MEDECINS SANS FRONTIERES

X-RAY MANUAL

Guideline for implementation and provision of x-ray services

Internal document

2014 edition

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Foreword

This manual is intended to inform on all aspects of diagnostic imaging for MSF project sites. It is a collaborative effort of the Médecins Sans Frontières Diagnostic Imaging Working Group.

The Diagnostic Imaging Working Group also aims to issue a French edition in the near future.

The Diagnostic Imaging Working Group would be grateful for any comments to ensure that this manual continues to evolve and remains relevant to the realities of the field.

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Abbreviations

ALARA	As Low As Reasonably Achievable
AP	Anterior-Posterior
CR	Computed Radiography
CT	Computed Tomography
DI	Diagnostic Imaging
DICOM	Digital Imaging and Communications in Medicine
DIWG	Diagnostic Imaging Working Group
DR	Digital Radiography
EHDD	External Hard Disk Drive
EI	Exposure Index
FDA	Food and Drug Administration
FFD	Film Focus Distance
HIV	Human Immunodeficiency Virus
HR	High Resolution
ICT	Information and Communication Technology
IR	Image Receptor
IRS	Image Receptor System
LBD	Light Beam Diaphragm
MoH	Ministry of Health
MRI	Magnetic Resonance Imaging
NAS	Network Attached Storage
OC	Operational Centre
OCA	Operational Centre Amsterdam
OCB	Operational Centre Brussels
OCBA	Operational Centre Barcelona-Athens
OCG	Operational Centre Geneva
OCP	Operational Centre Paris
OT	Operating Theatre
PA	Posterior-Anterior
PET	Positron Emission Tomography
QA	Quality Assurance
QC	Quality Control
TB	Tuberculosis
ToR	Terms of Reference
UPS	Uninterruptible Power Supply
WHIS-RAD	World Health Imaging System for Radiography
WHO	World Health Organisation

1. Introduction to diagnostic imaging

The intersectional 'MSF Diagnostic Strategy' recommends access to x-ray technology as a standard diagnostic tool in TB/HIV programs and surgical programs with an orthopaedic focus.

This manual is intended for use by health advisors, medical doctors/clinicians, radiographers/x-ray technicians, biomedical engineers and logisticians for the planning and implementation of x-ray services.

The role of imaging in diagnosis

Radiology is a core component of diagnostics and x-ray plays an essential role in the adequate provision of diagnostic services. Radiographs are widely used in the diagnosis of chest pathologies, the musculoskeletal system in orthopaedic work and in the case of general trauma in emergency settings. This fits the profile of MSF, where many projects are established to address trauma, tuberculosis and HIV. The availability of radiographs helps to improve the quality of diagnosis, assess response to therapy, and guide interventions.

This manual describes diagnostic imaging in MSF to field and headquarters staff and informs on topics such as selecting x-ray equipment, aspects of radiation protection, training and human resources, quality control, and teleradiology, among others.

Procurement

All x-ray units, image receptor systems and accessory equipment that are recommended in this manual are available under the section 'Diagnostic Imaging' in the current Medical Catalogue, Volume 2, Part B.

Consumable items such as film and chemistry can be found in the 'X-ray Supplies' section, Volume 2, Part A.

Example checklists to guide procurement are also included in the Medical Catalogue, Volume 2, Part B, and are available as an Annex to this manual (see Annex 1).

Diagnostic imaging working group

The Diagnostic Imaging Working Group (DIWG) is an intersectional working group aiming to set and improve the standards on quality of medical imaging in MSF projects.

For any questions on procuring or replacing equipment, installation, field visits, radiation protection, staff training, image interpretation, and other issues relating to diagnostic imaging please contact your medical/health advisor from your OC, the MSF intersectional radiographer/x-ray technician, as well as the biomedical engineer from your OC.

Legal considerations for X-ray archives

X-ray archives must be considered similarly to archives of medical files. Radiographs, even when stored as digital files, follow the same legal framework as all other medical records.

> You can direct questions related to diagnostic imaging to diagnostic.network@msf.org.

2. X-ray equipment

2.1 Overview of equipment

A radiology department includes several components of equipment. MSF projects may require a complete package of equipment items to begin providing x-ray services. However, some projects may only require replacement equipment items in order to support or improve an existing department. This chapter describes all items that are required in order to provide x-ray services and the rationale behind equipment choices. Complete details can be found in the following sections of this chapter, but firstly a brief introduction of all items:

2.1.1 An x-ray machine

This is the large piece of equipment that generates x-rays. Generally speaking, there are two types of x-ray machines: fixed or mobile. A fixed machine is larger and permanently installed in an x-ray room. A mobile unit is smaller and on wheels, and can be moved around a hospital or x-ray room as needed. A mobile unit however, requires more safety precautions and requires more experienced radiographers/x-ray technicians to operate safely and effectively.

2.1.2 An image receptor system (CR)

An image receptor system, often called CR (computed radiography), is separate to the x-ray machine and is the method in which the x-rays are captured for viewing. This can be done with film and chemistry processed in a dark room; or digitally, using a scanner and a computer. Both methods use x-ray cassettes, which are placed under the patient and the x-ray beam, and identical imaging technique by the radiographers/x-ray technicians. The only difference is how the image is captured and processed.

Film and chemistry requires x-ray cassettes containing film and a dedicated darkroom setup that uses chemistry to develop the film. A light box is also required for the clinician to view the film and make a diagnosis.

An **image receptor system (IRS)** or **computed radiography (CR)** system requires x-ray cassettes containing a phosphor screen, a scanner to process and erase the screen, and a computer to view and post-process the image by the radiographers/x-ray technicians. A high resolution medical computer monitor is also required for the clinician to view the image and make a diagnosis.

Generally speaking, all projects using film and chemistry are encouraged to transition towards digital imaging. Film and chemistry has proven to be one of the greatest challenges in resource-limited settings to achieving acceptable diagnostic image quality. For this reason the DIWG recommends a digital IRS or CR system for recording images.

2.1.3 Accessory equipment

Accessory items are also required such as radiation safety lead aprons, gonad shields, radiographic grid, positioning cushions and immobilisation devices.

2.2 X-ray units

2.2.1 What x-ray unit does MSF recommend?

Choosing diagnostic imaging equipment to be used in MSF projects must take many factors into account including technology advancements, the challenging environments of MSF project sites, cost and ease of use for staff who may have limited training.

The DIWG has searched for and field-tested equipment that is best suited to our clinical needs and work environments. For optimal diagnostic imaging provision we recommend an x-ray unit designed by the World Health Organization (WHO) developed especially for resource limited settings called:

WHIS-RAD (World Health Imaging System for Radiography)

The WHIS-RAD x-ray unit is straight-forward to use for technicians with limited training, has proven reliability under adverse environmental conditions, is easy to install, is low cost and has proven design for excellent radiation safety. The WHIS-RAD is capable of performing all routine general radiographic examinations.

Installation of the WHIS-RAD requires specific human resources support: within the mission, one member of the logistical team (logistics, biomedical or electrical) should be appointed as focal-point for the installation and should be present when the x-ray machine is installed by the manufacturer's technician. He/she will be trained together with the radiographer/x-ray technician on troubleshooting regarding installation, maintenance and repairs. The logistical team is responsible to make sure all requirements are set in place such as air-conditioning, electrical protection, networking, etc.

Figure 1: The main features of the WHIS-RAD x-ray unit

The WHIS-RAD is a fixed unit which requires its own x-ray room and some basic installation. It runs on a standard 16 A electrical outlet, but must be protected with a double conversion (online) UPS.

An indication of peak power consumption for an x-ray department including x-ray machine, digital imaging scanner, air conditioning, computer and online UPS is approximately 3800 W or 17 A.

Further information regarding power requirements can be obtained via the intersectional radiographer or directly from the biomedical engineer(s) at each operational centre (OC).

The cost of the WHIS-RAD is approximately € 20 000 - € 30 000 depending on the installation site (cost includes installation by manufacturer technician, 1 year warranty and spare parts kit). Costs and options for post-warranty corrective maintenance are negotiated at time of purchase.

2.2.2 What about mobile x-ray units?

As a general rule, the use of mobile x-ray units are not recommended for MSF project sites. The reasons for this are several: firstly, the successful and safe use of a mobile unit requires more user knowledge and competence than a fixed x-ray unit. To optimally use a mobile x-ray unit, a radiographer/x-ray technician must be well trained and highly experienced in mobile radiography. Secondly, there is the issue of increased radiation risk for the patient and those around the patient on the ward as the tube direction and the distance between the tube and patient can be varied; and lastly, there is likely to be increased damage to the unit itself when it is transported around a hospital with many uneven and bumpy surfaces. There is also concern about the power capacity of some low-end mobile units (< 16 kW) and their suitability for imaging of the chest, abdomen, pelvis and spine. The WHIS-RAD is recommended as it is more reliable, require less expertise for use due to fewer user variables, are safer and are less vulnerable to damage.

The exception to this may be in the case of an emergency where immediate x-ray services are required (as the WHIS-RAD requires an installation visit by the manufacturer) and where a mobile machine may be safely operated inside a tent. For further information regarding safe use of a mobile x-ray unit inside a tent, see point 4.3 ‘Radiation safety requirements for installations inside a tent’.

Installing a mobile x-ray machine also requires human resources support by an expatriate radiographer/x-ray technician and the logistical team. An expatriate radiographer/x-ray technician is necessary to provide training to national staff radiographers/x-ray technicians and evaluate the radiation safety aspects. The logistical team is responsible to make sure all requirements are set in place such as air-conditioning, electrical protection, networking etc.
Costs and options for post-warranty corrective maintenance of a mobile machine are negotiated at time of purchase.

Figure 2: The Siemens Mobilett mobile x-ray unit

2.3 Image receptor systems

2.3.1 Which image receptor system does MSF recommend?

As the x-ray beam passes through the patient it must be captured and processed in order to obtain a radiographic image. Traditionally this was done using x-ray film which needs developing with chemicals. Film and chemistry, however, have proven to be one of the greatest challenges in resource-limited settings to achieving acceptable diagnostic image quality.

For this reason the DIWG recommends a digital IRS for recording images. The IRS or often called CR system is made up of digital cassettes, a cassette scanner and a computer viewing station. The digital IRS is a separate component to the x-ray unit itself.

Instead of cassettes that hold x-ray film, the IRS uses cassettes holding digital plates made from phosphor. These plates are passed through a digital scanner and viewed on a computer monitor. The phosphor plates can be used for approx. 10 000 images and do not need to be replaced after each image like an x-ray film.

The digital imaging scanner is a scanner that can be positioned on a desk.

The cost of an IRS is approximately € 20 000 which includes the digital imaging scanner, the radiographer's/x-ray technician's workstation computer with a high-resolution monitor and a set of x-ray cassettes. There are no consumable items for an IRS. MSF recommends the Agfa CR-10X or Fuji Prima T models with the Agfa system being the first choice. However, the Carestream CR models were previously MSF standard and may be in use in some projects.

Figure 3: The Agfa CR 10X digital image receptor system

Figure 4: The Prima T CR digital image receptor system

A digital CR system can also be bought alone to replace a film and chemistry processing system while retaining a functioning x-ray unit.

Changing over to a digital CR system is highly recommended for all field sites continuing to use film and chemistry.

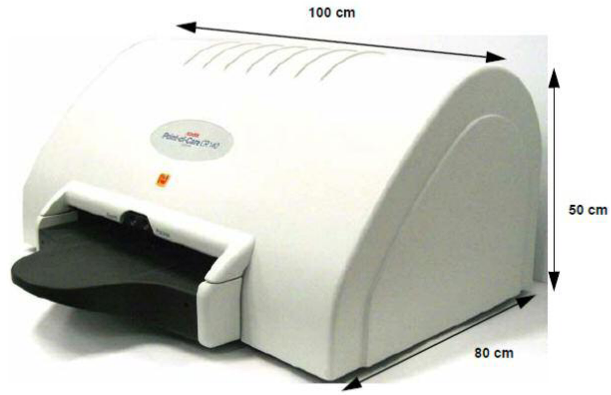


Figure 5: The Carestream CR digital image receptor system

2.3.2 What computers are needed to process and view a digital x-ray?

As digital images are not viewed as film on a light box, two additional computers and monitor workstations are required with the IRS. One is a standard computer and monitor (referred to as the IRS computer), which is used as a radiographer/x-ray technician workstation to process and archive digital images. The second is a high resolution (HR) medical workstation (referred to as the HR computer) used by clinicians to view radiographic images for diagnosis.

Digital x-ray images are produced in a medical imaging file format called DICOM (Digital Imaging and Communications in Medicine). When a clinician is viewing an x-ray image in DICOM format for making a diagnosis, a medical grade monitor that meets minimum requirements for resolution, contrast and brightness is required. Viewing a digital x-ray image by a clinician **for diagnosis** should always be on a **high resolution medical monitor**, not on a standard computer monitor (see catalogue item EDIMMONI30- for technical specifications for the HR monitor). Every project site that has digital imaging should therefore have **at least one** high-resolution medical monitor. The computer to which the HR monitor is connected is preferably an MSF standard computer. However, it may be necessary to deviate from MSF standard in order to mount a compatible video card for the monitor. Consult your sectional ICT (Information and Communication Technology) department for advice.

The HR computer can be located away from the x-ray room, optimally in a location with convenient access by clinicians. In projects where the workload is relatively low, it is possible for the radiographer/x-ray technician and the clinician to use the same workstation, in which case only one computer will be required.

The digital imaging scanner is connected directly to the IRS computer by a USB cable supplied with the scanner. Where an internal network is available, both the IRS computer and the HR computer can be connected to this network allowing image transfer between the two computers. Where no such internal network is available, the images can be transferred between the digital imaging scanner and the HR computers by connecting them directly using an ethernet crosscable. Alternatively, manual transfer of the images is possible by a USB key or external hard drive.

The radiographer's/x-ray technician's workstation runs the IRS software in order to view DICOM files; however, viewing these image files on the clinicians' workstation requires its own program: a 'DICOM Viewer'. The DICOM Viewer program recommended and supported by the DIWG and ICT WG is called **Clear Canvas** and the 'Community Edition Release' is available as a free download at: http://sourceforge.net/projects/clearcanvas/files/?source=directory. Select

'**DICOM Viewer**' and then download the '**CCDicomViewer2.0SP1.zip**' file for installation. (If your project has migrated to Windows 7, please then install the 64 bit edition).

Further ICT support is available directly from each OC or via the DIWG.

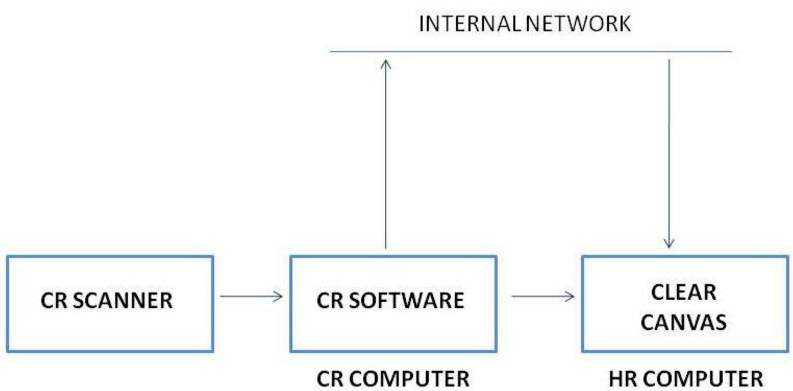


Figure 6: Set-up of digital imaging scanner and computers

2.3.3 How are images made available throughout the hospital?

Once the radiographer/x-ray technician has processed the image, it can be networked to the computer with the medical grade monitor or printed on a diagnostic quality printer (see below) for diagnosis. It is up to each project site to determine the best way to make these images available throughout the hospital. Suitable options depend on whether the image is being viewed for initial diagnosis or for review.

Standard computers

X-ray images can be exported from the radiographer's/x-ray technician's workstation or the clinician's workstation as a JPEG file to be saved on a USB key, hard drive, or copied onto a CD/DVD for viewing on a standard computer monitors. However, this image **should never be used for diagnostic purposes** but as a review only. Standard computer monitors do not have sufficient resolution for diagnostic purposes.

Portable devices

Portable devices such as iPhones, iPads, and digital picture viewers must not be used for initial diagnostic viewing of digital x-ray images but may be used for review of a case. The FDA (The U.S. Food and Drug Administration) has approved a DICOM app for iPads/iPhones; however, it is for exclusive use with CT, MRI and PET scans only, as these modalities require far less resolution for viewing than digital x-ray images. This **app is not approved for diagnostic purposes for digital imaging receptor images**. Full FDA news release is available here:
http://www.fda.gov/NewsEvents/Newsroom/PressAnnouncements/ucm242295.htm

Diagnostic Printers

In addition to viewing x-ray images on the HR monitor provided with the digital imaging scanner, if hard copies are required, x-rays can be printed with an x-ray film printer. X-ray film printers are dedicated diagnostic imaging medical printers that print x-rays on blue x-ray film. There are several options for x-ray film printers that produce diagnostic quality films such as the AGFA 5300 and the Fuji Drypix Lite. These printers have a mandatory DICOM input channel which receives DICOM image print requests from the IRS workstation. Using thermal technology, images are printed on blue film in high quality and adequate grey scale to be viewed on traditional light boxes. Unlike 'conventional' x-ray film development these are daylight printers; a dark room isn't required for the film or printer. Blue-based x-ray films are consumable items and must be the same brand and compatible with the printer. The printers use thermal technology and do not require cartridges. To evaluate the printer and film options that are compatible with the IRS available in your project, please contact your sectional biomedical engineer or the intersectional radiographer/x-ray technician.

Paper printed copies from a standard printer are **not of diagnostic quality** and **should not be used for diagnosis**.

2.3.4 How do we back up digital x-ray images?

A digital IRS produces a high volume of data; each image will be about 10 MB. It is important to size the storage capacity of the system appropriately and to have good data backup in case of problems. It is recommended that the ICT department within each section prepares a 'ghost image' of both the radiographer's/x-ray technician's workstation as well as the clinician's workstation to allow quick re-installation in case of computer breakdown. These 'ghost images' must be made available to the ICT-responsible in the field to allow them to re-install these workstations quickly if required.

In addition, backups must be made of the image data. There are three options for this:

DVD backup

Image files can be periodically backed-up to writable DVDs. The advantage of this method is its simplicity. The disadvantages are that any images made after the last back-up could be lost if the system malfunctions. Depending on the storage capacity of the system, images may need to be deleted and so will only be available on the DVD for viewing at a later date.

EHDD (External Hard Disk Drive)

Image files can be periodically backed-up on EHDDs. Compared to using DVDs the higher storage capacity of an EHDD is an advantage. In cases where no ICT expertise is available to install a NAS (see below) an EHDD is be the preferred option. The main disadvantage is the loss of data due to loss of the EHDD itself, corruption of the EHDD due to unsafe removal from a computer or due to overwriting the backups by newer data.

NAS (Network Attached Storage)

Image files are not stored on the computer but directly to a storage device on the network. The advantages of this method are that images can be viewed even when the radiographer's/x-ray technician's workstation is not on and all images previously made will be available for viewing. In addition, the NAS can be configured for automatic backup by keeping duplicate copies on separate hard drives. This has the disadvantage however of being more complicated to install.

2.3.5 Why did we change from developing film to digital?

Film requires 'wet developing' with the use of chemicals in a dark room. Using chemicals produces waste, is time consuming, and requires running water and drainage. It is also technically more difficult to obtain an image of high quality considering the many variables in wet developing. It might take up to 30 minutes to develop, fix and dry an image inside the darkroom. This process often results in artefacts and image faults. In addition, it is becoming increasingly more difficult to procure manual film processing equipment and x-ray film.

With a digital imaging scanner the image is available for viewing on a monitor in just a few moments. The image can be manipulated for improvement, which may save the radiographers/x-ray technicians from having to repeat a poorly performed radiograph and the patient from receiving a double dose of radiation. This is very important in the field where radiographers/x-ray technicians are often not formally trained. Additionally there is a greater margin for exposure error with a digital IRS.

The computer memory acts as a 'filing room' which not only saves space but also allows for quick retrieval of previous radiographs.

When considering the cost of film and chemistry, a digital IRS has also been calculated to be cheaper in the long run considering there is no longer a need for film and chemistry consumables.

Digital radiographic image acquisition also provides the advantage of rapid consultation over the internet with radiology experts via teleradiology. For more information, see chapter 8 'Teleradiology'.

2.3.6 Who will report on the x-rays?

While radiographers/x-ray technicians are medical professionals who operate x-ray equipment to produce radiographs, a radiologist is a consultant physician specialised in interpreting radiographs. Radiologists are not widely available to the field except in exceptional circumstances or for short training periods, therefore most radiographs in the field will be read by a locally available physician or clinician.

Teleradiology allows for specialist interpretation of radiographs by radiologists who are off-site. Ideally, a digital x-ray system is required for this service. For more information see chapter 8 'Teleradiology'.

2.4 Accessory equipment

There are several items of equipment that are required in an x-ray department. These items are for radiation safety, to assist the radiographers/x-ray technicians in positioning both the patient and the x-ray cassette, and also to improve image quality.

2.4.1 Lead aprons, gonad shields and thyroid collars

Why do I need protective lead garments?

Protective lead aprons, gonad shields and thyroid collars are made of lead or lead equivalent material and are worn to protect the body against ionizing radiation during an x-ray exposure. A lead apron and thyroid collar (lead shield worn around the neck) should be worn by all staff or carers of a patient who must remain in the x-ray room during time of exposure. A gonad shield is a lap apron also made of lead or lead equivalent material that can be given to a patient for extra protection during an x-ray examination when placed outside of the area of interest.

Figure 7: Lead aprons

2.4.2 Portable x-ray grid

Why do I need to use a grid?

A portable x-ray grid allows only the primary radiation to pass to the cassette while absorbing secondary or scattered radiation. It filters out randomly deflected radiation that can blur a radiograph. It consists of a housing containing lead foil strips separated by x-ray transparent spacers that are filled with aluminium. Absorbing scattered radiation makes a significant difference to the image contrast and diagnostic quality of a radiograph.

Figure 8: Portable x-ray grid

When do I need to use a grid?

An x-ray grid is a necessary accessory when using a mobile x-ray unit (fixed x-ray units such as the WHIS-RAD already have an x-ray grid built into them). A grid should be used with a mobile x-ray machine when imaging the following anatomy:

– Thoracic spine: AP & lateral views
– Lumbar spine: AP & lateral views
– Abdomen: AP & decubitus views
– Pelvis: AP & oblique views
– Hips: AP & lateral views

How do I use a grid?

The grid is placed on top of the x-ray cassette and positioned underneath the patient. There is a top and a bottom side to the grid; ensure that it is placed with the correct side facing upwards (this is identified on the grid itself). Also ensure that the grid is placed flat and perpendicular to the x-ray beam. Clean the grid regularly with warm, soapy water.

There are many different types of grids available and the following specifications are those of the grid available in the MSF medical catalogue:

– Parallel lines (i.e. not focused)
– 40 lines/cm
– Grid ratio 8:1
– 35 x 43 cm
– Carbon fibre protective cover (or similar)

A grid that meets these specifications has the most versatility for use in MSF projects. A different grid, i.e. with focussed lines or a lower grid ratio, can cause artefacts on the x-ray image. Using the wrong grid or using a grid incorrectly results in artefactual lines over the length of the image. This phenomenon is known as 'grid cut-off'. Grids are very durable when they are covered in carbon fibre, however, they should always be treated with care.

2.4.3 Positioning cushions

Why do I need to use a positioning cushion?

Positioning cushions assist the positioning and immobilisation of a patient or cassette when taking an x-ray. They reduce the need for repeat imaging resulting from patient movement and can also be used to support the x-ray cassette in the necessary position. They are particularly useful when imaging patients after trauma or surgery when patients have limited power and control over their movement.

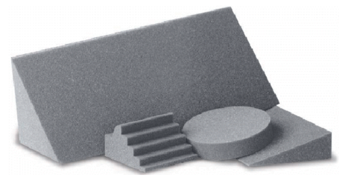


Figure 9: Portable positioning x-ray cushions

What can be used as a positioning cushion?

Positioning cushions must be made of radiolucent material specifically designed for use in an x-ray department and covered in a material that can easily be cleaned with warm, soapy water. While it may be possible to support a body part with another item found in the hospital or x-ray room, these items are rarely completely radiolucent. As their purpose is to directly support the body in an area within the x-ray beam, a non-radiolucent support can cover anatomy on a radiograph or produce artefacts that can be interpreted as pathology. A set of positioning cushions designed for medical use are described in the MSF medical catalogue.

Several positioning cushions should be available in each x-ray department in different shapes and sizes. The following dimensions can be used as a guide:
– 18 x 12 x 18 cm
– 7.5 x 7.5 x 18 cm
– 18 x 7.5 x 18 cm
– 18 x 18 x 48 cm

2.4.4 Immobilisation device

When do I use an immobilisation device?

An immobilisation device, such as a sandbag, can be used to limit the movement of a patient when taking an x-ray. As the object is heavier than a positioning sponge, it can apply adequate pressure to hold a body part in place.

Figure 10: Immobilisation device

Why are there no immobilisation devices in the MSF medical catalogue?

Sandbags can easily be made locally and as they are placed outside of the x-ray beam, there are fewer restrictions to their material or design. Ensure that the sandbags are adequately sealed and use a cover material that can easily be cleaned with warm, soapy water. The material does not have to be made of radiolucent material as they should always be used outside of the x-ray beam.

3. X-ray darkroom and manual processing

Manual film processing is no longer recommended in MSF. It is strongly advised that all departments move from manual film processing to a digital IRS.

Manual film processing in a dark room is one of the greatest limitations to achieving high diagnostic images. In addition, manual imaging requires significantly more skills of the radiographers/x-ray technicians than a digital IRS.
However, for those departments where we utilise a functioning darkroom and manual film processing, Annex 2 & 3, describes the minimum standards for a darkroom and manual processing procedures for radiographers/x-ray technicians.

> *Note*: It is never recommended that we implement manual processing in our x-ray departments due to the high level of training required for radiographers/x-ray technicians and the difficulties in ensuring diagnostic quality.

4. X-ray room structural requirements

X-rays are generated as a primary beam and are focused to the body part of interest (primary radiation). However, once x-rays pass through the body, some are absorbed and some are reflected as scatter (secondary radiation). In order to protect staff and patients from a risky exposure to secondary radiation strict criteria must be applied to the space in which an x-ray installation will be located.

All x-ray units require specially shielded rooms or areas to protect the radiographers/x-ray technicians and others who may be nearby. The site plan for all x-ray installations should be discussed with the intersectional radiographer/x-ray technician and the Field Support Unit/building referent within each OC. The design of an x-ray room should also be approved by the local regulatory authority wherever possible.

4.1 The x-ray department

The x-ray department should be located on the ground floor, close to the outpatient department as the majority of referrals will come from this department. It should also be located in an area where it will be easy to bring inpatients from the wards or the operating theatre.

An x-ray department will require two separate rooms:
- X-ray room with an x-ray unit and an optional cubicle for the x-ray control panel.
- Office/viewing room for image viewing, processing and administration. This room is also accommodates the x-ray control panel where there is no cubicle inside the x-ray room.

Whether the control panel is located inside the office/viewing room or behind a cubicle in the x-ray room, the patient should always be visible via a lead glass window (see also 'Cubicle for x-ray control panel' under point 4.2.6).

The x-ray department should have two doors: one is the patient entrance into the x-ray room from the waiting area; the other will be the door to the office. Ideally, the office should have one door to the control cubicle or x-ray room and one to the hospital corridor or waiting area (see figure 11).

4.2 Room requirements for x-ray installations for fixed and mobile machines

When considering room design, all methods should be used to minimise unnecessary exposure to both the primary x-ray beam and secondary x-ray scatter. The following recommendations are relevant to both the WHIS-RAD x-ray machine and a mobile x-ray machine when being installed in a healthcare facility. Exact shielding requirements are based on very detailed calculations by medical physicists and are also based on estimates of workload. As exact workload is often difficult to predict for every project site and construction and local radioprotection guidelines etc. can differ, the following conservative, universally applicable radiation protection requirements are recommended:

4.2.1 Room size

For a basic x-ray department with one x-ray unit and one office room a **minimum** space of total 25 - 30 m^2 is required. The x-ray room itself should be 16 - 24 m^2. This size ensures that there is sufficient space for a permanently built-in protective cubicle inside the x-ray room. If the x-ray control is to be located in the adjacent office/viewing room then the x-ray room may be a minimum size of 16 m^2. Bear in mind that the larger the x-ray room, the safer the space, as x-rays lose energy as they travel further.

4.2.2 Walls

The **minimum** size of an x-ray room is 16 m^2 and the walls should be built with material that absorbs radiation equivalent to 1 mm of lead, such as:

- 12 cm baked solid clay brick, or
- 8 cm solid concrete (density 2.35 g/cm^3), or
- 1 mm lead sheet over other wall materials.

In cases where an x-ray room is located in an already built structure of different material:

- If the construction is made of dry walls (wood/chipboard/plywood etc.), lead sheet of 1 mm must be used.
- If the construction is made of steel (i.e. hospitainer) lead sheet of 1 mm must be used.
- If you have a building made of brick types that are made with holes, an additional 1 mm lead lining is required to prevent radiation passing through the opening areas.
- If 1 mm lead sheets are not available, mobile x-ray shielding screens (available in the MSF medical catalogue) can be used as an alternative.
- Walls should be protected up to a height of 2 m.

Lead Sheeting

Where lead sheet is used, the sheets must overlap by a minimum of 10 mm or the joints must be covered with strips of the same thickness of lead. The use of lead sheet can be problematic due to its tendency to creep under gravity. Sheets must therefore be supported on both sides such as in a glued lead ply sandwich or similar supporting material. For further information on fastening sheet lead, please see Annex 4.

4.2.3 Doors and corridors

The entrance door should be 110 cm wide without step or threshold in order to allow easy passage of a patient trolley.

Ideally, access doors should be sliding doors as they can overlap at each side of the opening at the point where the door meets the wall. This overlap should be 10 cm on either side giving additional protection.

All door types should be lined with lead sheet of 1 mm thickness. The door frame must therefore be made of iron or steel to carry the weight of the lead sheet.

Always ensure that the width of the corridor is wide enough to allow a patient trolley to turn into the door of the x-ray room.

4.2.4 Ceiling and floors

The ceiling height should be a minimum 2.5 m to permit full angulation of a mobile x-ray tube arm and to accommodate the WHIS-RAD. Always check the precise ceiling height required against specifications of the x-ray machine.

If the space above is occupied, the thickness of the ceiling slab should be at least 10 cm.

Single storey buildings do not require a ceiling slab.

The floor should be level and strong enough to support the x-ray tube stand, which may weigh as much as 300 kg concentrated on a small area (20 x 30 cm). The best material is levelled concrete, covered by wood or PVC (polyvinylchloride). The floor should be waterproof, washable and free of dust.

If the x-ray room is above ground level, the floor must be a solid concrete slab of density 2.35 g/cm^3 and a thickness of 15 cm.

4.2.5 Windows and air conditioning units

The x-ray room is a closed area. This ensures radiation safety and also prevents dust entering the room. Dust and humidity can damage the equipment, therefore, a closed x-ray room and office should always be well ventilated. Forced ventilation (i.e. air conditioning) is recommended. Air conditioning is necessary if the indoor temperature may exceed 35°C and/or 70 % humidity. An air conditioning unit also protects against a dusty environment as doors and windows do not have to be open to get fresh air. The cold air from the air conditioning should not be directed immediately at the x-ray tube.

Windows and air conditioning units should be situated at least 2 m above the ground, measured from the outside of the room. If windows are lower than this height, the space outside of the window must be protected by 2 m radius so that nobody outside can be exposed to radiation. If this is impractical, the window should be blocked with 1 mm lead sheeting.

Windows of upper floor x-ray rooms can be of normal height provided there is no link to corridors or adjacent rooms (i.e. only to the outside).

An air conditioner should be purchased, installed and supported locally.

4.2.6 Cubicle for x-ray control panel

Those who work in an x-ray room should be protected at the generator control panel by a fixed barrier or a protective cubicle. This cubicle should allow space for the control panel as well as the operator (see Figure 11) and should be positioned in such a way that any radiation reaching the radiographers/x-ray technicians is reduced to an absolute minimum. The cubicle should be located so that unattenuated direct scatter radiation originating on the examination table or the bucky does not reach the operator in the cubicle. See figure 12 for examples of x-ray cubicle position.

The cubicle should be at least 1.75 m wide and the x-ray control panel should be fixed within the cubicle be at least 0.5 m from any open edge of the cubicle wall nearest to the examination table.

The cubicle should have at least one viewing window which will be placed so that the radiographers/x-ray technicians can view the patient during any exposure. The size of the lead acrylic or thick plate glass window should be at least 30 x 30 cm with at least 0.5 mm lead equivalence (see Figure 11).

The lead equivalence of the wall or panel as well as the protective glass should be 1 mm, i.e. 12 cm solid brick or 1 mm lead sheet.

The lead glass and protective material must overlap each other by at least 10 mm. All other structural joints should also overlap by 10 mm.

The minimum height of the cubicle is 2.1 m. Protection should extend down to the floor (small gaps at the base for cables are permissible).

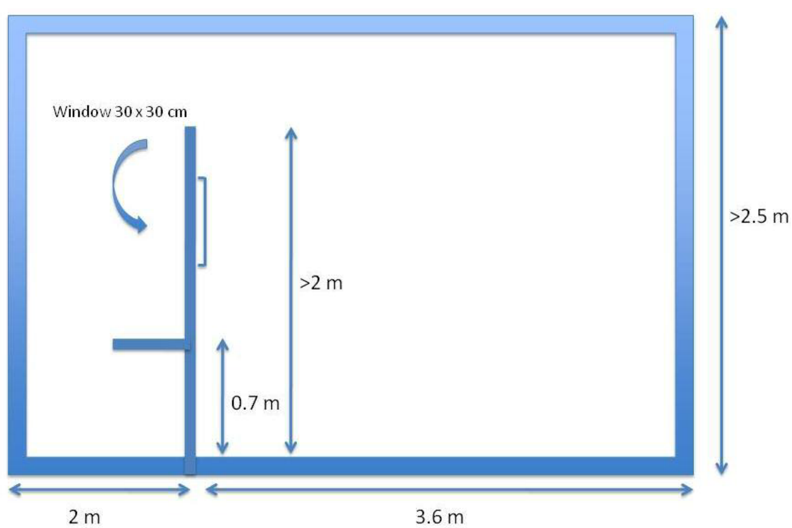


Figure 11: Cross-section of x-ray room showing cubicle wall inside the room for x-ray control panel, including window with 30 x 30 cm lead glass

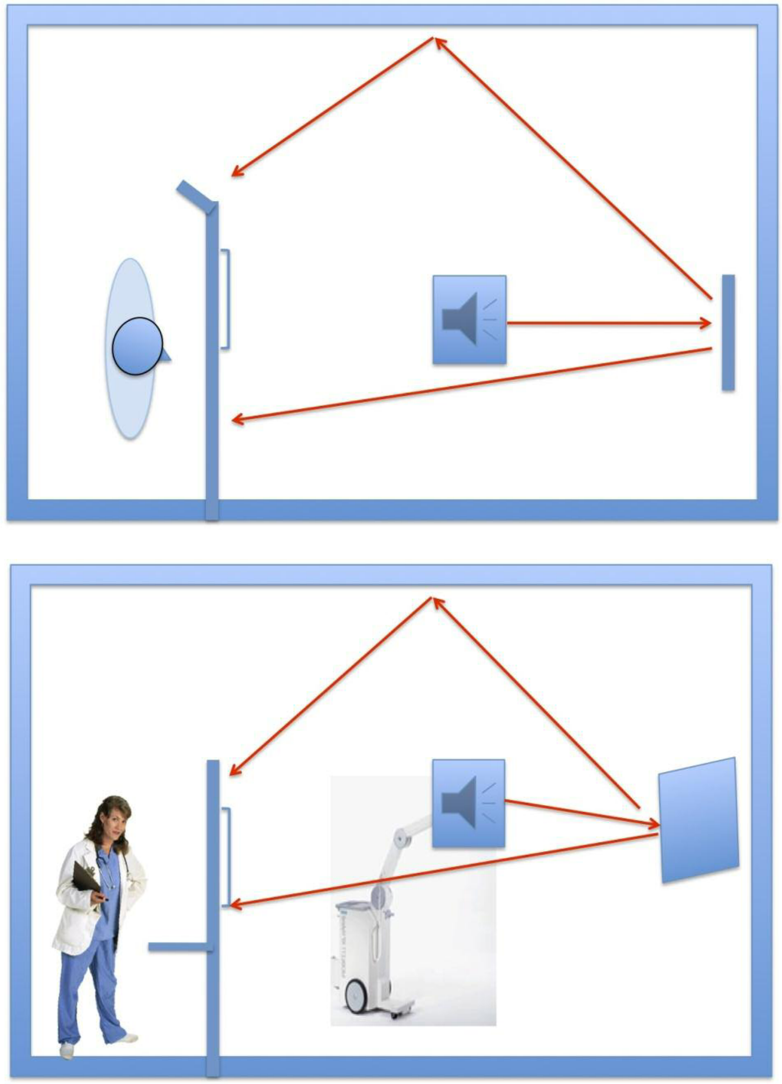


Figure 12: Arial and cross-sectional view
of how a cubicle protects staff from scatter radiation

4.2.7 Patient changing room

Providing a changing room for patients to prepare for their examination while the x-ray room is occupied can be beneficial in departments where patient load is high. When the changing room leads into the x-ray room the doors must be lined with at least 1 mm lead sheet.

Access doors from the changing room into the x-ray room must be lockable from the x-ray room side to prevent patients entering during radiation exposures.

4.2.8 Radiation warning signs

An internationally recognized radiation warning sign must be displayed at all entrances to the x-ray room. Warning lights for x-ray room entrances are not always necessary but should be considered for any entrance which cannot be observed or locked by the radiographers/x-ray technicians. Signs should be positioned at eye level adjacent to the room entrance with a recognised danger symbol and the words 'Caution: X-rays' (or similar).

4.2.9 X-ray department layout

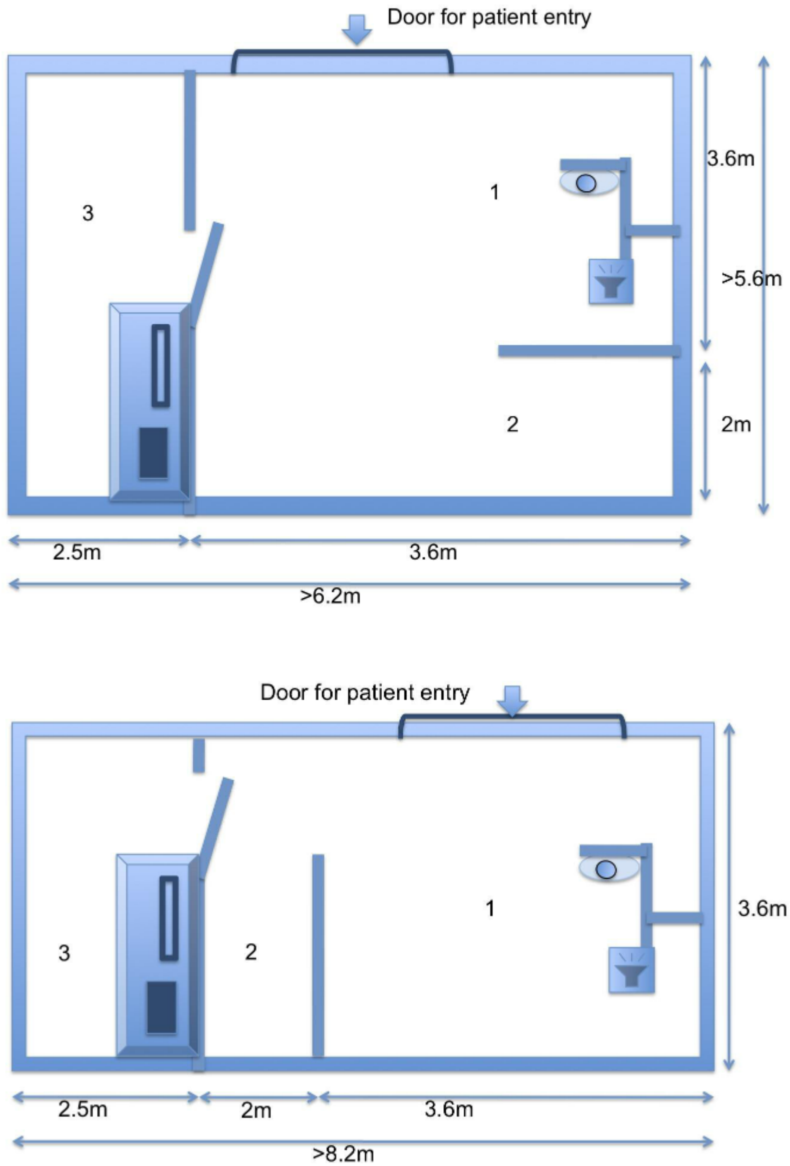


Figure 13: Example layouts of an x-ray room.
All dimensions are shown in meters.

1. X-ray room
2. Cubicle for control panel
3. Office for digital imaging processing

4.3 Radiation safety requirements for installations inside a tent

In an emergency situation where a mobile x-ray unit will be used inside a tent, there are different radiation safety considerations.

A lead-lined space inside the x-ray tent must be provided for the radiographers/x-ray technicians to safely work behind. This can be created by using two mobile radiation protection barriers (ITC code: EDIMRPBA1M-). Alternatively, a fixed cubicle can be built, similar to the standard x-ray room as described previously.

This lead lined space must be large enough to comfortably hold a table for the digital imaging scanner and computer.

The x-ray unit should be positioned towards the back of the tent and the radiographers/ x-ray technicians work area should be towards the front of the tent. This ensures that the radiographers/x-ray technicians are able to control the entry of staff and patients into the tent and avoid inadvertent entry into the radiation area.

Note: Ensure that the outside area of the back of the tent around where the x-ray unit is placed is restricted by at least 2 m so that nobody outside the tent is inadvertently exposed to radiation.

Patients who are waiting for imaging must not wait inside the tent, but in a waiting area outside the tent.

Radiation safety lead aprons and thyroid collars must be available for use.

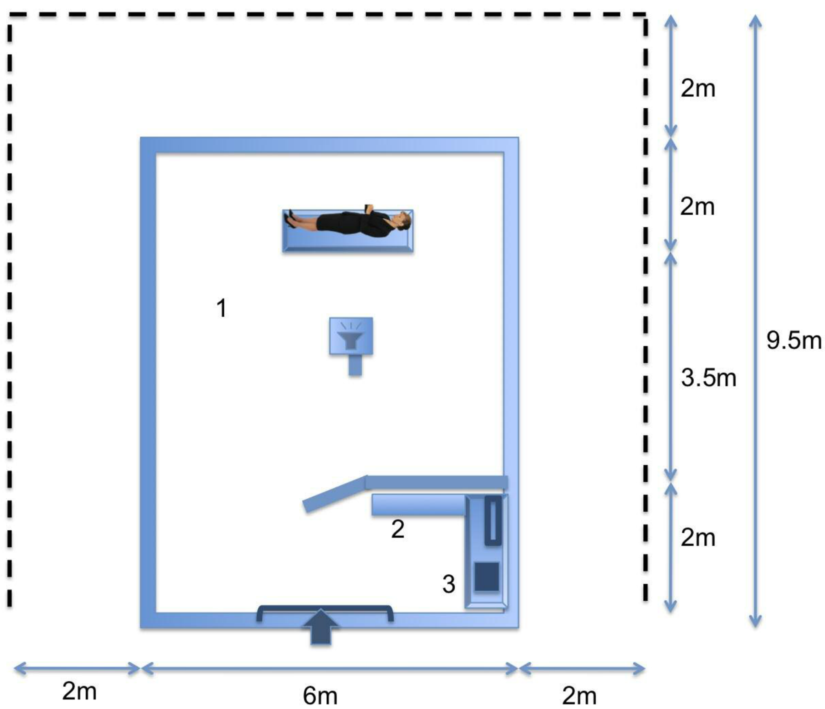


Figure 14: Example layout of an x-ray tent

Note: the tent is restricted around the outside by 2 meters.
1. X-ray room
2. Cubicle for control panel
3. Radiographers desk with digital scanner

5. Fluoroscopic x-ray systems and the operating theatre

5.1 Fluoroscopic x-ray system (C-arm)

A fluoroscopic x-ray system, also called c-arm, is an imaging device, which uses x-rays to produce a live image which is displayed on a monitor. It is used inside an operating theatre (OT) when intraoperative fluoroscopic guidance is required. The most common use of a fluoroscopic x-ray system in MSF projects is within orthopaedic surgical programs. Fluoroscopic x-ray systems allow an orthopaedic surgeon to see in real-time the exact placement of nails, screws and pins, and assess bone alignment when reducing fractures.

Figure 15: Fluoroscopic x-ray system (i.e. C-arm)

5.1.1 What kind of fluoroscopic x-ray system should be purchased?

A fluoroscopic x-ray system must be clinically versatile, have excellent image quality with low radiation dose and be affordable. It should be suitable for use with orthopaedic cases in the operating theatre. Fluoroscopic x-ray systems have been successfully placed in several MSF projects and the DIWG continues to field trial and assess the suitability of various models.

The cost of a fluoroscopic x-ray system is approximately € 70 000.

Note: The selection of a suitable fluoroscopic x-ray system should be discussed with the intersectional radiographer/x-ray technician and the biomedical engineer of the OC.

5.1.2 Who can operate a fluoroscopic x-ray system?

Using a fluoroscopic x-ray system requires the same level of training as other radiology equipment and should be considered equally. It is therefore only to be operated by a radiographer/x-ray technician or physician/surgeon who has undergone training in both the fluoroscopic x-ray system and in radiation safety. In the extreme cases where this is not feasible, operating theatre nurses may be trained in the mechanical functioning of the unit but the radiation is then to be produced only by the physician/surgeon using the foot pedal provided.

Local radiation laws should always be observed and may dictate who is legally allowed to operate medical radiation equipment.

It is highly recommended that an expatriate radiographer/x-ray technician accompanies all new x-ray installations and this includes fluoroscopic x-ray systems. All MSF appointed radiographers/ x-ray technicians should receive on-site training through an expatriate radiographer/x-ray technician. See chapter 6 'Training and Human Resources' for more information.

5.1.3 Who takes responsibility for the fluoroscopic x-ray system?

The **radiographer/x-ray technician** is responsible for operating the fluoroscopic x-ray system and for adhering to a regular cleaning schedule and to alert supervisors of any malfunctions/ problems. The radiographer/x-ray technician must also uphold all radiation safety regulations and ensure that staff/patients are following these regulations.

The field **biomedical engineer** is responsible to undertake regular maintenance and quality assurance checks according to the manufacturers guidelines.

5.1.4 What accessory equipment is required?

Wearing radiation protective lead aprons and thyroid collars is mandatory for staff in an OT when using a fluoroscopic x-ray system. Lead aprons with full protection (i.e. both front and back) and thyroid collars must be worn under sterile gowns by all staff remaining in the OT during x-ray exposure. Aprons protect staff from receiving an unnecessary radiation dose from scattered radiation. Consider how many people are present in the operating theatre during a standard procedure; it is recommended that 7 - 8 aprons/thyroid collars be made available.

> Please also consider if orthopaedic extensions are available for the surgical table in order to ensure radiolucency to x-rays.

5.1.5 Cleaning

The fluoroscopic x-ray system should be protected during the examination using plastic covers. The x-ray tube end of the fluoroscopic x-ray system and the foot pedal can be covered with any available plastic cover (i.e. plastic bag) as it is going under the table and does not need to be sterile. The detector end of the fluoroscopic x-ray system that is positioned over the patient must be protected with a dedicated sterile fluoroscopic x-ray system plastic cover. Where these are not available, a sterile drape secured with a Kocher clamp from the surgical kit is a suitable alternative.

The fluoroscopic x-ray system should be thoroughly cleaned using Surfanios solution at the completion of **every** examination, while unplugged. It is the responsibility of the radiographer/ x-ray technician to clean the fluoroscopic x-ray system.

5.1.6 What are the power and safety requirements?

Each unit will have slightly different requirements depending on manufacturer. Voltage, current and resistance parameters, for example, must be considered on a case-by-case basis depending on the unit purchased. As with all x-ray machines, a fluoroscopic x-ray system requires a double conversion UPS to protect the unit from unstable power supply and assure continuity of power.

The intersectional radiographer/x-ray technician and biomedical engineers from each OC can advise on this further.

5.1.7 Do we need to arrange a service contract?

Maintaining safety and function of a fluoroscopic x-ray system requires expert skills and it is for this reason that considering servicing and repair options must be arranged with the manufacturer at the time of purchase. Options available will vary from manufacturer to manufacturer. The DIWG have an arrangement with preferred manufacturers whereby a formal annual service contract may not be required, but conditions and costs for corrective maintenance are clearly defined at time of purchase based on the country of end use. The intersectional radiographer/x-ray technician and biomedical engineers from each OC can advice on service options for fluoroscopic x-ray systems as required.

5.2 Radiation protection in an operating theatre

The production of x-rays for use in medicine could lead to damage to living tissue. Provided protection measures are implemented, the risk of potential radiation-induced damage is minimal. The following practices should be considered when using fluoroscopy in an OT:

5.2.1 Room requirements

As a general rule, an OT should follow the same room requirements as an x-ray room for radiation safety:
- 12 cm kiln baked solid clay brick, or
- 8 cm solid concrete (density 2.35 g/cm^3), or
- 1 mm lead sheet over other wall materials.

However, as an OT is often larger than an x-ray room and the radiation output can be less, less radiation protection may be necessary.

Always discuss the requirements for radiation protection room requirements for an OT with the intersectional radiographer/x-ray technician or sectional biomedical engineer and verify against national regulations.

As a fluoroscopic x-ray system and the monitor trolley are heavy items (fluoroscopic x-ray system: 254 kg; monitor trolley: 138 kg), consider the need for floor reinforcement when operating inside a hospitainer.

5.2.2 Staff

Only staff essential to the procedure should be present in the OT. All staff should stand behind a lead protective barrier during exposure.

When there is no lead barrier or when staff is required to stand outside of the barrier, lead aprons must be supplied. Aprons protect staff from receiving an unnecessary radiation dose from scattered radiation.

Distance is the most important safety measure in reducing radiation dose to people not undergoing radiographic examination. Staff should stand outside the path of the primary beam and as far away as practically possible from the patient and the fluoroscopic x-ray system.

5.2.3 Pregnant patients and staff

- Every female patient of child-bearing age should be questioned as to the possibility of pregnancy.
- If the patient is unsure, perform a pregnancy test. If the patient is pregnant use an alternative examination or reschedule the procedure unless otherwise indicated by treating surgeon/physician.
- If the treating surgeon/physician decides that a pregnant patient must have the procedure, use shielding and minimum radiation dose.
- It is not recommended for pregnant staff to work inside an OT during fluoroscopy, even when wearing a lead apron.

5.2.4 Radiographic technique for radiographers/x-ray technicians

A fluoroscopic x-ray system must always be used with full radiation safety precautions in an OT and the following practices should be observed by the x-ray technician:
- X-ray beam should be centred directly over the area of interest.
- Collimate the radiation beam to the field size to decrease scatter radiation and to reduce the dose.

- Exposure time should be kept to a minimum. Avoid using the ‘continuous’ radiation option during fluoroscopy. Rather use the ‘pulsed’ option.
- Avoid long periods of radiation exposure by only screening intermittently with the radiation. With the ‘last image hold’ function, the last image will remain on the monitor after radiation exposure is stopped. When doctor/clinician requires a new image after repositioning, screen again.
- Reduce the need for repeat exposure by careful positioning and immobilisation of the patient or body part.
- Distance from the x-ray beam is always the best protection; don’t stand close to the fluoroscopic x-ray system if you don’t need to.
- Every person present in the OT must wear a full lead apron and thyroid collar.
- Always keep OT doors closed while working with x-rays.

5.2.5 Warning signs

There should be internationally understandable warning signs on the doors of the OT to indicate that x-rays are being produced. A warning light outside of the room, a large sticker or a flip-sign to signify x-ray use will help prevent unauthorised or inadvertent entry during a procedure.

5.2.6 Care of aprons

- To prevent damage to aprons when not in use, always hang them up on a hanger.
- Never fold aprons as this could cause cracks in the lead material.
- Undertake monthly visual inspections of all protective aprons for cracks, splits, rips or tears. Aprons should undergo an x-ray test once every 12 months to check for cracks in the lead that would let radiation through. For further information on testing of lead aprons, see chapter 11 ‘Quality Assurance’.
- Do not use defective aprons. If you find cracks in the apron, replace them immediately. Old lead aprons can be cut into pieces and the non-cracked areas can be used as smaller gonad shields.

6. Training and human resources

Diagnostic imaging support is a relatively new area within MSF and the number of x-ray installations is increasing across many programmatic areas. X-ray installations in MSF projects include both standard x-ray units and fluoroscopic x-ray units (i.e. c-arms) used in the operating theatre. As the frequency of x-ray installations increases, so should our capacity to train the radiographers/x-ray technicians at MSFs project sites.

6.1 Radiographers/X-ray technicians

In developed countries the profession of a radiographer/x-ray technician requires a university degree and registration with the appropriate health authorities. However, in many of the countries in which MSF is working, the lack and often poor quality of training facilities and academic institutions have left the door open for technicians who are not formally and/or properly trained to perform x-ray imaging.

Through field visits and evaluation of images undertaken in the past it has become apparent that a disparity exists between those sites that have benefited from expatriate radiographic training and those that have not had such training. The differences are noticed not only in the area of image quality and capacity of national staff, but also in the area of radiation protection where some sites were found to have grossly inadequate standards, potentially harming both staff and patients.

It is **strongly** recommended that an expatriate radiographer/x-ray technician accompany all new x-ray installations (including fluoroscopic x-ray system), also in emergencies.

6.2 Training by an expatriate radiographer/x-ray technician

For all new installations, the length of on-site training for MSF national radiographers/x-ray technicians will vary from 3 weeks to 3 months. In a country where there is a formal training structure for radiographers/x-ray technicians, 3 - 4 weeks may be sufficient to ensure safe and appropriate use of the x-ray unit and high image quality. In projects where there are no trained radiographers/x-ray technicians or skilled staff with a medical background, up to 3 months of training might be necessary to reach an appropriate and safe standard of practice. When selecting non-medical staff to be trained as radiographers/x-ray technicians, please discuss desirable criteria with the intersectional radiographer.

The intersectional radiographer manages a pool of radiographers/x-ray technicians and it is possible to request an English, French, Spanish or Russian speaking radiographers/x-ray technicians. Expatriate radiographers/x-ray technicians will be offered an expatriate staff contract and the project is required to cover the expenses of the visit. Please contact the intersectional radiographer for guidance in determining what length of assessment and/or training is recommended for your project site and to assist with hiring an expatriate radiographer/x-ray technician.

6.2.1 Main objectives for the expatriate radiographer/x-ray technician

– To accompany the installation of the x-ray unit/fluoroscopic x-ray system [as applicable].
– To evaluate safety measures in the x-ray room/OT and give recommendations for improvements/essential changes to current practice.

- To interview and hire national radiographers/x-ray technicians [where applicable].
- To train [i.e. theoretical and practical] national radiographers/x-ray technicians in the appropriate use and care of the x-ray unit/fluoroscopic x-ray system ensuring a high quality of diagnostic images. See details below.
- To inform and train staff on radioprotection standards and safe practices considering both staff and patients.
- To put protocols for daily tasks including quality control, image storage and safety practices in the x-ray department/OT into practice.
- To set-up teleradiology.
- To help set-up a system for archiving.

See Annex 5 for an expatriate radiographer/x-ray technician terms of reference (ToR).

6.2.2 On-site training for national radiographers/x-ray technicians includes

- Basic physics of x-ray production and properties.
- Use of the x-ray unit.
- Correct positioning and handling of patients.
- Determination of acceptable exposure factors for standard radiographic views.
- Image critique focusing on correct patient positioning, anatomy coverage, collimation and exposure.
- Use of the IRS including care of cassettes, periodic cleaning and maintenance of IRS screens and the scanner, use of the radiographer/x-ray technician computer workstation and all IRS software.
- Training in how to use teleradiology.
- Radiation protection principles according to MSF radiation protection guidelines.

See Annex 6 for an example of a national radiographer/x-ray technician job profile.

6.3 Evaluation of already existing x-ray units

For previously installed x-ray units or where MoH radiology facilities are utilised in the field, it can be difficult for someone without radiographic training to determine the adequacy of the x-ray unit in use, skill level of x-ray technicians and standard of image quality. An on-site evaluation of 1 - 2 weeks by the intersectional radiographer/x-ray technician or an expatriate radiographer/x-ray technician is therefore recommended to **all MSF run x-ray departments**. A visit to x-ray departments run by MoH or other partners can also be very useful. Evaluation field visits can be requested to the intersectional radiographer/x-ray technician to determine:

Capacity of the x-ray unit in your project

- Is the machine suitable to carry out the applications you need e.g. is it adequately powered?
- Does the machine rotate and lock the way it should?
- Does the machine require a maintenance/service visit?

Imaging processing: digital or chemical

- Are the radiographers operating the digital IRS appropriately?
- Is the film and chemistry system being used safely and appropriately?
- Is an image storage archiving system in place?

Standard of radiographers/x-ray technicians

- Are they adequately trained in positioning and exposures?

Radiographs

- Are they of an acceptable diagnostic standard?

Radiation safety practices

- Is the x-ray unit being operated safely?
- Are the radio-protective aprons in use still effective e.g. check for cracks?
- Is the x-ray room built according to safety recommendations?

Based on the outcomes of this evaluation, it can be determined if further follow-up training is required.

See Annex 7 for an example of an evaluation form for an x-ray department to be undertaken by an expatriate radiographer/x-ray technician.

7. Indications for x-ray imaging

This chapter covers general principles for requesting x-ray images as well as a list of x-ray views for each request. A standard list of indications is also included to inform when x-ray imaging can be helpful.

7.1 Referral guidelines

Indications for radiography should not be unduly restrictive as they may confirm the diagnosis, exclude the diagnosis, or reveal unsuspected pertinent findings.

– *Provide relevant clinical details on the request form, as well as a suspected working diagnosis.*

  Purpose of x-ray: Either a diagnosis is to be confirmed or ruled out. Most imaging investigations that do not specify an anticipated result turn out to be of little additional value. It often helps to try to formulate on the request form the purpose of the x-ray and how the result may impact or change the management. This step focuses on the decision making process whether or not to carry out the x-ray. It also helps the person interpreting the image to answer the question.

  Clinical details should include a brief summary of current symptoms and physical findings as well as pertinent past medical history such previous surgery or previous diagnosis of cancer or immune system compromise.

– *Only request an x-ray if the result will actually have an impact on the management of the patient.*

  For example, if pulmonary tuberculosis is suspected and proven by sputum tests, a chest x-ray is generally not necessary for diagnosis. However, a chest x-ray can use useful to exclude concurrent pathology or demonstrate complications of TB such as collapse, consolidation, pneumothorax, cavities etc. and serve as a baseline for follow-up and monitoring the evolution of disease. This can be particularly useful for paediatric patients.

  Similarly, if an abdominal perforation is suspected and the patient will go for a laparotomy, an x-ray is not indicated as it will not change management.

  An x-ray of the nasal bone is also unnecessary if you have clinical findings that the patient's nose is broken and there is no immediate treatment that needs to be done for which you require an image.

– *If a diagnosis is suspected* ***for which there is no treatment available****, it is not necessary to prove the diagnosis with an x-ray.*

  For example, in a patient with a head injury a skull x-ray to prove presence of a fracture is usually not indicated if there is no way to treat the related intra-cranial injury. The presence or absence of a fracture will not change management of that patient. (It may be necessary, however, to confirm a fracture where documentation of injury is required or to prompt observation or referral of a child).

  Similarly, if there is no treatment for spinal diseases such as stenosis, spinal x-rays are not indicated to confirm the diagnosis.

  However, if there is a differential diagnosis, then an x-ray may be helpful.

7.2 Standard and optional extra x-ray views

Below are the standard views for an x-ray according to each body part.

When sending a patient for an x-ray, please indicate clearly:
– The anatomy you would like to be x-rayed.
– The 'Left' or 'Right' side when requesting a limb x-ray.
– The standard views for that part of anatomy.
– Any optional extra views that you would like.
– Relevant clinical information and suspected diagnosis.

Anatomy Requested	Standard Views	Optional Extra Views
Chest	PA[a] if patient can stand AP[b] if adult patient is lying and for all children	Lateral
Abdomen	AP supine	AP erect or lateral decubitus
Pelvis	AP	Lateral Hip 'Frog leg' view for pediatrics
Upper Limb		
Shoulder	AP	Axial, trans-scapular (*when querying dislocation*)
Humerus	AP & lateral	
Elbow	AP & lateral	
Forearm	AP & lateral	
Wrist	AP & lateral	
Hand	AP & oblique	Lateral (*for foreign body*)
Lower Limb		
Femur	AP & lateral	
Knee	AP & lateral	
Tibia/Fibula	AP & lateral	
Ankle	AP & lateral	
Foot	AP & oblique	Lateral (*for foreign body*)
Spine		
Cervical	AP & lateral Lateral only for pediatrics	Odontoid (*for visualizing C1/2*), Swimmer's view (*when C6/7 is not visualized on lateral*)
Thoracic	AP & lateral	
Lumbar	AP & lateral	
Skull/Facial	AP & lateral	Water's view (*to assess facial trauma*)

[a] PA: Posterior-Anterior. I.e. back of patient facing the x-ray beam
[b] AP: Anterior-Posterior. I.e. front of patient facing the x-ray beam.

7.3 Standard x-ray indications

Chest (AP or PA view)	An erect **PA view** on full inspiration (demonstrating 10 posterior ribs) is the standard view. A supine **AP view** is indicated in paediatric patients and patients who are unable to stand for a PA view. A **lateral view** is helpful in determining if a mediastinal lesion is in the anterior/middle/posterior compartment or if a lesion is arising from the pleura, bone or muscular layer rather than in the lungs. It is also recommended in children suspected of TB and should be routine if available.
	Pneumonia in adults • In the absence of clinical improvement, it is advised to repeat CXRs 4-6 weeks after commencement of antibiotic therapy. If consolidation persists after that time it may be due to an atypical infection for which conventional antibiotics are not going to be effective, e.g. TB, or may be secondary to a centrally obstructing mass lesion.
	Pneumonia in children • Not routinely indicated.[1] • Indications for a follow-up CXR a) persistent symptoms despite treatment; causes for this would include an atypical infection such as TB or an endobronchial lesion such as an aspirated foreign body; b) round pneumonias when these can't be differentiated from a mass lesion. • Severely ill child. • Fever of unknown origin (sometimes children have pneumonia without showing clinical signs).
	Pleural effusion
	Haemoptysis
	Chest trauma • Not routinely indicated in minor trauma (e.g. proof of a rib fracture does not change management).
	Chest pain • Myocardial infarction: evaluate heart size and presence/absence of pulmonary oedema.
	Pericardial effusion
	Clinical cardiomegaly or heart failure

Abdomen	**Acute abdomen pain: suspicion of perforation or obstruction** • Supine abdominal x-ray (for gas pattern) • Erect abdominal x-ray (or left lateral decubitus view when a patient cannot stand) if supine abdominal x-ray is normal but clinically there is a strong suspicion of perforation. An erect abdominal or erect chest x-ray may be helpful in confirming a pneumoperitoneum in clinically equivocal cases. However, a) a normal x-ray does not exclude the presence of a pneumoperitoneum (20-60% of cases can be missed on plain film)[2]; b) if a pneumoperitoneum is suspected clinically, an x-ray is not necessary for confirmation of diagnosis since radiological signs may not always be present in this clinical scenario. However, an erect abdominal x-ray may be useful for demonstrating associated pathologies or possible causes. • A plain abdomen x-ray will demonstrate some obstructions (air-filled loops). Note: sometimes, obstructed, dilated bowel loops are fluid filled and therefore an obstruction may not be evident on an x-ray, hence clinical suspicion over-rules an x-ray which is negative for obstruction. Plain film detection for small bowel obstruction has an accuracy of 67%.[3]

Abdomen *(continued)*	**Abdominal trauma (see below: Trauma)**
	Not routinely indicated for: • Vague central abdominal pain or back pain • Gastroenteritis • Haematemesis • Pyloric stenosis • Uncomplicated appendicitis • Chronic constipation, encopresis or enuresis The preferred diagnostic tool for abdominal pathologies is ultrasound. Where no ultrasound service is available, an x-ray may be indicated to confirm calculus or obstruction in the case of pyloric stenosis in children.

Trauma	**Limb fractures** X-ray of the suspected fracture site as well as the joints above and below. Follow up films after reduction of a displaced fracture should be done to assess position.
	Major trauma: general screen in unconscious or confused patients • Cervical spine x-ray • Chest x-ray • Abdominal x-ray (will also demonstrate pelvis and spine) All views above can be obtained in the supine AP position.
	Major trauma: abdomen/pelvis • Chest x-ray: to exclude a pneumothorax large enough to necessitate chest drain insertion. • Pelvis x-ray: to exclude pelvic fractures. • Abdomen x-ray: in case of blunt or penetrating injury.
	Major trauma: chest • Chest x-ray: to exclude a pneumothorax large enough to necessitate chest drain insertion; to exclude haemothorax.
	Non-accidental injury in children • If a non-accidental injury in a child is suspected, an x-ray should be taken as formal documentation.

Musculoskeletal	**Extremities** • Suspected osteomyelitis • Septic arthritis where it is unsure if there is associated osteomyelitis • Suspected fracture (include views of the joint above and the joint below the suspected fracture) • Foreign body
	Spine • Indicated in TB endemic areas where bone destruction related to TB may influence management. • Not routinely indicated for patients presenting with waist/lower back pain with no history of trauma.

Skull	**Blunt or penetrating injury** (only where surgical intervention is available).
	Not routinely indicated for: • Headache • Possible pituitary problems • Possible space-occupying lesion • Epilepsy • Dementia or memory loss • Middle or inner ear problems • Nasal trauma • Sinus disease - mucosal thickening is a common incidental finding and not diagnostic

Recommendations based on European Referral Guidelines for Imaging (in conjunction with UK Royal College of Radiologists) and adapted for settings in which MSF operate.

References

[1] Integrated Management of Childhood Illness (IMCI)(2005). A joint WHO/UNICEF initiative. Geneva, World Health Organization/United Nations Children's Fund.

[2] Woodring JH, Heiser MJ (1995). Detection of pneumoperitoneum on chest radiographs: comparison of upright lateral and posterioanterior projections. *AJR*, 165:45-47.

[3] Maglinte DDT, Reyes BL, Harmon BH, Kelvin FM, Turner WW, Hage JE, Ng AC, Chua GT, Gage SN (1996). Reliability and role of plain film radiography and CT in the diagnosis of small-bowel obstruction. *AJR*, 167, December.

7.4 X-ray examinations involving contrast media

What is contrast media?

Contrast media is the term given to the different substances introduced into the body to assist visualization of internal structures during medical imaging procedures. There are many different types of contrast media which are used and administered in various ways specific to the indication and type of medical imaging examination being performed.
The two main types of contrast media relevant to MSF projects are:

– Gastrointestinal contrast media, e.g. barium sulfate solutions, Gastrografin®
– Iodine based intravenous (IV) contrast media

These types of contrast media are radio opaque, meaning they restrict the transition of radiation. As a result, contrast media appears a shade of white on x-ray and CT images, which provides a distinct contrast compared with surrounding structures.
Other forms of contrast media exist such as gadolinium based agents for MRI and contrast enhanced ultrasound agents, however these are beyond the scope of MSF projects.

Contrast media in MSF projects

Contrast media examinations are typically performed and/or reported by radiologist’s and are adjusted according to the clinical indication and condition of the patient at the time of the examination.

The use of contrast media is currently **not** approved in MSF project sites.

Detailed history taking, physical examinations, patient monitoring, plain film x-ray and/or ultrasound, telemedicine consultation and good surgical judgment/intervention are more appropriate in the context of MSF projects.

8. Teleradiology

8.1 What is teleradiology?

Teleradiology is the use of telecommunications to deliver radiological images from one location to another for the purposes of interpretation and/or consultation.

Changes in modern technology have created new opportunities for service delivery in radiology. The introduction of image digitisation and wider access to internet networks means that radiographs can now be transmitted to different locations.

Teleradiology improves patient care by allowing radiologists to provide radiographic reporting without actually having to be at the location of the patient. Radiologists are specialists in interpreting radiographs, which is particularly valuable in complex areas such as tropical medicine.

8.1.1 Teleradiology experience in MSF

Radiographic images from our field sites are sent with the patient history via the internet to a radiologist for consultation. Within 24 - 48 hours a report is then sent back to the field site for standard cases and within 3 - 4 hours for urgent cases. Teleradiology services are provided to all MSF projects free of charge. This is of enormous benefit to projects and encouraging its implementation into programs is a priority of the DIWG.

To date various programs have benefited from teleradiology:
– TB/HIV (including paediatrics) – especially for chest x-rays
– Paediatric
– Orthopaedic
– Surgical
– Obstetrics and sexual & reproductive health

8.1.2 How can we set up teleradiology in our project?

There are two options to producing digital x-ray images and taking advantage of teleradiology:

Imaging Receptor Systems: a digital x-ray system

The best option is to acquire initial images using a digital IRS (see chapter 2, 'X-ray equipment'). This is a system where a digital phosphor screen replaces film and the image is produced by being scanned through a digital imaging scanner rather than through a chemical processor. Images are then viewed directly on a monitor in digital format. This system can be added to any existing x-ray unit.

You will need:
– IRS with digital cassettes
– Internet connection

Digitising x-ray films

The second option is to digitise traditional x-ray film images (see point 8.2 'Digital photography protocol for x-ray films for teleradiology') by taking a photo of the film with a digital camera following the above named protocol. Images can then be sent via email as a jpeg file attachment.

You will need:
- Camera
- Tripod
- Light box (view box)
- Internet connection

> *Note*: When using this method, radiographs must be of an acceptable diagnostic image quality to begin with. If the radiographs are poorly acquired and developed they will still be of limited diagnostic value once they are digitised.

8.1.3 Who provides the teleradiology reporting service?

There are two options for radiograph reporting via teleradiology:

1. **International teleradiology service provider**

An international teleradiology service provider has offered to provide reporting to MSF free of charge. This service is widely available but only for images acquired via an IRS system and is not available for reporting from jpeg images i.e. digitised old style films. Reports are made available within 24 - 48 hours, or within 4 hours when the case is considered 'urgent'. The software program that manages the x-ray images will be configured to automatically 'push' the x-rays to the teleradiology service provider. The clinician will then be required to log on to the internet site of the teleradiology provider with an access code and verify the case by adding additional clinical information. The radiologist's clinical report is then available on the internet site to download and print as required.

2. **Consultant radiologists via the MSF telemedicine system**

MSF appointed consultant radiologists are also available to provide a reporting service via the MSF eReferral telemedicine. Radiologists report on x-rays that have been digitised from film with a digital camera or by an IRS system that are uploaded as jpeg files to the MSF telemedicine system (currently available in English, French and Spanish). A relevant summary of the patient's clinical history should accompany the image using the 'clinical history information required for reporting', found at point 8.3, as a guide.

Each project site will have slightly different requirements and the reporting service most suitable will be decided upon after discussion with the intersectional radiographer/x-ray technician and/or the leader of the Diagnostic Network. Once this has been arranged, more detailed information will be provided.

> To arrange a reporting service suitable for each project site, please email the intersectional radiographer/x-ray technician or: diagnostic-network@msf.org.

8.1.4 What kind of internet connection is needed?

The required internet connection will be dependent on the specific teleradiology service that will be provided to the project site and the method of image digitisation.

The international teleradiology service provider requires a minimum upload speed of approximately 128 kB to transfer the digital IRS images. Individual testing for latency and packet loss will be undertaken at each site that requests this service.

A digital IRS produces images that are 10 MB in size. Therefore, with a 128 kB upload speed, a 10 MB file will take just over 1 minute to upload and send. This time will be reduced with any increase in internet speed.

The internet requirements for the digital camera images (JPEGs) will be far less as the file sizes will be smaller.

8.2 Digital photography protocol for x-ray films for teleradiology

The use of digital cameras is becoming increasingly widespread in telemedicine. Known as 'store and forward' teleradiology, taking digital photos of radiographs for internet transmission offers an opportunity for physicians in the field to obtain specialist interpretation.

Nowadays, digital cameras have very high resolution and are able to capture images without losing much diagnostic quality.

The following points provide a step-by-step guide to setting up digital photography of radiographs for teleradiology in the field:

8.2.1 Camera selection

The minimum megapixel requirement needed for this purpose is 3.5 megapixels.

In addition, the camera should have an optical image stabilisation mode or any kind of Motion Detection Technology that helps to prevent blurred photos.

8.2.2 Camera settings

Megapixels

As most compact digital cameras these days have far higher resolution, set the picture size to a lower megapixel value of approximately 3.5 - 4 megapixels. If the resolution is too high, it makes the image file larger and more difficult to send via slower email connections without improving the quality of the photo of the radiograph.

The setting procedure will be slightly different for each camera but there is normally a menu option called 'Picture Size', or similar.

Compression

Set the compression option to 'high'. The procedure will be slightly different for each camera but there is normally a menu option called 'Quality', or similar.

Focus

Set the camera focus function to autofocus and always ensure that the camera has focused properly before making the exposure.

Zoom

Set the optical zoom to approximately the midpoint and then make minor adjustments to fit each film. Adjustments should be made until the radiograph fills the entire frame as best as possible without cutting off relevant anatomy. If required, place the radiograph sideways on the light box to better match the frame of the camera viewer (i.e. position the film in landscape if it was taken portrait).

Exposure

For photographing chest x-rays, adjust the exposure compensation setting manually to +1.3 EV. The procedure will be slightly different for each camera but there is normally a menu option called 'exposure', or similar. Using the auto exposure function will result in the lungs being too dark. Adjusting the setting manually will brighten the lungs so that a pathology is more apparent.

For photographing other anatomical areas, the exposure compensation setting may be kept to zero.

Ensure that the flash is set to 'OFF'.

Motion

To avoid motion while taking the photo, make use of the self-timer setting. This ensures that the camera has time to stabilise before the exposure is made and will reduce motion artefact.

8.2.3 X-ray set up

Light box

X-rays should be placed on a standard medical light box for viewing and photography. Ensure that the light is well diffused over the entire light box and that the illumination is uniform. If the light is uneven, it is possible to correct it by checking that the wattage of the bulbs or by replacing the cover with some partially opaque white plastic.

Each light box requires 2 - 3 vertically mounted 15 W (437 mm long) fluorescent tubes with a colour temperature in the range of 3600 – 4000 K°.

Black out

Extraneous light around the edges of the radiograph should be blocked out by using any opaque object. What is often easiest is to use is a blackened x-ray film. Take an unexposed sheet of x-ray film out of the darkroom and expose to light for a few minutes. Then fully develop the film; it will come out black. You can cut the film into strips and use the strips of blackened film to create a frame that will serve to block the extraneous light around the edges of the radiograph.

Tripod

The use of a small tripod is best to avoid motion blur of the photograph. The optimal distance to place the tripod is at approximately 70 cm from the light box. It is critical to position the camera exactly perpendicular to the film to avoid parallax image degradation that occurs when the camera is placed at an angle to the film. If a tripod is not available, then take the photo using a fast exposure setting, such as 1/500 second.

8.2.4 Transmission

Transmission to computer

Transfer the images to a computer via the memory card or by using the cables that are provided with the camera. Create a new directory for each patient.

The following instructions relate to the XnView program which is a standard MSF program and should be available at all field sites:

1. Open the XnView program and locate the image file via the directory on the left hand side of the viewer.
2. Highlight the image thumbnail.
3. In the viewer along the bottom, click on ‘Properties’ and take note of the ‘File size’.
4. The number given will be in bytes (i.e. 315 000 Bytes = 315 kB).
5. Double click on the image to open it in its own window.
6. Go to ‘File’ and then to ‘Save As’.
7. A ‘Save picture’ window will open; select ‘Options’ at the bottom.
8. An ‘Options’ window will open; select the ‘Write’ tab.
9. You will see a scroll bar called ‘Quality’ which has options from ‘Lowest’ to ‘Best’.
10. The lower the quality, the smaller the image size will be.
11. Reduce the quality to between 25% and 50% and click ‘Ok’.

12. You will be brought back to the ‘Save picture’ window. Change the ‘File name’ so that the reduced quality image is saved as a new file.
13. Go back to the ‘Browser’ tab and you will see your new file.
14. Repeat step 3 to check new file size. Aim for approximately 200 – 300 kB.
15. Open the new file and ensure that the image has not lost too much quality and can still be considered suitable for interpretation. For example, check for over-pixilation and loss of lung markings on a chest x-ray.

Transmission via internet

On the computer hard drive, locate the file to be emailed. The file is now ready to be sent to the MSF telemedicine system.

8.3 Patient information required for reporting

When using a digital camera to digitise film images for sending for teleradiology, it is important to include patient information and relevant clinical history to aid interpretation.
It is imperative that images are allocated and clearly marked with an identification number. For reasons of confidentiality when using the internet, this must be provided in place of the patient’s name.

Patient’s information needed for optimal interpretation of a radiograph should be sent with the digital image and must include:
- Patient’s identification number
- Age and gender of the patient
- **Brief description of current medical problem**: current symptoms and relevant positive physical examination and laboratory findings.
- **Significant past medical history**: past surgeries or treatment as they apply to the current medical problem.
- Any specific questions about the radiograph.
- Each radiograph should be labelled with the date that the image was obtained. If not possible on the radiography itself, add this information to the file name of the digital file.

The information needed should be provided in 200 words or less.

Teleradiology is also an opportunity for the referring clinicians to further develop their skills in image interpretation. Clinicians will be able to compare and learn what they observe on the radiograph with the reported findings by the radiologist.

Information on follow-up of patients for our consulting radiologists is also welcome to encourage a dynamic and interesting process, for example, informing them of the impact of the radiological findings to the patient’s treatment or final outcome.

9. Radiation protection

9.1 Minimising dose to patients and staff

The improper or unsafe use of radiography equipment has the potential to create a health hazard not only for the user but also for the general public in the environment surrounding the area of use. Radiation protection is the responsibility of all users of x-ray units. The governing principle in radiation protection is ALARA (i.e. As Low As Reasonably Achievable). ALARA encourages the use of radiation based on using dosages as low as reasonably achievable to attain the desired diagnostic goal.

The guidelines in this chapter are based on the ALARA principle and describe practices and procedures for the safe use of all x-ray units. These recommendations comply with international guidelines; however, they should always be used within the context of the national rules and regulations.

Radiographers/x-ray technicians working in controlled x-ray areas have significant potential for exposure to radiation in the course of their work and are directly responsible for the use and control of radiation. They require training in radiation management and the ALARA principle. All personnel using x-ray equipment must be taught how to prevent unnecessary exposure to radiation and are expected to be familiar with MSF radiation safety policies and procedures and to conduct their operations in accordance with them.

X-rays are generated as a primary beam and are focused to the body part of interest (primary radiation). Once x-rays pass through the body, some are absorbed and some are reflected as scatter (secondary radiation).

Always remember:
The most easily applied protective measure is to increase your distance from the source of both primary and secondary scattered radiation.

Increasing distance from the source of radiation results in a decrease in the intensity of the beam. According to the inverse square law, doubling the distance from the radiation source will result in a beam of one quarter its original intensity.

9.2 Basic radiation protection

- No radiological investigation should be done unless it is medically justified, i.e. that sound clinical reasons for the examination outweigh the possible risks.
- Close the doors to the x-ray room before making an exposure.
- Only required staff and necessary caretakers of the patient (e.g. parents of small children) are allowed to stay in the room during the exposure.
- Radiographers/x-ray technicians **must** stand behind a protective barrier during x-ray exposure.
- Essential personnel who remain in the room during an x-ray exposure must stand behind the protective barrier with the radiographer/x-ray technician or are obliged to wear a lead apron.

– Lead aprons should be made of a minimum of 0.25 mm lead equivalent material and undergo regular quality control for cracks. For further information on testing of lead aprons, see point 11.2 'Quality assurance, control and maintenance tasks'.

– For each patient, always search for previous exams to ensure that the same examination has not been recently undertaken. This ensures that the patient is not being irradiated twice for the same investigation, as often clinicians can be unaware of recent imaging.

9.2.1 X-ray practice

Radiographers/x-ray technicians should:
– Carefully position and immobilise the patient in order to reduce the need for repeat imaging.
– Collimate the x-ray beam to include only the area of interest.
– Use a portable x-ray grid where appropriate (for example during abdomen and pelvis examinations when an image is taken with a mobile machine or outside of the bucky of the WHIS-RAD).
– Use the highest practical kV and lowest practical mAs exposure settings as possible.
– Use gonad shields on the patient whenever the gonads are outside of the field of view of the radiograph.

9.2.2 Radiation and pregnancy of patients

Every female patient of childbearing age should be questioned as to the possibility of pregnancy. If the patient is unsure, perform a pregnancy test. If the patient is pregnant use an alternative examination or reschedule the procedure. If the referring physician decides that a pregnant patient **must** have the procedure, use shielding and minimum radiation dose.

9.2.3 Film badge dosimeters

Film badge dosimeters can be worn by staff members and are used for monitoring passive exposure to ionising radiation. However, film badges do not offer staff protection from radiation and are not a fail-safe measuring tool.

The Medical Coordinator is responsible for ensuring that local radioprotection laws are adhered to in each project that offers radiology services. Thus, the Medical Coordinator should enquire regarding local radiation protection laws and availability of dosimeters for staff monitoring. An enquiry at the local radiation safety authority such as the Atomic Energy Authority is a good starting point if it exists in the country of operations.

International supply and monitoring of badges is not a feasible option therefore dosimeters are not supplied from headquarters. When adequate protection is provided to radiographers/x-ray technicians (see chapter 4 'X-ray room structural requirements') then there is no risk of adverse radiation exposure.

9.2.4 Prohibited exposures from radiographic units

Individuals should not be exposed to the x-ray beam except for purposes of direct medical care as requested by an authorised health care provider.

Deliberate exposure is specifically prohibited for any of the following purposes:
1. Exposure of an individual for training or demonstration purposes.
2. Exposure of an individual for purposes of equipment calibration or quality assurance.
3. Exposure of an individual for any purpose other than health care of the individual being exposed.

9.3 Pregnant radiographers/x-ray technicians

9.3.1 I'm pregnant! Can I still work in the x-ray department?

Yes, a pregnant health care worker can continue working in an x-ray department. However, she should always keep her exposure to ionising radiation as low as possible. She can be accommodated in the department by being allowed to work in areas that have a lower risk to exposure. For example, this would mean that pregnant radiographers/x-ray technicians, nurses or doctor/clinicians who are operating x-ray equipment should avoid using mobile x-ray units where a lead screen is not available or using fluoroscopic x-ray systems in operating theatres. See also Annex 9 'International Commission on Radiological Protection' for further details.

As a general guideline, pregnant employees should:
- Minimize their time of exposure to radiation.
- Maximize their distance from the radiation source.
- Take advantage of available protective equipment such as lead aprons, shield barriers, and protective cubicles whenever practical.

9.3.2 Will there be any harm to my unborn baby?

The foetus is sensitive to high doses of ionising radiation and this is especially true during the first three months of gestation. There is the assumption of a small risk of harmful effects from low doses of radiation increasing the probability of harm to the foetus. Pregnant women should therefore take all measures possible to reduce unnecessary radiation exposure to their unborn baby.

9.3.3 Who is responsible for my safety?

There are responsibilities for both the employee and the employer when it comes to the radiation protection of a pregnant staff member. The employer must ensure that a pregnant woman is not subjected to unnecessary discrimination due to her pregnancy and that appropriate radiation protection equipment is available, such as lead screens and lead aprons. The responsibility for the protection of the unborn baby also lies with the woman herself, who should declare her pregnancy to management as soon as she is aware that she is pregnant so that appropriate considerations can be made. The functional manager of a pregnant staff member must inform on the risks of radiation to pregnancy if appropriate protection recommendations are not adhered to.

10. Radiographic principles for radiographers/ X-ray technicians

10.1 Basic principles of x-rays

X-radiation is a form of electromagnetic radiation, which is produced when fast moving electrons impact on a tungsten target. The energy of the x-rays produced is dependent on the energy of the electrons.

X-rays can penetrate substances that are opaque to visible light and are gradually absorbed the further they pass through anatomy. The amount of x-ray absorption depends on the atomic number and density of the anatomy and the energy of the x-rays. It is the x-rays that are not absorbed by the body that reach the x-ray cassette. For example, x-rays will pass more easily through air (i.e. lungs) than through bones which have a greater anatomical density. Where x-rays pass easily through the anatomy the area of the radiograph will be dark and where fewer x-rays pass through the anatomy, the area of the radiograph will be light. It is the accumulation of these shades of grey that result in a radiographic image.

The x-rays that are absorbed by the body result in excitation and ionisation of the atoms of the cells which they pass through. Excitation is the process of raising an electron to a higher energy level and ionisation is the process in which an electron is completely removed from an atom. Both excitation and ionisation can cause biological changes to living tissue, damaging or killing the affected cells. Damage to cells by x-radiation can either be genetic (e.g. chromosomal damage or mutations) or somatic (e.g. immediate damage such as radiation burns, cancers). Radiation is a particular hazard as its effects may be painless and latent.

10.2 Positioning and exposure factors

A good diagnostic radiograph should be an accurate demonstration of the anatomy under examination.

Positioning

Good positioning is vital to ensure that there is minimum distortion of anatomical structures. The region of interest (body part) should be:

– Directly under the central ray.
– Parallel with the cassette.
– Close to the cassette (no air gap).

Exposure

Exposure represents the amount of ionisation produced in air by radiation. An exposure factor is made up of three elements: kV, mA and time.

– <u>kV</u> determines the penetrating power of the photons. The greater the potential across the x-ray tube, the faster the electrons will move and the higher the energy of the x-ray photons.
– <u>mA</u> is determined by the tube current. The higher the current, the greater the intensity of the beam.
– The <u>time</u> of the exposure controls for how long the x-rays are produced. The time in seconds (s) and mA are generally represented together as mAs.

Good exposure factors are necessary to clearly demonstrate the structures of interest with:
- Adequate contrast and density.
- No artefacts on the radiograph that might obscure any part of the anatomy or imitate pathology.

Controlling the energy and quantity of the x-ray beam is necessary to produce a radiograph of high diagnostic quality. The anatomy of each patient requires a considered selection of the appropriate exposure factor for each examination.

See Annex 10 for example exposure charts for use with a WHIS-RAD x-ray machine in combination with a digital IRS.

10.3 Exposure manipulation

kV determines the penetrating power of the x-ray beam.
- X-rays taken with low kV have high contrast (black/white and little grey).
- X-rays taken with high kV have low contrast (more shades of grey).

mAs determines the amount of x-rays that reach the x-ray cassette.
- A low mAs technique results in an underexposed (pale) radiograph.
- A high mAs technique results in an overexposed (dark) radiograph.

Distance also affects the x-ray beam intensity according to the inverse square law. Doubling the distance from the x-ray source to the x-ray cassette will result in a beam of one quarter its original intensity.

In summary:
kV controls the number of shades of grey on a radiograph (contrast) and mAs controls how dark they are (density).

Adjusting exposure factors
- Always change kV in increments of at least 15 % for a noticeable change in radiographic contrast.
- Always change mAs in increments of at least 30 % for a noticeable change in radiographic density.

Making changes to either the kV or the mAs will always have an effect on the other. If the kV is decreased by 15 % to increase the contrast of the radiograph but the overall density was adequate, then the mAs will need to be increased by 50 % to maintain an adequate level of density. If kV is increased by 15 %, the mAs should then be reduced by half.

Inversely, if the mAs is reduced by 50 % in order to demonstrate an increase in shades of grey, the kV must then by increased by 15 % to maintain the same density.

- If radiographs are dark and grey, reduce the kV.
- If radiographs are dark and black, reduce the mAs.
- If radiographs are light with little contrast between structures, increase the kV.
- If radiographs are light but with good contrast between structures, increase the mAs.
- When x-raying a patient with dry plaster cast on a limb, increase the average exposure by 10 kV or double the mAs.

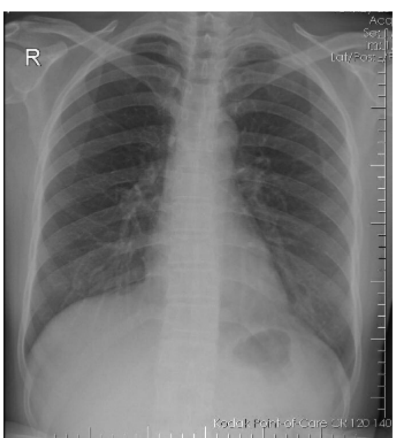
10.3.1 Digital assessment – clinical technique factors

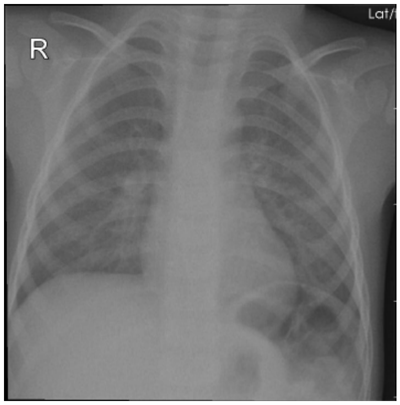
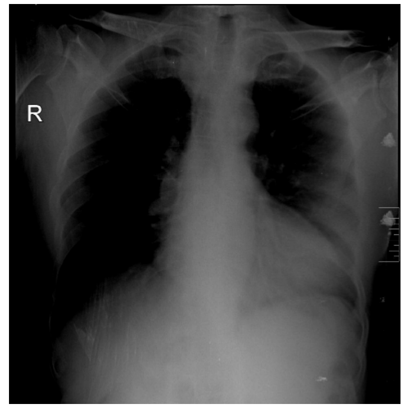
Each digital IRS image shows an exposure value to determine if a radiograph has been appropriately exposed. The name, value and range are different between vendors.

FUJI	**AGFA**	**CARESTREAM**	**Indication and action**
S number	**lgm Value**	**Exposure Index**	
> 1000	< 1.45	< 1250	Underexposed: REPEAT
301-1000	1.45-2.04	1250-1849	Underexposed: Review
150-300	**2.05-2.35**	**1850-2150**	**Acceptable range**
149-50	2.36-2.95	2151-2750	Overexposed: Review
< 50	> 2.95	> 2750	Overexposed: REPEAT

Evaluate images and use this number as a guide to highlight general patterns in over- or under-exposing.

10.4 X-ray image examples

ACCEPTABLE	**ACCEPTABLE**
	
This chest x-ray is well positioned, covering all necessary anatomy and has good contrast and density.	This wrist x-ray is well positioned, covering all necessary anatomy and has good contrast and density.

UNDEREXPOSED	OVEREXPOSED
	
This x-ray is too light, but the contrast between structures is reasonable. To correct this exposure, the mAs should be increased by at least 30 % in order to increase the density.	This x-ray is too dark and the contrast between the structures is too high. The mAs should be reduced by at least 30 % to decrease the density, and the kV should be decreased by at least 15 % to reduce contrast.
ANATOMY CUT-OFF	**ANATOMY CUT-OFF**
	
This x-ray of the forearm should show both the wrist and the elbow joints on one image. This is possible with careful positioning of the arm diagonally across a 35 x 43 cm x-ray cassette.	This x-ray of the lower leg should show both the knee and the ankle joints on one image. This is possible with careful positioning of the lower leg diagonally on a 35 x 43 cm x-ray cassette.

MARKER COVERING ANATOMY	ARTEFACT
	
The right (R) marker is covering anatomy. Whether using lead markers directly on the cassette, or placing markers digitally, always place them in the lateral position, well clear of all anatomy.	This x-ray image shows dark 'fogging' at the top of the image and dark lines running up and down the image. This is a result of a damaged digital phosphor screen. This screen must be replaced.

10.5 Scatter radiation and image contrast

As x-rays pass through the body some are deviated from the direction of the primary beam and can result in scatter radiation. The amount and direction of scatter radiation depends on the intensity of the x-ray beam and the anatomical density. Scatter radiation reduces the level of image contrast; excess scatter radiation will result in anatomy appearing less sharply defined.

10.5.1 Reducing scatter radiation and grids

There are several methods to reducing scatter radiation. The x-ray beam should always be limited to only the area of interest. The smaller the area of the x-ray beam, the fewer scattered photons will be produced. For larger parts of anatomy such as the abdomen, pelvis and spine, a **radiographic grid** should be used:

A radiographic grid allows only the primary radiation to pass to the x-ray cassette and filters out randomly deflected radiation that can blur a radiograph. A grid is a thin metal sheet the same size as an x-ray cassette and consists of a large number of lead strips interspaced between radiolucent strips. It is placed on top of the x-ray cassette and positioned underneath the patient. Using a grid will increase image contrast but it can also block some of the x-rays that contribute to the image density. Therefore, the x-ray exposure will need to be increased when using a radiographic grid. As a guide, increase the mAs by 30 % to maintain appropriate density.

A radiographic grid is automatically built into the bucky (tray for the x-ray cassette) in the WHIS-RAD, but must be purchased as an accessory item when using a mobile x-ray machine. There are many different types of grids available and the following specifications are those of the grid available in the MSF medical catalogue:

- Parallel lines (i.e. not focused)
- 40 lines/cm
- Grid ratio 8:1
- 35 x 43 cm
- Carbon fibre protective cover (or similar)

A grid that meets these specifications has the most versatility for use in MSF projects. If a different grid is purchased, i.e. with focussed lines or a lower grid ratio, this will cause artefacts on the x-ray image. Artefacts, by using the wrong grid or using the right grid incorrectly, will cause lines to be visible up and down the image. This is known as 'grid cut-off'. Therefore, always use a grid the right way up (indicated clearly on the grid) and perpendicular to the x-ray beam, i.e. not tilted at an angle. Grids are very durable when they are covered in carbon fibre. However, grids should always be treated with care and wiped down every day with standard hospital cleaner.

11. Quality assurance

11.1 Quality assurance program

A quality program in diagnostic imaging aims to ensure that the images produced are of a sufficiently high quality to provide adequate diagnostic information while keeping the radiation dose as low as possible.

Quality assurance (**QA**) tasks are concerned directly with purchase, monitoring and testing all components of the x-ray system, including the x-ray and accessory equipment.

Quality control (**QC**) tasks concern all factors regarding image quality and contribute to a department's overall quality program, including administrative procedures to verify that testing is performed and evaluated regularly.

This chapter outlines QA and QC tasks, as well as regular maintenance tasks, that are indicated by the DIWG to be undergone within x-ray departments.

11.2 Quality assurance, control and maintenance tasks

Tasks	Frequency	Persons responsible
Quality assurance		
1. Service options and warranty period	At initial purchase	Headquarters
Quality control		
2. Image evaluation (PACEMAN)	Every 3 months	Intersectional radiographer
3. Send image DVD/USB to DIWG	Every 3 months	Intersectional radiographer
Maintenance		
4. Archive images	Weekly	Radiographer/x-ray technician
5. Cassette inspection	Monthly	Radiographer/x-ray technician
6. Intensifying screen inspection	Monthly	Radiographer/x-ray technician
7. Phosphor screen cleaning	3-monthly	Radiographer/x-ray technician
8. Positioning cushion inspection	Monthly	Radiographer/x-ray technician
9. Roller cleaning of digital scanner	Monthly	Radiographer/x-ray technician
10. Collimator alignment test	Every 6 months	Radiographer/x-ray technician

11. Maintenance of the WHIS-RAD	Every 6 months	Logistician
12. Lead gown test	Yearly	Radiographer/x-ray technician
13. Light bulb replacement	As required	Radiographer/x-ray technician or logistician

(1) Service options and warranty period

At the time of selecting and procuring diagnostic imaging equipment, consideration must be given to the maintenance requirements of the unit and options for servicing should issues arise. Options available will vary from manufacturer to manufacturer. MSF has an arrangement with preferred manufacturers whereby a formal annual service contract may not be required, but conditions and costs for corrective maintenance are clearly defined at time of purchase based on the country of end use. The intersectional radiographer and the biomedical engineer(s) from each OC can advise on service options for each item of diagnostic equipment as required.

(2) Image evaluation (PACEMAN)

PACEMAN is a technique for radiographers/x-ray technicians to determine if a radiograph is of diagnostic quality. It is designed as a method for critique of radiographic images. A selection of films can be marked against the criteria and evaluated for quality. A chart can be used to record overall results providing an overview to highlight weak areas and guide improvements. This can be done by an expatriate radiographer/x-ray technician during an evaluation or training visit, and continued every 3 months by the project radiographer/x-ray technician. See Annex 11 for a PACEMAN recording template.

PACEMAN is an acronym used to remember the following:

- **P**osition
- **A**rea
- **C**ollimation
- **E**xposure
- **M**arkers
- **A**esthetics
- **N**ame

Below is a summary of the qualities that are needed for each letter of PACEMAN.

(P) - Position
Is the patient in the correct position?
Is the patient rotated?
Does the image correctly show joint spaces?

(A) - Area
Is the desired anatomical area entirely covered?
E.g. for an abdominal film is pubic symphysis to diaphragms covered?
Have you exposed an area that is not required?

(C) - Collimation
Is the image properly collimated?
E.g. are collimation lines seen on an extremities film?

(E) - Exposure
Were the exposure factors set correctly?
Does the image have adequate contrast and density?
Are there any factors that need to be changed to produce a better image?

(M) - Markers
Have markers been placed on the image?
Are they correctly identifying left and right?

(A) - Aesthetics
Is the image nice to look at?
Is the anatomy centred?

(N) - Name
Does the image correctly identify the patient?
Does it have any other relevant identification details?
E.g. episode number or department labels.

(3) Send image DVD to DIWG

Where a digital x-ray system exists, a USB, CD or DVD with a sample of recent images should be sent to the intersectional radiographer every three months for QA so that feedback can be given to the radiographers/x-ray technicians in how to improve practice and technique. X-rays can be exported as JPEG images from the IRS software to a USB, CD or DVD. For patient confidentiality the anonymise option must be used prior to exporting. The exact process differs depending on the IRS software. Please refer to the IRS software operators' manual or contact the intersectional radiographer if you require assistance. This QA also serves to provide an indication to the overall function of the x-ray unit.

Please send the images for every fifth patient or all images if there are not more than 20 images per month for QA.

Send to:	Médecins Sans Frontières Diagnostic Network Plantage Middenlaan 14 1018 DD Amsterdam Netherlands

(4) Archiving images

Archives must be made of the image data. Archiving should be performed on a **weekly basis or daily** if case loads are high. There are three options for this:

DVD backup

Image files can be backed-up to writable DVDs. The advantage of this method is its simplicity. The disadvantages are that any images made after the last back-up could be lost if the system malfunctions. Depending on the storage capacity of the system images may need to be deleted and so will only be available on the DVD for viewing at a later date.

EHDD (External Hard Disk Drive)

Image files can be periodically backed-up on EHDDs. Compared to using DVDs the higher storage capacity of an EHDD is an advantage. In cases where no ICT expertise is available to install a 'network attached storage' (NAS; see below) an EHDD is be the preferred option. The main disadvantage is the loss of data due to loss of the EHDD itself, corruption of the EHDD due to unsafe removal from a computer or due to overwriting the backups by newer data.

NAS (Network Attached Storage)

Image files are not stored on the computer but directly to a storage device on the network. The advantages of this method are that images can be viewed even when the radiographer's/ x-ray technician's workstation is not in use and all images previously made will be available for viewing. In addition, the NAS can be configured for automatic backup by keeping duplicate copies on separate hard drives. This has the disadvantage however of being more complicated to install.

(5) Cassette inspection

Cassettes are the light tight covers that hold the digital plate or film between the intensifying screens. Through regular use they are easily damaged resulting in possible light leakage and poor film screen contact. Cassettes are available in several sizes and most field sites will have two sizes available.

What should I check?

– Hinges
– Catches
– Casing
– Cleanliness

Figure 16: Example of an x-ray cassette

Where a cassette is found to be faulty, attempt repair or replace the cassette. Cassettes should be cleaned every morning and after contact with a patient with a damp cloth and wiped dry.

(6) Intensifying screen inspection

Intensifying screens are fixed inside the cassette and fluoresce when hit by radiation. This light emission contributes to the blackening effect on the resulting radiograph. Foreign material on the surface of the screens will damage or create artefacts on the image.

This inspection can only be done on cassettes designed for film. Digital cassettes do not open in a way that allows inspection of the intensifying screens.

How should I inspect?

– Inspect in bright conditions.
– Check that screens are firmly fitted.
  • Loose screens should be refitted with double sided tape.
– Check for abrasions and foreign material on screen surface.
  • Is there surface damage? This can cause artefacts - replace cassette.
  • Is there discolouration? This is an indicator of deterioration - replace cassette.

Figure 17: Intensifying screens inside a cassette

How should I clean the intensifying screens?

- Clean in bright light conditions in a dust free area.
- Apply screen cleaner (available from manufacturer) or mild soap (not detergent) sparingly with a lint free cloth, such as a gauze swab.
- Use a circular motion over the whole surface.
- Finish with long strokes from top to bottom.
- Do not pour cleaner/soap directly onto the screen.
- Wipe dry with a lint free cloth.
- Leave cassette open for 30 minutes to dry.
- Finish with an inspection.

(7) Phosphor screen cleaning

A phosphor screen replaces traditional film and goes inside the x-ray cassette. It absorbs radiation and is then scanned by a digital imaging scanner and produces a radiographic image.

Phosphor screens can be manually removed from the x-ray cassette using the tool provided by the manufacturer. Provided they are well cared for, a phosphor screen should last many years, or approximately 10 000 images.

How should I clean the screens?

- Clean in bright light conditions in a dust free area.
- Apply screen cleaner (supplied from manufacturer) or mild soap (not alcohol based) with a lint free cloth such as a gauze swab. Do not pour cleaner/soap directly onto the screen.
- Wipe the screen with a linear motion over the whole surface.
- Finish with long strokes from top to bottom.
- Wipe dry immediately with a lint free cloth. Do not allow to air-dry.

Finish with an inspection

- Check for scratches and foreign material on screen surface and re-clean if necessary with a lint free cloth and screen cleaner.
- Do the dirt particles remain? Replace screen.
- Is there surface damage or discolouration? Replace phosphor screen (ensuring the phosphor side is facing the correct way. The printed serial number indicates the back of the phosphor screen and should be facing the back of the cassette).

(8) Positioning cushion inspection

Positioning cushions are useful aids to maintaining the position of the patient. A range of cushions should be available in each x-ray room. They must be radiolucent. As they directly support the body in an area within the x-ray beam, a non-radiolucent support can cover anatomy on a radiograph or produce artefacts that can be interpreted as pathology. It is for this reason that positioning cushions should be purchased from the MSF medical catalogue where it is ensured they are designed for medical use. Positioning cushions should be wiped clean at the end of every day, or immediately after use if they are obviously contaminated.

What do I inspect for?

- Likelihood of contamination.
- General cleanliness.
- Shape, smell and firmness.
- Pieces breaking off.

X-ray test

- Place positioning cushion on an x-ray cassette, set FFD (focus film distance) to 100 cm and collimate to cover the cushion. Set exposure of 50 kV and 6 mAs. Expose and process.
- Look for radio-opaque shadows within the cushion.

What do I do if a positioning cushion is faulty?

- If the cushion has deteriorated to the extent that it no longer fulfils its function, then replace it.
- If radio-opaque shadows are detected, wash and dry the cushion and redo testing.

(9) Roller cleaning of digital scanner

The rollers of the digital imaging scanner require periodic cleaning to rid them of dust and dirt particles that gather during use. These particles damage the phosphor screens and may cause artefacts on images. Roller cleaning plates can be purchased from the manufacturer via the usual method of procurement and should be used once a month. Only cleaning plates provided from the same manufacturer as the IRS are to be used.

(10) Collimator/x-ray beam alignment test

The collimator (also LBD – Light Beam Diaphragm) is the part of the x-ray unit that provides an accurate method of controlling the size of the x-ray field and placing it over the area of interest. The purpose of the light in a collimator is to allow more accurate collimation of the x-ray beam by planning the x-ray field using the projected area of light on the patient, prior to exposure. The light must, therefore, coincide with the x-ray beam. If they do not, areas of interest can be excluded from the field, or too large an area can be irradiated when performing the actual exposure.

The collimator receives much use and is often knocked during regular work which leaves it vulnerable to inaccuracy of the correspondence between the light beam and the x-ray beam, blown light bulbs and mechanical problems.

How do I do the test?

- Make sure that the tabletop/bucky is level and the central ray is set exactly at 90°.
- Place a cassette on the tabletop.
- For a mobile x-ray or a non WHIS-RAD unit set the x-ray tube exactly 100 cm from the cassette. For the WHIS-RAD place a cassette in the bucky, this distance is fixed at 140 cm.
- Switch on the collimator light and centre it to the middle of the cassette.
- Collimate to approximately 3 cm within the edge of the cassette leaving a boarder all around that is outside of the light field.
- Place the coins in pairs, one inside the light field and one outside, so that where the coins touch is exactly the edge of the light field. Alternatively, un-bend a paperclip to form a right angle and place in each corner of the beam inside the light field.
- Place a lead marker within one corner of the light field so that the radiograph can be related to the x-ray field and then also the collimator shutters.
- Expose the cassette and process as normal.

How do I evaluate?

- For perfect alignment, the light field should coincide with the x-ray field.
- The irradiated area must not be greater than the area covered by the light.
- At 100 cm FFD the irradiated area must not be more than 10 mm smaller than the area covered by the light, at 140 cm FFD the area must not be more than 14 mm the area covered by the light (that equals a 1% tolerance).
- If the alignment is unacceptable, a service engineer should be contacted. Until then, the radiographers/x-ray technicians must adjust collimation practice to compensate for this.

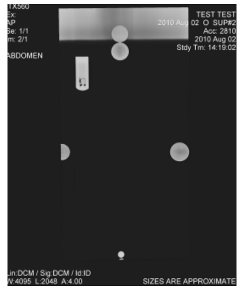


Figure 18: Poorly aligned collimator

(11) Maintenance of the WHIS-RAD

1. Switch circuit breaker off in electrical cabinet and check that power is off at the device
2. Wait for 30 minutes.
3. At the back of the tube head, tighten the metal rings where the cable attaches on both sides.
4. Open plastic casing of the rube head (three screws) and tighten the screws for the cable connections inside.
5. Open the generator cabinet and tighten the two large metal rings inside at the top.
6. Unscrew the allen head bolt to open the ‘door’ of the cabinet. Clean every corner of the generator with an air compressor and look closely for insects and nests.
7. Close the generator cabinet.
8. The online UPS in the x-ray office should also be cleaned with the compressor to remove dust from the filters.

(12) Lead apron test

Lead readily absorbs radiation and is used in many forms for protection. Lead rubber has a lead effectiveness (usually between 0.25 mm and 0.5 mm) and has the advantage of being lighter and more flexible than lead and therefore ideal for making items which can be worn e.g. lead aprons. Lead rubber tends to deteriorate over time with regular use and mishandling and therefore cleaning and x-ray testing for cracks is important.

How do I routinely care for lead aprons?

- Weekly cleaning, or as necessary. Clean with soap and water.
- Never fold any item of lead rubber.
- Aprons should be hung up on hangers.
- Do not store near a heat source.
- Check condition of fastenings on gowns.
- Inspect surface covering for tears or signs of deterioration, including at the seams.

How do I do an x-ray test?

- Place lead apron over x-ray cassette and make separate exposures to cover the surface of the whole gown. Set exposure to approximately 50 kV and 6 mAs. Process as normal.
- Look for cracks or other abnormal variations of density on the image.
- This test can also be done by using a fluoroscopic x-ray system where available.

What do I do if an apron is faulty?

- Initiate repairs or cleaning of outer material.
- Lead rubber found to be cracked or defective should be replaced.

Note: lead aprons being withdrawn can be cut up into smaller pieces, avoiding the cracked sections, and used as gonad shielding.

(13) Light bulb replacement

The light bulb in the collimator can fail at any time. Always ensure that there is a correct spare bulb available. Refer to the technical manual of the x-ray machine for the exact type of light bulb required. This task should be undertaken by the radiographer/x-ray technician together with the project biomedical engineer or logistician.

How do I change the light bulb?

1. Switch off the power.
2. Remove the collimator housing.
3. Check that the spare light bulb is the correct type.
4. Before removing the old bulb, check to see if the new bulb must be fitted a specific way round.
5. Replace the faulty bulb with the new one.
6. Replace the housing and tighten the screws.
7. Test.
8. Ensure that the spare bulb is replaced as soon as possible.

12. Reference resources for diagnostic imaging

The World Health Organisation (WHO) guides are most suited for use in our projects. The WHO manuals provide specific instructions on radiographic positioning, exposure technique and interpretation oriented toward less-experienced radiographers/x-ray technicians and clinicians.

All resources listed below are available for ordering (see Annex 1 Checklists to guide procurement - reference resources).

Recommended diagnostic imaging resources are:

1. The WHO manual of diagnostic imaging: radiographic technique and projections
2. The WHO manual of pattern recognition in diagnostic imaging
3. The WHO manual of diagnostic imaging: radiographic anatomy and interpretation of the chest and the pulmonary system
4. The WHO manual of diagnostic imaging: radiographic anatomy and interpretation of the musculoskeletal system
5. The WHO Quality assurance workbook for radiographers and radiological technologists
6. The WHO basics of radiation protection for everyday use – How to achieve ALARA: working tips and guidelines
7. The WHO technical series: x-ray equipment, maintenance and repairs
8. The WHO technical series: diagnostic imaging: what is it?
9. Tuberculosis Coalition for Technical Assistance: Handbook for district hospitals in resource constrained settings on quality assurance of chest radiography for better TB control and health system strengthening
10. The Imaging of Tropical Diseases. Philip Palmer & Maurice Reeder. DVD. Available as an online reference: http://tmcr.usuhs.edu/
11. Merrill's Pocket Guide to Radiography

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Annex 1. Checklists to guide procurement

WHIS-RAD installation*

Code	Name of Article	Quantity
EDIMDISE3--	DIGITAL IMAGE RECEPTOR SYSTEM, DIGITAL IMAGING SCANNER (Agfa CR10X) + Accessories (incl. digital imaging scanner, computer and software, high resolution monitor for reporting, four 35 x 43cm cassettes and cleaning supplies)	1
ADAPHDDE3--	HARD DISK DRIVE, external 3.5”	1
EDIMAPRF1L-	RADIATION SHIELDING APRON, FRONTAL, 0.35 mm Pb equivalent, L	2
EDIMAPRF1M-	RADIATION SHIELDING APRON, FRONTAL, 0.35 mm Pb equivalent, M	1
EDIMAPRF1S-	RADIATION SHIELDING APRON, FRONTAL, 0.35 mm Pb equivalent, S	0
EDIMGONS1A-	GONAD RADIATION SHIELDING APRON, 0.5 mm Pb equivalent, adult	1
EDIMGONS1C-	GONAD RADIATION SHIELDING APRON, 0.5 mm Pb equivalent, child	1
EDIMLETT1D-	LETTER, BRASS, 10/15 mm, "DROITE", 10/10th	*
EDIMLETT1G-	LETTER, BRASS, 10/15 mm, "GAUCHE", 10/10th	*
EDIMLETT1L-	LETTER, BRASS, 10/15 mm, "LEFT", 10/10th	5
EDIMLETT1R-	LETTER, BRASS, 10/15 mm, "RIGHT", 10/10th	5
EDIMPOCU1--	POSITIONING CUSHIONS, set	1
EDIMRPSH1R-	RADIATION PROTECTION LEAD SHEETING, roll	*
EDIMRPWI1--	RADIATION PROTECTION WINDOW	*
EDIMXRAY6--	X-RAY UNIT, FIXED, WHIS-RAD, basic, 100 to 250 mA	1
PELEUPSD6--	UPS DOUBLE CONVERSION, 6 kVA, 230 V	1

* Please discuss installation with the biomedical engineer of your OC and the intersectional radiographer/x-ray technician prior to purchase.

Mobile x-ray installation*

Code	Name of article	Quantity
EDIMDISE3--	DIGITAL IMAGE RECEPTOR SYSTEM, DIGITAL IMAGING SCANNER (Agfa CR10X) + Accessories (incl. digital imaging scanner, computer and software, high resolution monitor for reporting, four 35 x 43cm cassettes and cleaning supplies)	1
ADAPHDDE3--	HARD DISK DRIVE, external 3.5”	1
EDIMAPRF1L-	RADIATION SHIELDING APRON, FRONTAL, 0.35 mm Pb equivalent, L	1
EDIMAPRF1M-	RADIATION SHIELDING APRON, FRONTAL, 0.35 mm Pb equivalent, M	2
EDIMCAHO1S-	CASSETTE HOLDER for X-ray film, vertical, stand	1*
EDIMCAHO1W-	CASSETTE HOLDER for X-ray film, vertical, wall mounted	*
EDIMCOLL1--	RADIATION SHIELDING COLLAR, 0.5 mm Pb equivalent, w/collar	3
EDIMGONS1A-	GONAD RADIATION SHIELDING APRON, 0.5 mm Pb equivalent, adult	1
EDIMGONS1C-	GONAD RADIATION SHIELDING APRON, 0.5 mm Pb equivalent, child	1
EDIMGRID1M-	X-RAY GRID, 35 x 43 cm	1
EDIMLETT1D-	LETTER, BRASS, 10/15 mm, "DROITE", 10/10th	*
EDIMLETT1G-	LETTER, BRASS, 10/15 mm, "GAUCHE", 10/10th	*
EDIMLETT1L-	LETTER, BRASS, 10/15 mm, "LEFT", 10/10th	5
EDIMLETT1R-	LETTER, BRASS, 10/15 mm, "RIGHT", 10/10th	5
EDIMPOCU1--	POSITIONING CUSHIONS, set	1
EDIMRPBA1M-	RADIATION PROTECTION BARRIER, mobile	2*
EDIMRPSH1R-	RADIATION PROTECTION LEAD SHEETING, roll	*
EDIMRPWI1--	RADIATION PROTECTION WINDOW	*
EDIMXRAY7--	X-RAY APPARATUS MOBILE (Mobilett XP Hybrid)	1
PELEUPSD6--	UPS DOUBLE CONVERSION, 6 kVA, 230 V	1

* Please discuss installation with the biomedical engineer of your OC and the intersectional radiographer/x-ray technician prior to purchase.

Fluoroscopic x-ray system (i.e. C-Arm) installation*

Code	Name of article	Quantity
EDIMXRFL1--	FLUROSCOPIC X-RAY SYSTEM, MOBILE	1
EDIMAPRO1L-	RADIATION SHIELDING APRON, FULL, 0.35 mm Pb equivalent, L	2
EDIMAPRO1M-	RADIATION SHIELDING APRON, FULL, 0.35 mm Pb equivalent, M	4
EDIMAPR01S-	RADIATION SHIELDING APRON, FULL, 0.35 mm Pb equivalent, S	1
EDIMCOLL1--	RADIATION SHIELDING COLLAR, 0.5 mm Pb equivalent, w/collar	7
EDIMGONS1A-	GONAD RADIATION SHIELDING APRON, 0.5 mm Pb equivalent, adult	1
EDIMGONS1C-	GONAD RADIATION SHIELDING APRON, 0.5 mm Pb equivalent, child	1
EDIMGONS1N-	GONAD RADIATION SHIELDING APRON, 0.5 mm Pb equivalent, neon	*
EDIMPOCU1--	POSITIONING CUSHIONS, set	1
EDIMRPSH1R-	RADIATION PROTECTION LEAD SHEETING, roll	*
PELEUPSD6--	UPS DOUBLE CONVERSION, 6 kVA, 230 V	1
EHOETABO215	OPERATING TABLE, SUGINOX) ORTHOPEDIC TRACTION SYS ORT5000C	*
EHOETABO2A-	TABLE, OPERATING, SURGICAL, MECHANICAL (SURGINOX 4080A-202	*

* Please discuss installation with the biomedical engineer of your OC and the intersectional radiographer/x-ray technician prior to purchase.

Reference resources

Code	Title
L012XRAB04E	Basic radiation protection. How to achieve ALARA
L012XRAB06E	The technical series: Diagnostic imaging: What is it?
L012XRAB07E	The technical series: X-ray equip. maintenance & repairs
L012XRAB11E	WHO manual of pattern recognition in diagnostic imaging
L012XRAB13E	WHO manual of diagnostic imaging: radiographic technique
L012XRAB15E	WHO manual of D.I. X-ray anatomy: musculoskeletal system
L012XRAB16E	WHO manual of D.I. X-ray anatomy: chest & pulmon. system
L012XRAB17E	Quality assurance workbook for radiographers and rad. techn.
L012XRAB18E	Handbook for District hospitals. Chest radiography for TB
L012XRAB19E	Merrill’s Pocket Guide to Radiography
L012XRAB20F	Techniques de radiographie ostéo-articulaire: Savoir-faire

Annex 2. The x-ray darkroom for traditional film development

The x-ray darkroom

The darkroom is a light-tight room where processing of radiographs is carried out. It is important to consider the basic requirements for this room as a radiograph can easily be ruined through a poorly designed darkroom and unsuitable processing procedures. Health issues must also be considered as the darkroom is a small confined space where hazardous chemicals are used under lowlight conditions. The darkroom should be designed to make film processing an efficient and standardised procedure as it is carried out in darkness. Every piece of equipment should be in its specific place.

Size

The minimum size of the darkroom should be 5 m^2 (2 m x 2.5 m) but a preferable size is 10 m^2. The darkroom should also never be too large. The darkroom must be large enough to accommodate the size of the processing equipment but not so large that total darkness becomes difficult to achieve. There must be enough space to separate dry working areas from the wet chemical processing tanks.

Layout

The position of the various items in the darkroom must follow a logical sequence so that the x-ray technician starts at the dry bench, taking the film from the cassette and clipping it into a hanger. The film is then taken from the dry workbench to the processing tanks. Once processing is complete, the film then goes to the drying rack.

The processing tank must be located along an outside wall as this will simplify drainage and water supply. The master tank should stand about 5 cm away from the wall. The wet film drying rack should be on the opposite side of the dry bench. Alternatively, the drying rack can be placed outside of the darkroom if there is not enough space inside.

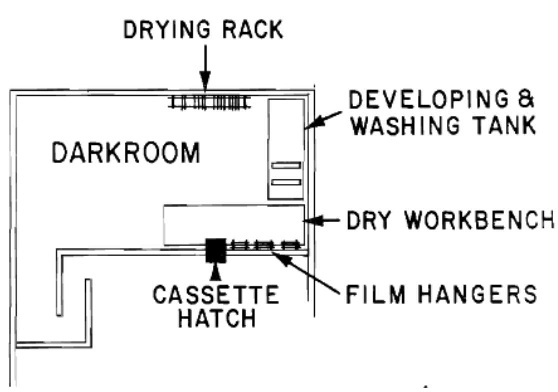


Figure 19: Suggested layout of a darkroom (Note: cassette hatch is optional)

Walls and ceiling

The darkroom walls and ceiling should be painted cream or yellow in order to reflect the room illumination. Black or any other dark colour should not be used as it leads to the use of a stronger safe light. The finish should be semi-gloss to avoid reflections and to simplify cleaning.

One wall must be strong enough to support plumbing and any of the walls should be strong enough to carry shelves.

Windows

A window is desirable in the darkroom for ventilation but must be completely lightproof. It should be fitted with solid internal shutters or heavy, totally opaque back material fixed to an inside frame This frame must be permanent and at least 8 cm wider than the window all the way around in order to completely block light coming through. The glass in the windows should be replaced with wood or hardboard, painted black on the inside. Painting the glass of the window black is generally unsatisfactory; it does not last and nearly always allows light to come into the darkroom. Black-out curtains are also unsatisfactory as they tend to attract dust and erode from the chemicals.

Doors

The entrance to the darkroom will require a lightproof door. The door should be about 90 cm wide and will need wide overlapping panels around the entrance to prevent light entering the darkroom when the door is shut. The inside door frame and the edges of the door should be matte black in colour. Curtains are not satisfactory to cover an open door frame, even if they are very thick.

The door should not have a key hole.

Floor

The darkroom floor should be waterproof and washable. It can be any colour. Where possible, the floor should slope slightly away from the door towards a floor drain which should be under or close to the processing tank.

Ventilation and air conditioning

An extraction fan is recommended for all darkrooms to ensure adequate ventilation at a minimum rate of 10 - 12 air changes per hour. The duct must have several bends to prevent light entering the darkroom and fogging the film.

An air conditioner is helpful in a hot or humid climate. When the temperature of the processing room exceeds 32°C, the x-ray films may become fogged (sensitised) by the heat. Then air conditioning is obligatory.

Water & Electricity

Water

The darkroom should have a running water supply for the processing tank. The taps should be located close to but not overhanging the processing tanks. The water and chemistry should be maintained at a temperature between 15°C and 24°C inside the processing tanks. Some processors will have a thermostat to control the temperature; otherwise hot water should also be available in the darkroom if temperatures are cool.

Electricity

The darkroom also requires a good independent electrical supply for the processing tanks and the safe lights.

Equipment

Dry workbench

There must be a ‘dry’ workbench in the darkroom. A dry bench is a firm, smooth surface in the darkroom to support cassettes while films are changed. The workbench should be well away from the processing tanks.

There should be nothing on the dry bench except the films and cassettes. It should be about 120 - 130 cm long, 50 - 60 cm deep and positioned at a suitable height for standing. The top must be smooth; either polished wood, vinyl, standard porcelain tiles, formic or equivalent. The colour of the tops should be deep red or deep blue as light colours can cause film fogging. Beneath the work surface there should be one shelf with enough space to store a one week supply of x-ray film boxes standing vertically upright, side-by side.

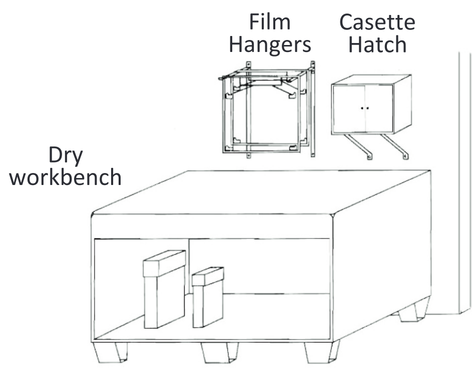
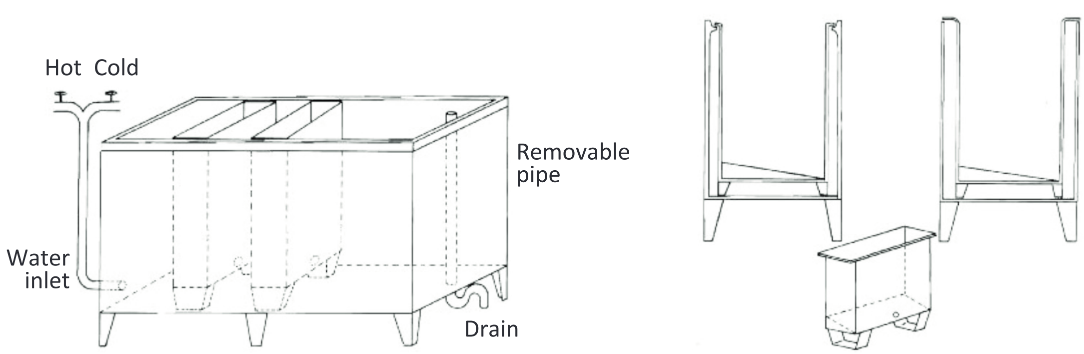


Figure 20: Dry bench with rack for storing empty film hangers
(Note: cassette hatch is optional)

Processing tanks

The processing tank contains two parts: the master tank and the insert tanks. The master tank serves as a water bath to hold the insert tanks and is usually large enough to provide free space between the insert tanks. The water assists in maintaining constant temperature in the insert tanks. The insert tanks are removable containers for the individual processing solutions (developer and fixer) and are spaced inside the master tank. These tanks should be supplied with covers made of the same material as the insert tanks. Always cover the tanks when not in use to keep out dirt and reduce the rate of evaporation and oxidation. Liquids draining out of the master tank must run through pipes made of porcelain or earthenware or special quality plastic or corrosion-resistant stainless steel. X-ray chemicals will cause standard metal pipes to leak after a few months.



Master Tank: 50 cms wide
80 cms high
150 cms long
13 cms from floor to bottom

Insert Tank: 38 cms wide
61 cms high
11.5 cms long

Figure 21: Processing tanks - master tank with inserts for chemistry

Film drying rack

Film hangers are metal frames to hold films while they are processing and drying. A simple drying rack can be made to hold the film hangers during the drying process (up to one hour). A drying rack can be made of wood, steel, brass or plastic and can be fixed to the wall opposite the dry bench, next to the processing tanks.

The rack can be made of two parallel rods at a height, which will not cause any obstruction or injury on the dark. Below the rack on the floor should be an additional shallow trough or tray to catch the drips. Alternatively, the floor beneath it should be of a material, which is waterproof and easily drained. X-ray films will drip chemical residues even after washing and the floor surface or the tray should be capable of accepting chemical contamination. The trays can usually be purchased locally, be made of plastic and placed side-by-side underneath the drying rack.

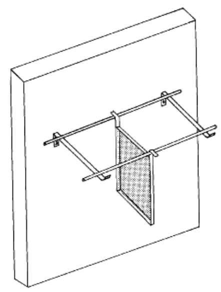


Figure 22: Film drying rack

If the dark room is not large enough, the drying rack can be in the x-ray room or anywhere else suitable where it is not too dusty. Wet films can become coated with dust and insects before they are dry and it is difficult to clean films after this has happened.

Safelights

Every darkroom needs one or two lights with coloured safelight filters that will not fog x-ray films. Red is the most acceptable colour and suits almost any type of x-ray film. A safelight should be positioned 120 cm above the working bench and should be preferably pointing upwards. If the light is pointed facing upwards, the bulbs can be 25 W. If the light points directly onto the work bench the bulb should not exceed 15 W.

White light is also needed in the darkroom, but it must never be a fluorescent light as often they continue to glow after they are turned off. The switch for the white light should be located inside the darkroom so that it cannot be turned on unexpectedly by somebody on the outside.

Testing the darkness of the darkroom

When the door of the darkroom is shut there must not be any light coming into the darkroom.

In order to check this: go into the darkroom, close the door and stay inside without light for 10 minutes. Then look around carefully for any light that enters the room through holes or cracks and cover them.

Fogging of films in the darkroom

If the processed films are hazy and you suspect that there is fogging in the darkroom, test the amount of light in the room itself in the following way: with the darkroom door closed and only the safelights on, place an x-ray on the film bench. Carefully place two or three metal objects (keys, coins, etc.) on top of the film and leave the film there with only the safelights on for 2 minutes. Then process the film. If the film shows shadows of the objects placed on it then there is too much light in the darkroom. You must find the source or all the films in the darkroom will be spoiled.

Check the following:

– Is the coloured filter of the safelight damaged? Check the filter to make sure it is not blistered, scratched or losing its colour.
– Is the bulb too strong? Make sure it is 25 W or less.
– Are there too many safelights?

Remember: films can be fogged by light even when immersed in the processing chemicals. Never switch on the white light or open the door when films are processing.

Cleaning

The darkroom should be kept clean at all times: both the bench and the floor must be clean and dry. There should be no dust, dirt or moisture in the air where the x-ray films and cassettes are handled. The floor should be cleaned with a damp mop every week.

Reference for all images in Annex 2

Palmer, PES., Hanson, GP. (2011). Diagnostic Imaging in the Community: A manual for clinics and small hospitals.

Annex 3. Manual x-ray film processing

X-ray film

X-ray film is made of a blue tinted plastic base covered in an emulsion. The emulsion contains silver halide crystals that are energised by both radiation and white light exposure. This causes the x-ray film to turn black. Unexposed x-ray film will be transparent and clear after processing; there should be no haziness of grey-black patches.

Film expiry

Each packet of film has a date marked on the box and indicates for how long the x-ray film will give satisfactory results. You cannot achieve good results with old films.

Film storage

- Film should be stored in between 10 - 24°C. High temperatures will damage the film before the expiry date.
- Do not store x-ray films in the x-ray room as radiation will fog the film.
- It is safe to store film with other items such as food and drugs but not where they may get wet or be exposed to any sort of gas (ammonia, gas for heating etc).
- Always store x-ray film boxes standing upright and not stacked on top of one another as they are sensitive to pressure.

Film handling

Film can be easily damaged if it is not handled with care. Observation of the following can reduce the chance of damage and film artefacts:

- Ensure clean and dry hands when handling films.
- Hold the films only at the edges and ideally in the corners.
- Do not eat, drink or smoke in the darkroom.
- Check film boxes at delivery to unsure they have not been damaged in transit.
- Use the oldest film in stock first.

Processing solutions

After an x-ray film is exposed, it needs to be processed with two types of chemistry called developer and fixer.

Developer is a chemical solution that converts the exposed silver halide crystals on an exposed x-ray film into black metallic silver. This results in a visible image.

Fixer chemistry enables fixation of the film and hardens the film surface. Fixation clears all undeveloped crystals before washing so that the film will not discolour or darken with age or exposure to light.

Washing the film with tap water removes all of the processing chemicals and any residual undeveloped silver crystals. If it is not washed for long enough, the image will eventually discolour and fade.

Preparing processing solutions

Developer and fixer chemicals come either in powder form, as ready-mixed solutions, or in liquid concentrate. All are acceptable for use. Always prepare the solution exactly according to manufacturer's instructions and store prepared chemistry for later use in closed brown bottles. Chemistry in powder or concentrate form should be prepared in buckets and stirred with rods dedicated to each chemical. Mark one bucket and rod with 'D' for developer and the other with ‘F’ for fixer. Chemistry should be prepared outside of the darkroom in a space that is well ventilated. ***If there are any spills, clean immediately with water***.

The chemistry insert tanks in the darkroom should be clean and empty of old chemistry before refilling. Wash the tanks with water; do not use soap or washing solutions. Always use the same tank for each chemical. Fill the one or two additional insert tanks for rinsing the film with water, and where existing, the outside water bath with water until 2 cm from the top.

The level of the chemicals in the tanks should be replenished from the storage bottles every few days. How often depends on how often the processing tank is used. There should be enough chemistry to completely cover the x-ray film when it is submerged.

Replacing processing solutions

The chemicals must be completely changed according to the manufacturer's directions. There are many factors that will determine when it is necessary to replace the chemistry, such as how many x-ray films are developed, exposure of the chemicals to air, and the amount of water dilution. One guide for knowing that chemistry should be changed is whenever the developing time required for the image exceeds the recommended time by 10% (see table later in document for recommended developing times).

If unsure, as a rough guide, replace **x-ray chemistry approximately once a month**.

Processing procedure

The processing of the x-ray film is a very important step to obtaining and good quality diagnostic image. Complete film processing has stages of: development, fixation, washing and drying.

1. Take the cassette containing the exposed film into the darkroom. Close the door to the darkroom, turn on the coloured safe light and turn off the white lights.
2. Remove the film from the x-ray cassette and clip the film into the film hanger of the same size.
3. Put the film into the tank of developer solution and move it up and down once or twice in the tank. The film can then be left to develop. The time taken for development depends on the temperature of the chemical solutions. See below, ‘Developing times for manual processing’.
4. Meanwhile, with clean dry hands, take a new film from the film-box and refill the cassette.
5. Once the developing time has passed, lift out the film hanger and dip the film two or three times into the first insert tank with washing water. If you do not have a dedicated insert tank for washing water, rinse the film directly in the surrounding water bath.
6. Put the film into the tank of fixer and leave it there for at least 5 minutes (more than 5 minutes will not damage the film).
7. After 5 minutes, remove the film hanger out of the fixing tank and put it into the second insert water tank or directly into the surrounding water bath.
8. It is now safe to turn on the white light in the darkroom but first make sure the film box is firmly closed. Leave the film in the washing tank for 30 minutes.
9. After 30 minutes, remove the film in the film hanger and hang it to dry on a film drying rack. This should be in a dust free environment and drying temperature should not exceed 35°C.

10. When the film is dry, remove it from the film hanger and write the patients name in ink, including the date and patient hospital number. **Ensure that the details are written on the correct side of the film so that it can be read clearly when viewed in AP position**. Make sure the left (L) and/or right (R) lead markers are also clearly visible. If not, rewrite again in ink.

Developing times for manual processing

The most important factors to consider for developing are the temperature of the chemical and the amount of time the film is allowed to be in contact with the chemical. The higher the temperature of the solution, the less time needed. **The preferred condition for manual processing is 4.5 to 5 minutes at 20°C**. Keep a non mercury thermometer and a timer accurate in minutes and seconds in the darkroom to check your processing solution.

Check the temperature of the chemistry twice per day (i.e. in the morning and in the afternoon).

For processing master tanks with hot and cold water flow, adjusting the temperature of the incoming water can regulate the temperature. Given time, the chemicals will be the same temperature as the water in the water bath. Otherwise, adjust your processing time according to the actual temperature of the chemistry.

Temperature time table

Temperature of developer (°C)	Developing times (minutes)
15	7
16	6.5
17	6
18	5.5
19	5
20	4.5
21	4
22	3.5
23	3

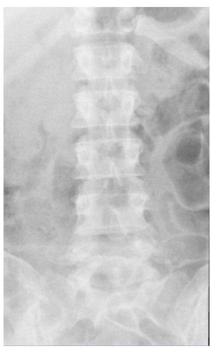
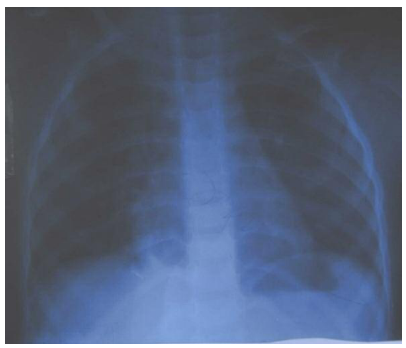
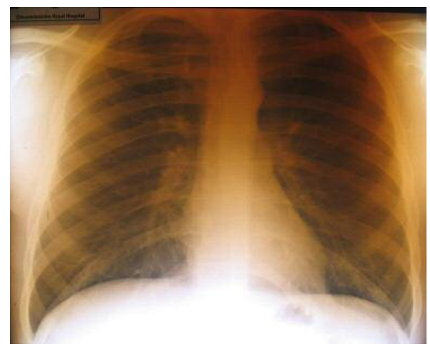
Under- and over development & under- and over exposure: assessing your image

If the x-ray film comes out **too light**, it can be because it was underexposed (too little radiation) or because it was **underdeveloped** (not enough time in developer chemistry). An underdeveloped x-ray film will also have poor contrast and the background will be grey instead of black.

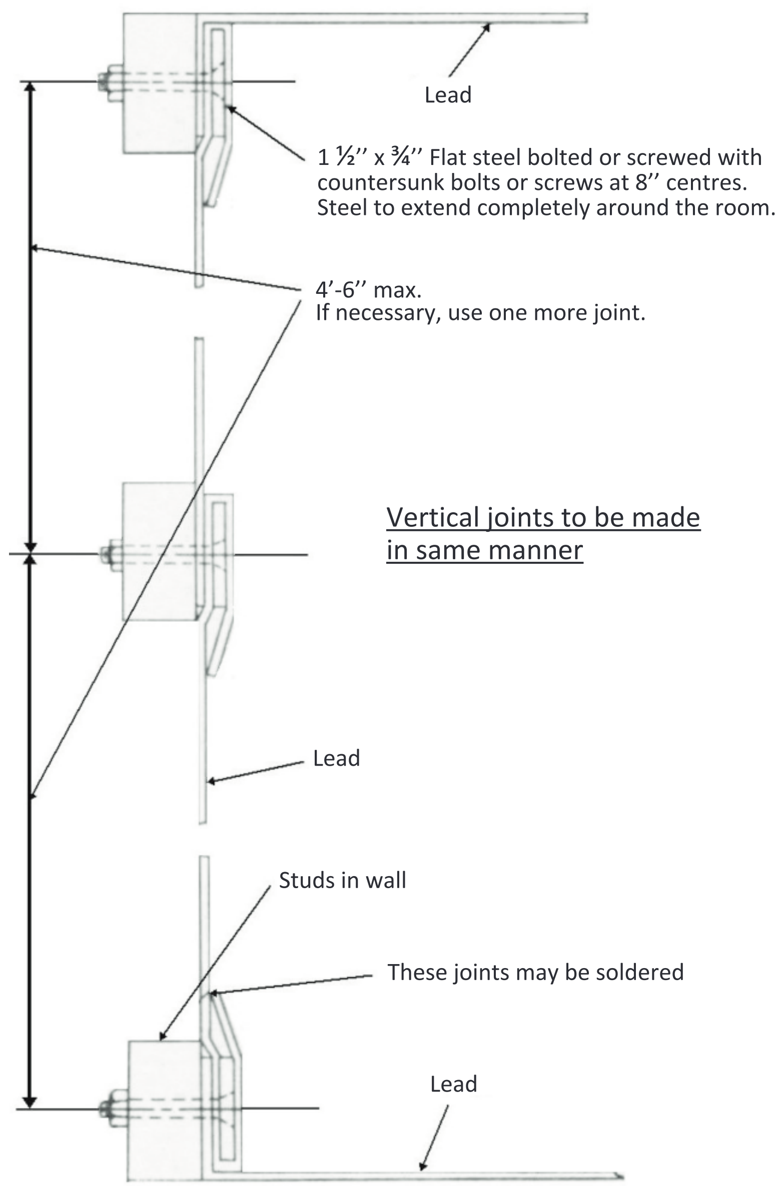
If the x-ray film comes out **too dark**, it can be because it was overexposed (too much radiation) or because it was **overdeveloped** (too long in developer chemistry). An overdeveloped film will also have poor contrast.

If the x-ray film has a **brown colour**, it can be because it was **not rinsed thoroughly after fixation**. This is called 'fixer retention'.

Examples of poor processing technique

Underdeveloped /Underexposed	Overdeveloped/ Overexposed	Fixer retention
		

Annex 4. Sheet lead fastening diagram



Conversions

1 ½" = 3.8 cm
¾" = 1.9 cm
4'6" = 1.4 m

Annex 5. Terms of reference: expatriate radiographer/x-ray technician

MSF Section:

Country:

Project site:

Dates:

Name of radiographer/x-ray technician:

Background

Give mission specific background to the project and the hospital.

Overall objective

To increase the competences in diagnostic imaging (e.g. use of equipment, quality of radiographs, radioprotection) in MSF projects, with the goal of improving the medical care.

Specific objectives (as applicable)

- To accompany the installation of the x-ray unit/fluoroscopic x-ray system.
- To evaluate safety measures in the x-ray room/OT and give recommendations for improvements/essential changes to current practice incl. radioprotection.
- To interview and hire national radiographers/x-ray technicians.
- To train (theoretical & practical) national radiographers/x-ray technicians in the appropriate use and care of the x-ray unit/fluoroscopic x-ray system ensuring a high quality of diagnostic images.
- To put protocols for daily tasks including quality control, image storage and safety practices in the x-ray department/OT into practice.
- To inform and train staff on radioprotection standards and safe practices considering both staff and patients.

Profile of radiographer/x-ray technician

- Licensed radiographer/x-ray technician with at least 5 years working experience.
- Experience with a fluoroscopic x-ray system (as applicable).
- Experience in training and coaching.
- Ability to demonstrate initiative, work independently and problem solve.
- Ideally experienced in working in resource-limited settings.
- Computer literacy: Microsoft Office is essential.
- Fluent in English and optimally in French (reading and writing).
- Commitment to the values upheld by MSF.

Place in the organization

While in the field the radiographer/x-ray technician is functionally accountable to the Medical Coordinator and hierarchically accountable to the Project/Field Coordinator.

Reporting

By the end of the visit a report must be sent to the Medical Coordinator, Field/Project Coordinator, Health Advisor/polyvalent and the intersectional radiographer.

Annex 6. Job profile: national radiographer/x-ray technician

Location

Based in:

Functional and hierarchical lines

Hierarchically accountable to the Project/Field Coordinator and functionally accountable to the Medical Team Leader, Medical Focal Point or Medical Doctor/clinician.

Responsibilities and activities

- Responsible for radiology service provision.
- To produce images of adequate diagnostic quality.
- To keep accurate record of all images produced, and to be able to provide weekly summaries of all radiography work completed.
- Communicate with patients and staff in a clear and respectful manner and uphold patient confidentiality at all times.
- Responsible for maintaining all equipment according to maintenance schedule including adherence to a regular cleaning schedule of equipment, and to alert supervisor of malfunctions/problems.
- To uphold all radiation safety regulations, to ensure that staff/patients are following these regulations, and to inform staff about radiography safety.
- To ensure that all areas of radiation are clearly marked and respected.
- Undertake regular quality assurance checks on equipment and radiographs.

Requirements

- Certified in Medical Imaging/Radiation Technology (where possible).
- Minimum of two years practical experience as radiographer/x-ray technician.
- Experience, or eagerness to learn, digital imaging systems.
- Flexible and adaptable to changing circumstances.
- Ability to work independently while remaining open to coaching and learning.
- Ability to organize and prioritize workload, using initiative when appropriate.
- Ability to work well as part of a multi-cultural team of national and expatriate staff. Previous experience working with an NGO is desirable.
- Commitment to the aims and values of MSF.
- Excellent communication skills, both written and orally.
- Computer literate.

Annex 7. Evaluation of an x-ray department by expatriate radiographer/x-ray technician

Project: **Section:** **Date:**

Project background:

Average examinations per day:

Types of examinations:

Name and position of all national radiographers/x-ray technicians:

X-ray unit

- Type: include model name and manufacturer's name.
- Installation date.
- Date of last service? By who? Give contact details.
- LBD test (light beam diaphragm test: does the light correspond with the x-ray field?)
- Check full range of movements and locks on arm and table

Processor/Digital imaging scanner

- Type: include model name and manufacturer's name.
- Installation date.
- Date of last service? By who? Give contact details.
- Cassettes: how many? In good condition?
- Phosphor screens: how many? In good condition?
- Film: stored upright in radiation safe area? Good supply?
- Chemistry: changed monthly? Good supply?

Accessories

- Table: wheel locks working?
- Positioning cushions: available? Cleaned regularly?
- Grid: available? Used appropriately?
- Lead aprons: available? Checked regularly for lead cracks?
- Hangers for lead aprons: available? Are they being used?

Radiographic technique

- Positioning technique: general, trauma, paediatrics, plaster, fixations.
- Exposure selections: appropriate use of exposure chart? Good manipulation of exposures?
- Patient care: patient treated respectfully? Explanation of examination?
- FFD consistency (with mobile unit only).

Protocols/Manuals

- Availability and use of: exposure charts, imaging protocols and reference manuals.

Image evaluation

- Image critique using PACEMAN assessment (20 % of previous month's images, randomly selected by digital x-ray number).

Staff organisation

- Staff availability and roster. Suitable for department needs?

Radiation safety: room, staff and patients

- Room construction according to guideline? See chapter 4 of x-ray manual.
- Working to ALARA principle.
- Warning signs on doors.
- Use of gowns for staff.
- Use of aprons for patients.
- Care of gowns and aprons.
- Pregnancy checks for female patients.

Administration

- Daily task sheets: are they available and referenced each day?
- Patient register: available and completed for each patient?
- Image storage and retrieval: are digital images archived?

Quality Assurance

- QA program implemented: See chapter 11 of x-ray manual.

Maintenance/Service contract

- Options available for corrective maintenance?

Radiographers/x-ray technicians training required

–

–

Areas for attention

–

–

Annex 8. Radiographer/x-ray technician competency evaluation

Project: **Section:** **Date:**

Radiographer's/x-ray technician's name:

Department / Hospital:

Evaluator's name and email:

A radiographer/x-ray technician is responsible for providing high quality diagnostic images about any anatomical detail within the patient's body. The best possible diagnostic image should be produced while ensuring that the radiation dose which the patient receives is kept to a minimum following the ALARA principle: 'As Low As Reasonably Achievable'.

The responsibilities of radiographers/x-ray technicians are to:

1. Prepare the room properly for the patient.
2. Brief the patient on the nature of the procedure and explains what will be done and what will be asked of the patient for the procedure.
3. Provide positioning and immobilization devices as needed.
4. Select the proper technical factors based on the ALARA principle, patient size and suspected pathology.
5. Select and operate the equipment according to the examination protocols and the characteristics of the equipment.
6. Provide radiation protection in accordance with safety standards and legislation.
7. Ensure that side markers are on the images and are correctly placed.
8. Ensure that the patient's name and other required information is correct and is on the image(s).
9. Process the image.
10. Inspect the image for technical sufficiency and take corrective action, repeating the examination if necessary.
11. Ensure that all established protocols are followed.
12. Maintain the functioning of the processing equipment or digital imaging scanner/computer and follow all necessary QA procedures.
13. Carry out the administrative responsibilities including:
    a. Producing and maintaining the required patient records (i.e. patient register).
    b. Maintaining an orderly and clean work area.
    c. Conducting the required inventory and function check of the x-ray room(s) and inform the necessary people for necessary supplies or in case of equipment malfunction.

The following evaluation is to be undertaken by an expatriate radiographer/x-ray technician.

		Excellent	Good	Fair	Poor	Comments
KNOWLEDGE						
1.	**Anatomy** Ability to identify the major bones and bony landmarks involved in radiography of the chest, spine, abdomen, extremities, pelvis & skull.					
2.	**Properties of x-rays and x-ray equipment** Basic knowledge of the properties of x-rays, the control factors affecting the x-ray beam, and the operation of the different types of equipment.					
3.	**Radiation protection** Basic knowledge of the effects of ionising radiation and the principles of radiation protection.					
4.	**X-ray cassettes, imaging plates/ film, and processing procedures** Basic understanding of the structure and function of x-ray cassette, imaging plate or film, and IRS or chemistry processing procedures.					
5.	**Radiographic technique** Understanding of the terminology used in radiography, radiographic equipment and accessories, the factors affecting image quality, record keeping, the conduct of a radiographic examination and the importance of correct use of side markers.					
6.	**Exposure standardisation** Understanding how the radiographic factors (kVp, mA, time, film focus distance) affect the quality of a radiograph and how to alter these factors for differences in patient size, the use of grids and the application of plaster.					
7.	**Positioning techniques** Appreciation of the positioning techniques required to produce diagnostic radiographs of the chest, spine, abdomen, extremities, pelvis & skull.					
8.	**Image artifacts** Appreciation of image faults and the errors that produce them in relation to x-ray technique and processing.					

		Excellent	Good	Fair	Poor	Comments
PRACTICAL PROFICIENCY						
1.	**Exposure parameters** Demonstrated ability to alter exposure parameters to compensate for incorrect exposures, different body thicknesses, and the use of grids, plaster, etc.					
2.	**Image artifacts** Demonstrated ability to identify various image faults and how to prevent their recurrence.					
3.	**Production of radiographs** Demonstrated ability to produce diagnostic radiographs of the chest, spine, abdomen, extremities, pelvis & skull, that have a high standard of image quality.					
4.	**Processor operation (film/ chemistry processing)** Demonstrated knowledge of processor operation and the ability to maintain processor cleanliness and chemical preparation.					
5.	**Problems and faults in the darkroom (film/chemistry processing)** Demonstrated ability to identify problems and faults in the darkroom and be able to carry out light and safelight tests.					
6.	**Use of computerized radiography equipment (digital processing)** Demonstrated ability to use IRS equipment to produce an image, perform any post processing necessary, print and export the image electronically to CD / USB / hard drive including regular archiving of images.					

Annex 9. International Commission on Radiological Protection

Pregnant women working in x-ray departments

The following recommendations regarding pregnancy and medical radiation are given by the International Commission on Radiological Protection[1]. Points that have been deemed most relevant to the MSF field context have been extracted and summarised. It is important to note that there are often specific regulations of the country itself that MSF is working within and these should always be considered alongside international regulations.

– Restricting dose to the foetus does not mean that it is necessary for pregnant women to avoid work with radiation or radioactive materials completely, or that they must be prevented from entering or working in designated radiation areas. It does, however, imply that the employer should carefully review the exposure conditions of pregnant women. In particular, their working conditions should be such that the probability of high accidental doses and radionuclide intakes is insignificant.

– When a medical radiation worker is known to be pregnant, there are three options that are often considered in medical radiation facilities: 1) no change in assigned working duties; 2) change to another area where the radiation exposure may be lower; or 3) change to a job that has essentially no radiation exposure. There is no single correct answer for all situations and in certain countries there may even be specific regulations. It is desirable to have a discussion with the employee. The worker should be informed of the potential risks, local policies, and recommended dose limits.

– Change to a position where there is no radiation exposure is sometimes requested by pregnant workers who realise that risks may be small but do not wish to accept any increased risk. The employer may also arrange for this in order to avoid future difficulties in case the employee delivers a child with a spontaneous congenital abnormality which occurs on average at a rate of about 3 in every 100 births in the general population. This approach is not required on a radiation protection basis, and it obviously depends on the facility being sufficiently large and flexible to easily fill the vacated position.

– Changing to a position that may have lower ambient exposure is also a possibility. In diagnostic radiology, this may involve transferring a technician from fluoroscopy to the general x-ray area or some other area where there is less scattered radiation to workers.

– There are many situations in which the worker wishes to continue doing the same job, or the employer may depend on her to continue in the same job in order to maintain the level of patient care that the work unit is customarily able to provide. From a radiation protection point of view, this is perfectly acceptable providing the foetal dose can be reasonably accurately estimated and falls within the recommended limit of 1 mGy foetal dose after the pregnancy is declared. It would be reasonable to evaluate the work environment in order to provide assurance that high-dose accidents are unlikely. The recommended dose limit applies to the foetal dose and it is not directly comparable to the dose measured on a personal dosimeter. A personal dosimeter work by diagnostic radiology workers may overestimate foetal dose by about a factor of 10 or more. If the dosimeter has been worn outside a lead apron, the measured dose is likely to be about 100 times higher than the foetal dose.

– Finally, factors other than radiation exposure should be considered in evaluating pregnant employees' activities. In a medical setting there are often requirements for lifting patients and for stooping or bending below knee level. There are a number of national groups that have established non-radiation related guidelines for such activities at various stages of pregnancy.

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[1] International Commission of Radiological Protection, Pregnancy and Medical Radiation, Annals of the ICRP, Publication 84, Pergamon Press, Oxford (2000).

Annex 10. Exposure charts

The exposures below are a guideline for use with the WHIS-RAD and the Carestream CR. Exposures with other x-ray units or processors may vary slightly and the chart should then be adjusted accordingly.

These protocols and techniques are matched with the “WHO: The WHO manual of diagnostic imaging: radiographic technique and projections”, which is a standard recommended resource and should be available for reference at every site.

Radiograph	Standard views	Patient position	Cassette size in cm	kV	mAs	Bucky	WHO manual reference
Chest							
adult male	PA	Erect	35x43	120	2.5-3.2	Yes	Page 6
adult female	PA	Erect	35x43	120	2.0-2.5	Yes	Page 6
adult male	Lateral	Erect	35x43	120	5	Yes	Page 7
adult female	Lateral	Erect	35x43	120	4	Yes	Page 7
adult male/ female	AP	Supine	35x43	80	4	Yes	Page 10
Chest Infant	AP	Supine	24x30	66	2	No	Page 16
Chest child < 3 years	AP	Supine or Erect	24x30	70-75	2	No	Page 15
	Lateral	Supine or Erect	24x30	80-90	3	No	
Chest child 3-8 years	AP	Erect	24x30	75-80	2	No	Page 6
	Lateral	Erect	or 35x43	80-90	4	No	Page 7
Abdomen adult	AP Supine	Supine	35x43	75	25	Yes	Page 18
	AP Erect	Erect	35x43	75	30	Yes	Page 19
	Left lat decub	Right side up	35x43	75	30	Yes	Page 20
Abdomen infant	AP	Supine	24x30	66	2	No	Page 18
Abdomen child 1-6 years	AP	Supine or Erect	24x30 or 35x43	70	5	No	Page 18
Shoulder	AP	Erect, supine or sitting; Palm up	24x30	70	12	Yes	Page 65/68
	Lateral	Erect or sitting; Palm down	24x30	70	32		Page 69
Clavicle	AP Angle +20	Supine or Erect	24x30	70	12	Yes	Page 62
Scapula	AP	Supine or Erect	24x30	75	16	Yes	Page 63
	Lateral	Supine or Erect	24x30	75	32	Yes	Page 64
Humerus	AP	Erect	35x43	60	8	Yes	Page 71
	Lateral	Erect	35x43	60	8	Yes	Page 72
Elbow	AP	Sitting	24x30	55	5	No	Page 73
	Lateral	Sitting	24x30	55	5	No	Page 74

Radiograph	Standard views	Patient position	Cassette size in cm	kV	mAs	Bucky	WHO manual reference
Forearm	PA	Sitting	35x43	60	5	No	Page 76
	Lateral	Sitting	35x43	60	5	No	Page 77
Wrist	PA	Sitting	24x30	55	5	No	Page 78
	Lateral	Sitting	24x30	55	5	No	Page 79
Hand	PA	Fingers fanned	24x30	55	4	No	Page 81
	PA Oblique	Fingers straight	24x30	55	4	No	Page 81
	Lateral	"Ok" sign	24x30	55	4	No	–
Thumb	AP Lateral	Sitting	24x30	55	4	No	Page 81
	Lateral	Sitting	24x30	55	4	No	Page 83
Pelvis	AP	Supine	35x43	75	25	Yes	Page 86
	Frog leg (infant)	Supine	24x30	55	6	No	Page 110
Hip	AP Pelvis	Supine	35x43	75	20	Yes	Page 86
	Lateral Hip	Supine, oblique	35x43	75	16	Yes	Page 88
Femur	AP	Supine	35x43	75	16	Yes	Page 91
	Lateral	Lying on side	35x43	75	16	Yes	Page 92
Knee	AP	Supine	24x30	60	6	No	Page 94
	Lateral	Lying on side	24x30	60	6	No	Page 95
Lower leg	AP	Supine	24x30	60	5	No	Page 99
	Lateral	Lying on side	24x30	60	5	No	Page 100
Ankle	AP	Supine	24x30	60	4	No	Page 102
	Int. obl.	Rotate 15° int.	24x30	60	4	No	Page 102
	Lateral	Rotate foot out	24x30	60	4	No	Page 103
Foot	AP	Foot flat down	24x30	60	4	No	Page 104
	Oblique	Rotate 30° int.	24x30	60	4	No	Page 107
	Lateral	Rotate foot out	24x30	60	4	No	Page 105
Toes	AP Foot	Foot flat on cassette	24x30	60	3	No	Page 104
	AP Oblique Foot	Rotate 30° int.	24x30	60	3	No	Page 106
Cervical spine No trauma	PA or AP	Erect	24x30	75	20	Yes	Page 46
	Lateral	Erect	24x30	70	12	Yes	Page 47
Cervical spine After trauma	AP	Supine	24x30	75	20	Yes	Page 49
	Lateral – cross table	Supine	24x30	70	16	Yes	Page 50
	Odontoid view	Supine	24x30	75	16	Yes	Page 51
Thoracic spine	AP	Supine	35x43	75	30	Yes	Page 53
	Lateral	Lying on side	35x43	80	40	Yes	Page 54

Radiograph	Standard views	Patient position	Cassette size in cm	kV	mAs	Bucky	WHO manual reference
Lumbar spine	AP	Supine	35x43	75	40	Yes	Page 55
	Lateral	Lying on side	35x43	85	50	Yes	Page 57
	Lateral –LS Junction	Lying on side	24x30	85-100	64	Yes	Page 59
Facial Bones & Sinuses	Water's view	Head tilted back 45°	24x30	75	20	Yes	Page 38
	Lateral	Erect or supine	24x30	75	20	Yes	Page 40
Mandible	PA	Sitting Erect	24x30	75	32	Yes	Page 41
	Oblique Lateral	Sitting Erect	24x30	75	16	Yes	Page 42
Skull	AP	Supine	24x30	70	40	Yes	Page 35
	Lateral	Supine	24x30	70	32	Yes	Page 37

Annex 11. X-ray image assessment using PACEMAN

MSF Section: Project site: Date:

Acceptable: ✔

Inacceptable: x

20 % of previous month's images, randomly selected by digital x-ray number.

	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	Total Acceptable
Positioning																															/30
Area																															/30
Collimation																															/30
Exposure*																															/30
Markers																															/30
Aesthetics																															/30
Name																															/30

* Exposure to be within the optimal Exposure Index range for the Carestream120, i.e. 1850-2150 .

Annex 12. X-ray request form template

Name of Hospital: ______________________________________

Patient details

Name: ___________________________________ Patient ID number: ______________

Date of birth: ____/____/____ Age: ___________________________

Sex: ☐ Male ☐ Female

Address: ____

____

____

Telephone: ________________________________

X-ray views requested

Clinical indication for x-ray
(brief patient history, symptoms and examination findings)

Details of referring doctor/clinician

Name: ___________________________________ Signature:

Contact: __________________________________

Achevé d'imprimer en France par ISI, 93210 La Plaine Saint-Denis
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