Have any accessory equipment available, e.g. foam pads and lead-rubber.

Preparation of the patient

- Correctly note the details on the request form ready for checking with the patient:
- Patient's full name, date of birth and address.
- Correct examination requested and reason for the X-ray.
- Is the patient fit and ambulant or have any physical needs?
- Mode of transport.

If applicable ensure the patient is undressed and dress them in a radiolucent gown.

The patient is asked:

- If they have carried out any required preparation for the examination.
- If they understand the nature of the examination and if they have any questions prior to proceeding.
- For verbal permission to proceed with the examination.
- For written consent if an examination incurs a higher risk, e.g. angiography.

To be able to give consent (adult or child) the patient should meet the following criteria. They should:

- Understand the risk versus benefit.
- Understand the nature of the examination and why it is being performed.
- Understand the consequences of not having the examination.
- Be able to make and communicate an informed decision.

If these conditions are not satisfied then other individuals may be able to give consent, e.g. parents, or in an emergency situation the examination may proceed if it is considered in the best interest of the patient (see hospital policy). Page 7 has a full page timeline.

Undertaking the examination

Patient care

At the commencement of the examination introduce yourself to the patient and ask permission to take the X-ray. If the patient has been prepared for the examination, check they have followed the instructions, e.g. undressed appropriately and in a gown, nil by mouth or any other preparation. Make a positive identity check on the patient using the details on the request form and ensure that the correct examination is indicated along with the rationale for the X-ray examination.

- Check the pregnancy status of the patient.
- Check for the patient's infection status, i.e. MRSA or other transferable diseases, to prevent cross infection by appropriate methods.
- Visibly clean hands in front of the patient before you start the procedure.
- Patient identity. Once again the patients' identity is established using the departmental protocol, which normally asks the patient to state their full name, address and date of birth. These are then cross referenced with the request form. The examination must not proceed unless the radiographer is sure of the identity of the patient.

Introduction (*cont.*)

The procedure is explained to the patient in easy to understand terms.

Radiographic procedure

It is important that the department protocols are followed for the examination and that the equipment is used safely and proficiently. The preliminary exposure should be set on control panel (make sure the exposure factors are optimised for the patient body type).

As part of the procedure ensure:

- The patient is positioned accurately in relation to the examination being undertaken.
- The X-ray tube is positioned and centred to the patient and image receptor.
- The beam is collimated to the area of interest.
- Appropriate radiation protection is carried out.
- An anatomical marker is correctly applied to the image receptor.
- Instructions are effectively communicated to the patient.
- Radiographers and other staff/carers stand behind the lead glass protective control screen and exposure undertaken after the exposure factors confirmed on control panel.
- Image acquisition is correct first time.
- The patient waits whilst the image is checked.
- The image is assessed for diagnostic quality.
- You wash your hands or clean them with alcohol gel in sight of the patient.
- You consider using pads and sandbags to immobilise the patient when necessary. Distraction techniques may also be of value with paediatric patients.

Introduction (*cont.*)

Radiation protection

Patient protection

Radiation protection and patient dose matters are discussed in depth at the end of this chapter. The following section summarises some of the important aspects of the examination, which includes before and during the procedure both in terms of the patient, staff and carers with consideration to relevant legislation.

On reviewing a request for an X-ray examination, the radiographer needs to consider carefully if the request for the examination is appropriate and has sufficient information to undertake it. In other words – is the examination justified? The radiographer should consider several questions when assessing any request for imaging:

Will the examination change the clinical management of the patient?

- While this can be a contentious area, the radiographer should consider if the requested examination will be of benefit to the patient and if the findings will affect the treatment or management of the patient. If the examination is not going to change the management of the patient the radiographer should seek further information from the referrer until they are satisfied the request is justified.
- The Radiographer has a duty of care to have a further discussion with the referrer. This must establish if the examination is justified or not under the radiation regulations and protocols of the department.

Does the completed request comply with local protocols?

For example, is the request card completed in a legible manner? Are the requested projections in line with the departmental protocol?

What are the risks/ benefits of the examination?

Even low X-ray doses can cause changes to cell DNA, leading to increased probability of cancer occurring in the years following the exposure. While in many cases the probability of this occurring is low, this risk should always be balanced against the benefits of the patient undergoing the examination. This is often acutely emphasised when a seriously ill patient or a young patient undergoes frequent X-ray examinations and the need to consider carefully each request is very important. Consultation with radiological colleagues is often required if there is any doubt over the legitimacy of any request.

Does the request comply with government legislation?

Legislation varies between countries; however, the request should comply with national legislation where applicable. In the UK the underlying legislation is known as the Ionising Radiation (Medical Exposure) Regulations (IRMER) 2000.[1] This legislation is designed to protect patients by keeping doses 'as low as reasonably practicable' (ALARP). The regulations set out responsibilities:

- Those that refer patients for an examination (Referrers).
- Those that justify the exposure to take place (Practitioners).
- Those that undertake the exposure (Operators).

Radiographers frequently act as practitioners and operators and as such must be aware of the legislation along with the risks and benefits of the examination to be able to justify it.

Is there an alternative imaging modality?

The use of an alternative imaging modality that may provide more relevant information or the information required at a lower dose should be considered. The use of non-ionising imaging modalities, such as ultrasound and MRI should also be considered where appropriate.

Optimisation of radiographic exposure

The radiographer has a duty of care to ensure that the exposure delivered to the patient conforms to the departmental optimisation policy. This ensures that that the ALARP principle has been applied.[2]

Optimisation will involve consideration of a number of factors associated with image acquisition including:

- Exposure factors applied.
- Image detector system used.
- Patient compliance.
- Collimation and field size.

Diagnostic reference levels

Statutory dose limits do not apply to individual medical exposures. However, IRMER requires employers to establish diagnostic reference levels (DRLs) for their standard diagnostic and interventional procedures in order to assess whether these exposures are optimised. These local DRLs are based on the typical doses received by average sized patients when they undergo common procedures. DRLs have been established as a critical method in determining if a patient has been over irradiated. Contemporary practice will involve imaging departments publishing a list of DRLs for all common X-ray examinations. Patient dose must be recorded for all examinations. This will be given in different formats such as:

- Dose (kerma) area product (DAP) – Gy cm^2.
- Entrance surface (skin) dose (ESD) – mGy.
- Exposure factors/examination room.
- Fluoroscopy times.

This will be explained fully in the radiation protection section at the end of this chapter, but it is important that the radiographer ensures that the local DRL has not been exceeded.

Introduction (cont.)

Avoiding exposure in pregnancy

All imaging departments should have written procedures for managing the small but significant radiation risk to the foetus (Fig. 1.1). Radiographers should refer to their departmental working procedures and apply them as part of their everyday working practice. The chart opposite has been constructed using joint guidance from the Health Protection Agency, the College of Radiographers and the Royal College of Radiologists (2009). Most departmental procedures will follow a similar procedure although practices may vary between departments according to specific circumstances. The procedure for pregnancy is usually applied to examinations that involve the primary beam exposing the pelvic area. Examinations of other areas can be undertaken as long as the radiographer ensures good beam collimation and employs the use of lead protection for the pelvis.

Evaluating and minimising the radiation risks in pregnancy

If a decision is made to irradiate a woman who is pregnant it will be in conjunction with the referring clinician who will have decided that there are overriding clinical reasons for the examination to take place. In such cases the relatively small radiation risk to the patient/foetus will be outweighed by the benefit of the diagnosis and subsequent treatment of potentially life-threatening or serious conditions. These could present a much greater risk to both parties if left undiagnosed.

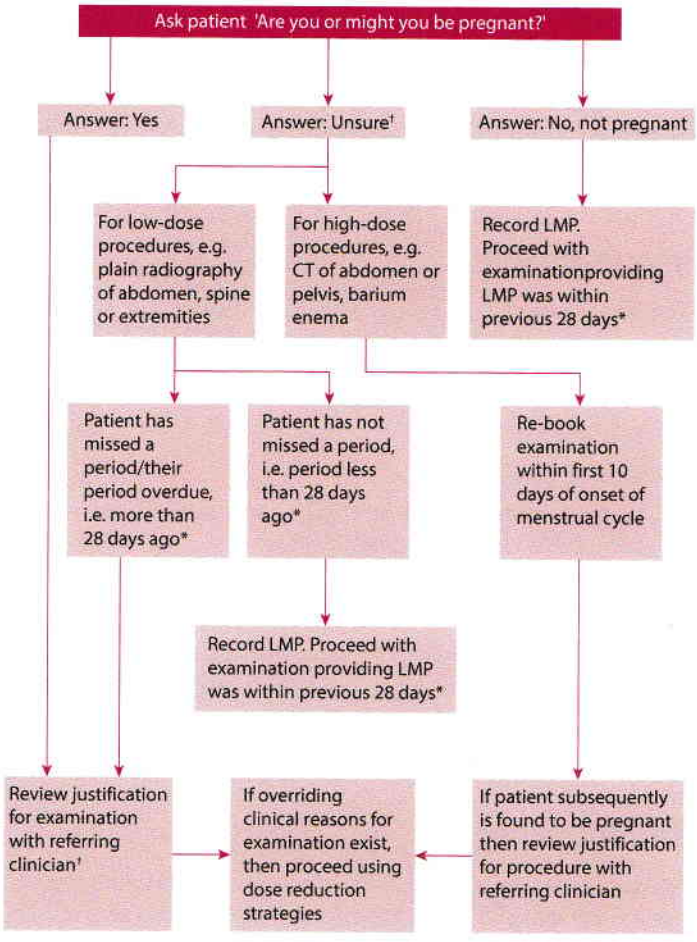
To minimise the risks when examining pregnant women the radiographer should adopt the following strategies:

- Use of the highest imaging speed system available, e.g. 800 speed or equivalent settings for CR/DDR.
- Limit collimation to area of interest.
- Use of shielding (can the uterus be shielded without significant loss of diagnostic information?).
- Use of the minimum number of exposures to establish a diagnosis.
- Use of projections that give the lowest doses.
- Use pregnancy tests if doubt exists.

Staff and other personnel protection

Radiography is undertaken in conformance with relevant radiation legislation. This will be discussed in detail and the end of the section. The following section summarises some of the important protection aspects:

- Adherence to the local Radiation Rules.
- Monitoring of staff radiation doses.
- Staff doses conform with the ALARP principle. Adherence with the use of a controlled area both for static, mobile radiography and fluoroscopy.
- Collimation and limitation of X-ray beam.
- Use of personal protective equipment (PPE) when appropriate.
- Safe use of X-ray equipment.



A typical 'pregnancy rule' for women of child-bearing age. *Some women have menstrual cycles of more or less than 28 days or have irregular cycles. CT, computed tomography; LMP, last menstrual period.

Fig. 1.1 Typical flow chart for 'pregnancy rule'.

Introduction (*cont.*)

Post-examination and aftercare

Immediately following image acquisition the image will be reviewed to ensure it is of diagnostic quality; the patient will be managed and be given instructions as to what to do next and the examination will be completed in terms of the imaging information of the X-ray procedure.

Image quality

The image is reviewed using the '10-point plan':

1. Patient identification.
2. Area of interest is included.
3. Markers and legends.
4. Correct projection.
5. Correct exposure indicator (EI) – optimum EI and within acceptable range. Limited/no noise.
6. Optimum definition – can you see the detail of the relevant anatomy/structures, i.e. is it sharp?
7. Collimation is restricted to the area of interest.
8. Are there any artefacts and are they obscuring anatomy?
9. Any need for repeat radiographs or further projections.
10. Anatomical variations and pathological appearances.

Patient aspects

At this important stage of the procedure the Radiographer has a duty of care to ensure the patient is given and understands instructions. They need to know what to expect next in regard to the report from the examination, who will receive the report and how long this process will take. There will be local protocols to ensure the process is robust and the patient is managed effectively, e.g.:

- Go back to clinic immediately.
- The report will be posted to your GP within a certain timeframe.
- Arrange transport via porters/ambulance or ensure the patient has transport home.
- It is important that the patient takes all their belongings and valuables home with them.
- The radiographer should answer any questions the patient or carers may have on the examination /process within their scope of practice.

Imaging informatics

- It is important that the acquired images are viewed carefully using optimised conditions, e.g. ambient light conditions and the monitor is correctly adjusted. This may mean manipulating the image on the workstation monitor to demonstrate different areas of the image (Fig. 1.2).
- For extremity and axial radiography ensure an acquired image of a body part is displayed on a single monitor in order to ensure optimum display (i.e. only one image per monitor).
- Department/manufacturers' recommendations regarding any specific algorithms associated with a body part must be followed.
- Any further post processing must be carefully considered before the images are sent to picture archiving and communication system (PACS).
- Check the EI is of an optimum value to evaluate exposure to the patient and there is minimal /no noise on the image.
- The images are sent to PACS so the referring clinician can view the image and the image can be reported by the reporting radiographer or radiologist.
- The examination is completed on the Radiology information system (RIS), making sure the image is in the correct patient folder and the documentation regarding exposure details/dose reading and number of images taken is completed.
- The radiographer who is acting as the practitioner and operator must be identified on the RIS system.

Fig. 1.2 Students and tutor at the monitor.

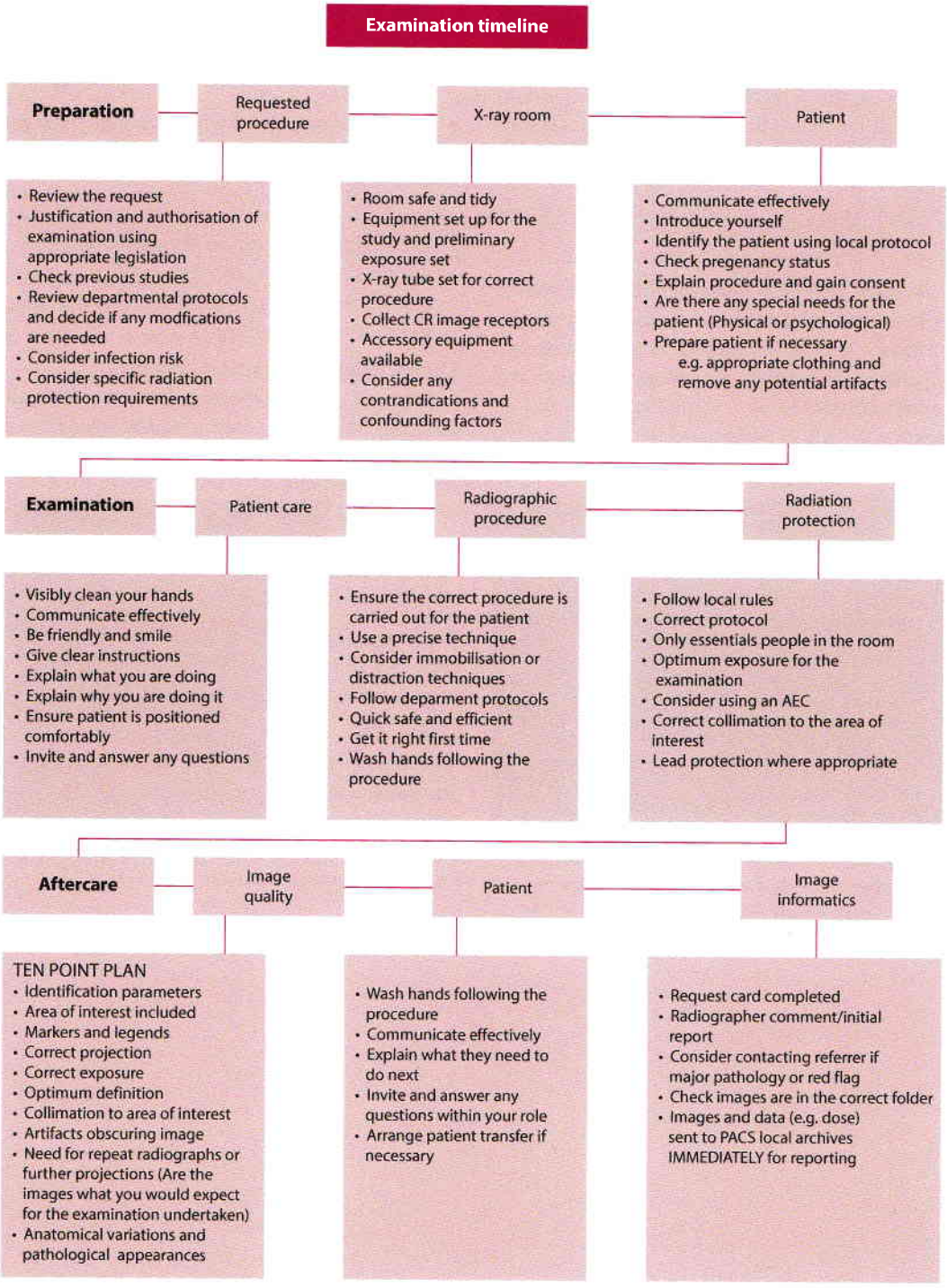


Fig. 1.3 Flow chart of the patient journey.

Image evaluation – 10-point plan

It is imperative that radiographic images are properly evaluated to ensure that they are fit for purpose, i.e. they must answer the diagnostic question posed by the clinician making the request. In order to do this effectively the person undertaking the evaluation must be aware of the radiographic appearances of potential pathologies and the relevant anatomy that needs to be demonstrated by a particular projection. Points to consider when evaluating the suitability of radiographic images include:

1. Patient identification: do the details on the image match those on the request card and those of the patient who was examined? Such details will include patient name and demographics, accession number, date of examination and the name of the hospital.
2. Area of interest: does the radiograph include all the relevant areas of anatomy? The anatomy that needs to be demonstrated may vary depending on the clinical indications for the examination.
3. Markers and legends: check that the correct anatomical side markers are clearly visible in the radiation field. Ensure the marker that has been used matches the body part on the radiograph and that this in turn matches the initial request from the clinician. Ensure the correct legends have been included if not stated in the examination protocol, e.g. prone/supine. It is poor practice not to include a marker within the radiation field when making an exposure.[3]
4. Correct projections: does the acquired image follow standard radiographic technique as outlined throughout the book, with the patient being correctly positioned together with the appropriate tube angulation?

   It is important to consider the pathology in question and the clinical presentation of the patient. If debating whether a projection is acceptable always consider if the 'diagnostic question' has been answered.
5. Correct exposure: the evaluation of the suitability of the exposure factors used for a radiograph will depend on the equipment and medium used to acquire and capture the image.

Conventional screen/film-based imaging

- Image density: the degree of image blackening should allow relevant anatomy to be sufficiently demonstrated, thus allowing diagnosis.
- Image contrast: the range of useful densities produced on the radiographic image should correspond to the structures within the area of interest. Each anatomical area should be of sufficient contrast to allow relevant anatomical structures to be clearly visualised.

Digital image acquisition systems

Given the wide exposure latitude of digital systems, the primary task when evaluating the image is to assess for over- or underexposure. The imaging equipment will usually give a numerical indication of the exposure used, the EI. The reading is compared with a range of exposure limits provided by the manufacturer to see if it is above or below recommended values. Unfortunately, the method used is not standardised by the different manufacturers.

Underexposure: images that are underexposed will show unacceptable levels of 'noise' or 'mottle' even though the computer screen brightness (image density) will be acceptable (Fig. 1.4a).

Overexposure: image quality will actually improve as exposure increases due to lower levels of noise. However, once a certain point is reached, further increases in exposure will result in reduced contrast. Eventually a point is reached when the image contrast becomes unacceptable (Fig. 1.4b).

NB: There is considerable scope for exposing patients to unnecessarily high doses of radiation using digital imaging technologies. When evaluating images it is important always to use the lowest dose that gives an acceptable level of image noise. The EI must be in the appropriate range and must be within the national and local DRLs.

6. Optimum definition: is the image sharp? Look at bone cortices and trabeculae to ensure movement or other factors have not caused an unacceptable degree of image unsharpness.
7. Collimation: has any of the area of interest been overlooked due to over-zealous collimation? Check relevant soft tissues have been included. Also look for signs of collimation to evaluate the success of the collimation strategy you used. This can then be used for future reference when performing similar examinations. Collimation outside the area of interest will increase both radiation dose and image noise (due to increased scattered photons).
8. Artefacts: are there any artefacts on the image? These may be from the patient, their clothing, the equipment or the imaging process. Only repeat if the artefact is interfering with diagnosis.

Fig. 1.4a Underexposed digital radiograph.

Image evaluation – 10-point plan (cont.)

9. Need for repeat radiographs or further projections: a judgement is made from evaluations 1–8. If one or more factors have reduced the diagnostic quality to a point where a diagnosis cannot be made the image should be repeated. Would any additional projections enhance the diagnostic potential of the examination? For example, radial head projections for an elbow radiograph. If a repeat is required it may be appropriate to image only the area where there was uncertainty in the initial image.
10. Anatomical variations and pathological appearances: note anything unusual such as normal variants or pathology that may influence your future actions (see point 9) or aid diagnosis. For example, if an old injury is seen it may be worth questioning the patient about their medical history. This could then be recorded to aid diagnosis.

Fig. 1.4b Overexposed digital radiograph.