Chapter | 23 |

Computed Tomography

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CHAPTER OUTLINE

This chapter will consider:

- Principles of care before, during and after CT
- Special procedures and circumstances
- Interventional CT
- Physical and radiation risks
- Radiation dose reduction

INTRODUCTION

This chapter will highlight the importance of patient care and will provide some practical aspects of patient care in the computed tomography (CT) department.

Effective patient care encompasses all aspects of healthcare. Radiography is a people-oriented profession and requires proficiency in a wide variety of communication techniques, which is a key component of good patient care. The most skilled and proficient practitioner will become inept if effective communication, which accentuates patient care, is not provided. Modern day patient care elevates the patient to the core of our radiographic responsibilities.

Patient care in CT departments is aimed at enhancing the patient's wellbeing through the duty of care provided. It is imperative that the techniques and protocols applied in CT departments validate this principle. The information explosion of the twentieth century has resulted in better informed patients, well aware of the level and type of service expected. Practitioners should ensure that the patient is informed of all aspects pertaining to the CT examination and their subsequent management. This chapter will provide tips on patient care before, during and after CT examinations. The second part of this chapter deals with the physical and biological risks for patients undergoing CT examinations.

APPROACHES TO GOOD PATIENT CARE

When performing CT examinations, practitioners need to consider the following fundamental points of patient care:

Namely that all patients be:

- Treated with respect and dignity
- Treated fairly, irrespective of their social status, race, gender, mental or physical status, sexual orientation, religion or beliefs.

Practitioners should further take cognisance of the patient's emotional state; a patient in severe pain is less likely to cooperate or be in the mood for light-hearted conversation. The way patients are treated should thus befit their mood.

PATIENT CARE BEFORE IMAGING

Before patients are brought into the scanner room, practitioners need to ensure that they:

- Introduce themselves to the patient by their name and title
- Address patients according to their titles. It will be discourteous to address an unmarried female as 'Mrs' and vice versa
- Always correlate the identity of the patient to prevent a CT examination performed on the wrong patient. A good and safe method is always to check the age and sex of your patient. It is important that patients are called Mr Peter Smith, as it will prevent Mrs Smith from responding in the waiting area. Patients with names or

surnames that sound similar, will often respond when called in the waiting area. Confirm their identity by asking them their date of birth (which you would have checked already). Knowing the sex and age of your patient before they are called will alert you when the wrong patient responds to your call. Performing a CT examination on the wrong patient will have serious medico-legal risks for the practitioner, and should be prevented at all costs

- Check that the request form and folder (if you are not employed in a paperless hospital) is accompanying the right patient. If your CT department employs a Radiology Information System, ensure that all the necessary administrative duties such as entering of the patient, billing for the procedure and transfer of patient data to the CT department has occurred. It is also important to check whether previous radiological procedures and results are available. Previous radiographic examinations and results are needed to compare progress or regression of disease
- Determine whether the clinical history justifies the clinical examination. By knowing the clinical indications and associated radiographic appearance of the pathology on CT, practitioners will ensure that the correct CT examination is requested
- Understand the medical terminology on the request form, as this will guide your radiographic approach. If a patient has a clinical history of claustrophobia, practitioners will know to attend to their fear for narrow spaces by pointing out to them that the gantry is in fact an open entity
- Ensure that all relevant patient details such as the patient's name, hospital identity number, examination number were correctly entered on the Radiology Information System (RIS) or Picture Archiving and Communication System (PACS) or control panel of scanner. Incorrect entering of patient's details may cause confusion and may pose a medico-legal risk if wrong results are matched with the wrong patient. Incompatible patient data will lead to non-integrity of patient data, which will hamper merging CT examinations with other imaging studies, when using RIS or PACS.

Explanation of the CT procedure

A patient centred healthcare philosophy demands that patients be informed of all matters related to their management. When explaining the procedure, the practitioner should refrain from using scientific jargon. Some aspects that need to be conveyed to the patient are:

- In which position they will be placed on the scanner table
- Whether they will be palpated during the CT examination
- For how long the examination will take place
- Whether any breathing or other instructions will be requested
- Warn patients about the table and gantry movements that will take place. Patients unfamiliar with CT scanning often get frightened once the table or gantry movement occurs
- Whether there will be a need for delayed sequences
- Patients should be encouraged to indicate to the practitioner when they feel uncomfortable by showing a hand or lifting their feet.

Good patient care should determine that no procedure will be explained to patients in the waiting room, especially where other patients can hear you. Similarly, personal details of patients should never be asked in front of others, including staff, as this will be violating their right to privacy. Personal questions should be asked in the privacy of the scanner room, behind closed doors. Where there is a need for contrast media administration, the patient should be informed about the risks and side-effects of contrast media. Informed consent should be obtained prior to administration thereof. (To read more about contrast media reactions and contrast nephrotoxicity, see Chapter 11, Drugs and contrast agents.)

The need for informed consent

Every patient is entitled to provide informed consent before any procedure can be performed. This doctrine is underscored by the patient's right to know and participate in his/her own healthcare. Informed consent is therefore needed for all invasive procedures performed in the CT department such as those requiring contrast media administration.

In order for a patient to give an informed consent, the patient has to be informed of:

- The nature of the treatment
- Any risk, complication and expected benefits or effects of such treatment
- Any alternatives to the procedure and their risks and benefits.

Other procedures in CT imaging that require informed consent are for:

- Fine needle aspiration biopsies (FNAB) of the lung nodules, liver lesions or abscess drainage
- Facet block injections.

Practitioners have a duty to ensure that informed consent is signed for such invasive procedures, as they will not be exempt from any lawsuit that may arise from failure to obtain informed consent. (See Chapter 29, Ethical and legal considerations in professional practice, for more background on the medico-legal responsibilities of the practitioner.)

Patient preparation before the CT examination

Patient preparation is an important but often overlooked part of the CT examination.

- It is important that patients are appropriately dressed for all CT examinations. No metal objects should be worn over or near the anatomical area to be examined. Metal objects will cause artefacts, which will result in a repeat of that sequence and additional radiation dose to the patient
- Patients should be dressed in a disposable non-transparent gown for all CT examinations, except for a CT of the brain, sinuses and/or facial bones
- Bowel cleansing should be adequate to ensure a CT examination of diagnostic value. The presence of stool may mimic an endoluminal mass lesion or mask the presence of either a polyp or colonic carcinoma. Fluid residues can cover the colonic mucosa, covering areas of internal bowel surface
- Any residual barium from previous barium studies should be identified to prevent streak artefacts, which may lead to a repeat or suboptimal CT examination. It is therefore important to verify whether the patient underwent any barium study prior to the CT examination. If this is the case, a conventional antero-posterior radiograph of the abdomen should be performed to establish whether the bowel is free from any residual barium. If barium is evident in the GIT, the CT examination will need to be postponed.

Patient preparation for CT of the brain, sinuses or facial bones

- Metal objects such as rings, nose or tongue studs, hairpins, dentures containing metal and glasses and hearing aids, should be removed before starting the CT examination, as they cause unwanted streak artefacts.

Patient preparation for CT of the chest

- Ensure that patients remove metal objects such as nipple rings or underwear containing metal.

Patient preparation for CT of the abdomen/pelvis

- Patients who will undergo CT imaging of the abdomen need to remove metal objects such as navel rings, as if discovered only during the surview (topogram), it will require a repeat surview, which will cause an unwanted additional dose to the patient
- Do not assume that the patient is aware that money should be removed from pockets when wearing underwear or tracksuits
- Ensure that the patients followed the bowel preparation prescribed by your department
- It is essential that the 10-day rule be applied to all females within childbearing age. The 10-day rule is used to prevent unintended exposure of the child *in utero* to radiation. Embryos between 2 and 15 weeks' gestation are considerably more sensitive to adverse radiation effects, such as microcephaly (and accompanied mental retardation), central nervous defects and growth retardation.

Room preparation

Preparing the scanner room in the CT department is essential and should be completed before the patient enters the room. It is not proficient professional radiographic practice to invite a patient into a scanner room that is untidy or disorganised. Practitioners should therefore refrain from preparing the scanner bed, or tidying the room when the patient has already entered. If the room is disorganised upon entering, it may result in patients becoming distrustful towards you. It is imperative to aim to deliver a first class service to your patients.

In preparing the scanner room, the practitioner should consider:

- Clean linen has been placed on the bed prior to the patient entering the scanner room
- Remove any foot pedestals/objects which may compromise the patient safety or transfer onto the scanner bed
- Ensure that a drip stand or drip hook is available, if needed
- If contrast media is to be administered, ensure that emergency drugs and accessories are available. Emergency drugs should be unexpired. Ensure that other accessories such as laryngoscope and sphygmomanometer is in a working condition and available on the emergency cart
- When preparing for contrast media administration, accessories such as cotton wool, tourniquet, syringes, butterfly, Jelco needle or other appropriate needles should be available
- Ensure that ventilators are in a working condition, and that oxygen supply is available
- If the pump injector is to be used, it should be free from contrast media or blood
- Gonad shields are available and clean
- Sponges needed for patient support, and immobilisation straps are available and clean
- Ensure that you are aware of the emergency evacuation procedure for the scanner on which you will perform the examination. Most scanners have a manual override at the foot end of the scanner bed. This is used to

pull the bed out of the gantry in an emergency, such as when a patient experiences a cardiac arrest or convulsion, or when technical errors occur such as malfunctioning of the gantry, or power failures
- Also ensure that you are well aware of where the emergency power disconnection switch is located, so that power can be disconnected should mechanical malfunction of the scanner occur.

PATIENT CARE DURING THE PROCEDURE

- Before transferring the patient onto the scanner bed, the practitioner needs to ensure that the patient's privacy is protected by closing all doors leading to the scanner room
- During the CT examination, the patient should be observed, as they can move, lift their head or move their arms over the area of interest, causing unwanted artefacts and exposure to their limbs
- Ensure that easy venous access will be available by removing excess clothing. Remove any long sleeves which will hamper venous access
- For invasive procedures such as rectal catheter placement or (therapy procedures) close curtains covering the lead glass between the control area and the scanner room
- Scanner beds are hard and every effort should be made to ensure that the patient is comfortable on the bed. For support and comfort, a supporting pillow or knee rest can be placed under the knees
- Placing of a sponge or pillow under the shoulders of terminally ill patients, who often have little subcutaneous fat, is also recommended. Patients who are comfortable on the bed are more likely to lie still
- Ensure that all limbs are secured/immobilised and are not hanging off the side of the scanner bed. This is particularly crucial for para- or quadriplegic patients
- The comfort of the patient on the scanner bed can be further enhanced if the procedure is performed in the shortest time possible, without compromising quality of care
- Patients positioned on the scanner bed should always be covered with a bunny blanket or sheet. This will portray a level of professionalism expected from all practitioners
- Ensure that the patient understood breathing or other instructions when needed
- During positioning of the patient, the patient's eyes should not be exposed to the laser light as this may be harmful to the eyes.

CT of chest or abdomen

- When positioning a patient for a chest CT, ensure that their arms are placed on a supporting sponge or pillow above their head, as their arms will become fatigued if not properly supported. The patient's elbow should be straightened as bending the elbow may hamper the flow of contrast media, especially if the needle is inserted in the antecubital vein
- Never leave the patient on the scanner bed without informing them of the reason why they need to be kept on the scanner bed, e.g. when performing delayed sequences.

Care for escorts

- Ensure that patient's escorts are wearing lead rubber aprons to protect sensitive organs against scatter radiation
- It is advisable that escorts stand as far as possible from the gantry to minimise their exposure to scatter radiation. The use of thyroid shields is also recommended
- Escorts accompanying restless patients should be informed not to place their arms inside the gantry aperture, as this will expose their arms to ionising radiation and may cause artefacts over the anatomical part to be scanned
- It is equally important to apply the 10-day rule to female escorts to prevent unintended exposure to an unborn child *in utero*. No pregnant escort should be allowed in the scanner room.

AFTERCARE OF THE PATIENT

- All patients should be assisted off the scanner bed by lending support. Supporting them with your hand will show compassion, which is a sign of good patient care
- Elderly patients often suffer from postural hypotension and may feel dizzy when getting off the scanner bed. The hypotension and dizziness is caused by a slight drop in their blood pressure while being supine on the scanner bed. It is recommended that the elderly be allowed to sit up for a minute or two, to allow their blood pressure to recover
- All personal belongings, removed before the examination, should be returned
- If contrast media was administered, there may be a need to check for delayed contrast media reactions. Inform the patient if this is the case. Remove butterfly/needles safely. Apply firm pressure on the puncture site to prevent bleeding. Any blood spilled at the puncture site should be cleaned using cotton wool. Ensure that the drips for inpatients are opened using the roller clamp
- Discard used needles and syringes safely by placing them in the sharps container

- Patients should never leave the CT room if they are not completely dressed. It is unprofessional practice to allow patients to leave the CT room half dressed
- Enquire whether your patient has follow-up visits or referral to other departments
- Inform the patient when the results of their CT examination will be available and how it will be relayed to their referring physician
- Always ensure that the scanner room is clean and tidy for the next examination, especially when working in busy CT departments, as this will render the room available for the next patient and practitioner
- All equipment and accessories used should be stored safely and neatly
- Outpatients should be provided with a contact number of the CT department should they wish to contact them, especially in cases of delayed contrast media reaction.

PATIENT PREPARATION FOR CONTRAST MEDIA ADMINISTRATION

Contrast media in CT imaging is usually administered to enhance, inter alia, pathological processes such as neoplasms, inflammatory conditions, e.g. abscesses, cysts, encephalitis, meningitis, tuberculous meningitis or congenital diseases such as aneurysms and arterio-venous malformation. Most pathological processes trigger an increase of blood flow at their location. Since contrast media travels in the bloodstream, enhancement of these pathologies is often evident due to the higher than usual blood flow (and thus contrast media) in that region.

Contrast media should only be administered if there is clinical justification. Even though contrast media in use is relatively safe today, there is still a potential risk of a patient experiencing an allergic reaction to contrast media (see also Chapter 11, Drugs and contrast agents).

The following aspects should be considered when preparing patients for contrast media administration:

- Practitioners need to ensure that the patient needing contrast media administration is informed of the side-effects thereof
- Written consent should be provided prior to administration
- The volume/dose to be administered should be appropriate for the CT examination
- The iodine concentration should be appropriate for the CT examination. In CT angiography or CT venography studies, contrast media with a higher iodine concentration (e.g. 300 mgI/mL) should preferably be used. This is to ensure adequate opacification of vasculature
- Contrast media allergies must be established before contrast media administration
- Establish whether the patient's renal function is adequate. Contrast media administration is usually contraindicated for patients with renal impairment, dehydration or cardiac failure. (See also Chapter 11, Drugs and contrast agents.)
- Patients with a hypersensitivity to contrast media should preferably be examined without the use of contrast media to reduce their risk of an allergic reaction.
- Hypersensitivity to previous contrast media administration is a good predictor for a patient at risk of an allergic reaction. Where contrast media is required for such patients, they can be treated with appropriate antihistamines or anti-anaphylaxis to reduce their risk of an allergic reaction
- Contrast media to be used should not be expired. It is the duty of all practitioners to check the expiry date before administration.

Contrast media administration for paediatrics

- Ensure that the dose to be administered for paediatrics is safe. As a guide, the formulae of 1 millilitre of contrast media for every 2 kilograms of body weight can be applied.

Pump preparation prior to contrast media administration

Every effort should be made to use the pump injector safely. The incorrect use of the pump injector can potentially be lethal to patients. The three major risks in the unsafe use of the pump injector in CT are the following:

- Accidental injection of air can cause an embolus, which may lead to an infarct of tissue distal to the embolus
- Passing of bacteria or other pathogens into the patient's body (which can cause septicaemia). This can occur when an aseptic technique was not followed during drawing up and injection of contrast media
- Rupturing of veins if flow rate of the pump is too high. Rupturing of veins can cause a local haematoma or extravasation of contrast media

The following guidelines can be used for the safe use of the pump injector:

- Ensure that correct settings (flow rate and volume) are selected on the pump injector for each examination. A flow rate of 3 mL/second is usually employed. Younger patients and those receiving chemotherapy, requires a slower flow setting on the pump injector
- Remove as many air bubbles as possible by turning knob underneath pump injector
- Care should be taken that the extension tube is connected using an aseptic technique. No contamination

of the tip of the extension tubing should occur, such as falling on the floor or touching the scanner bed
- Pump is turned upside down (nozzle pointing downward) to ensure that any residual air bubbles are transferred to the top (back) of pump injector. This will prevent injection of tiny amounts of residual air bubbles
- Ensure that the heat wrap (cover) is placed around the syringe of the pump to heat up contrast media, to prevent injection of contrast media that is too cold, which may disturb the thermodynamics of the blood
- Practitioners should ensure that the pump injector activation is synchronised with the acquisition of the CT sequences, to prevent mistiming of intravenous injection.

Contrast media extravasation

- Extravasation is caused when contrast media leaks into the soft tissue surrounding the puncture site
- Extravasation is mostly caused by needles not correctly placed in the lumen of the vein. Extravasation of contrast media will lead to a suboptimal enhancement of vascular or pathological processes, as an inadequate volume of contrast media will be travelling through the patient's body
- Extravasation of contrast media may result in a repeat dose of contrast media and even a repeat CT examination which means an unwanted radiation dose
- Extravasation may also cause a haematoma at the puncture site which can be painful
- Patients receiving chemotherapy generally have fragile veins, which often blow up during contrast media administration. Care should be taken that the pump injection is halted once any blowing up of the vein is noted
- It is imperative that the correct flow rate is selected for the pump injector to prevent rupturing of the veins.

CARE FOR INTRAVENOUS DRIPS

- Practitioners should always ensure that the intravenous drips of patients are in working order
- Ensure that infusions do not occur too fast or too slow by closing or opening the roller clamp where appropriate. A too slow infusion may result in patients not getting the required medication or fluids in time, while a too fast infusion may cause medication overload which may compromise homeostasis
- If the roller clamp is left open, blood will flow into the tubing which may block the tube, requiring replacement of such tubing
- If infusion does not occur, the vein may become thrombosed, which will necessitate another phlebotomy and unnecessary pain
- For trauma patients in shock, infusion needs to be maintained in order to restore the required electrolyte balance especially after severe blood loss
- The tubing should never be kinked, or placed underneath the patient, as it will restrict flow of medication (or fluid), compromising patient treatment
- Drip bags should never be placed on the scanner bed, or hanging too low, as this will result in retrograde flow of blood into the extension tubing.

PATIENT CARE FOR CRITICALLY ILL OR TRAUMATISED PATIENTS

Critically ill patients from the resuscitation departments, intensive care units (ICU), or terminal wards, need to receive preferential treatment and require a high level of care. These critically ill patients should always be accompanied by a nurse practitioner. A seriously ill patient may react differently due to pain, stress or anxiety. If patients are coherent, communication should occur as with normal patients. It is important to work quickly and efficiently while continuing to communicate with the patient even if they do not respond. Informing the patient of what is about to happen may be reassuring even in the absence of a verbal response.[1]

The following aspects should be considered when examining critically ill patients in the CT department:

- Always give preference to critically ill or traumatised patients
- Keep a close watch over their vital signs as this may drop in a short space of time, which will require emergency resuscitation
- The scanner room should be unoccupied when they arrive, so that the examination can be performed immediately upon arrival
- Ensure that the ventilators and suction apparatus are in working condition
- Assist escorts with the transfer of the patient by ensuring that vital stats monitors are safely positioned on the scanner bed, as these may fall off during table movement
- Ensure that the breathing tube of the ventilator, extension tubing of drips and other lines, will not be stretched beyond capacity during table movement
- The patient should be taken off the bed immediately after the scan and transported back to the ward. Post-processing functions such as copying or transfer of images, should occur only after the patient has left the department.

PATIENT CARE FOR THOSE UNDER THE INFLUENCE OF SUBSTANCES

CT practitioners who work after hours or do call, will often need to examine patients under the influence of alcohol or drugs. The practitioner will via communication establish their level of coherence. Some patients will be able to cooperate fully, whilst others might be irrational, hyperactive or even aggressive. The secret is not to provoke any bad behaviour.

Practitioners should:

- Work as speedily as possible in order to get them back to their department
- Do not counter aggression with aggression as it may lead to violence or reprisal from aggressive patients
- If the patient is restless, and if their composure allows, apply immobilisation of the limbs (if required)
- Often it is useful to postpone the CT examination until the patient's level of cooperation has improved, provided that the patient's clinical condition will not be jeopardised by the postponement.

PHYSICAL RISKS IN CT

The risks for patients undergoing CT examinations can be classified into two categories – direct physical risks (to the patient's self), and biological risks posed by the ionising radiation. Practitioners should aim to minimise these risks at all costs. Each of these risks poses their own challenges and will be discussed separately.

Handling of restless patients

There is always a danger of the patient falling off the scanner bed. Patients most at risk from falling off the bed are restless children, the elderly, psychiatric, patients under the influence of substances (alcohol and drugs), critically ill patients who have suffered cerebrovascular accidents or serious trauma. It is imperative that restless patients be immobilised using immobilisation straps. Immobilisation straps should not be applied too tightly as it may compromise blood flow to immobilised limbs. Restless and confused patients should never be left alone in the scanner room (or the waiting room) as they may try to climb off their beds.

During the CT examination, practitioners should always watch these patients during scanning, especially if a gantry tilt or bed movement is to occur, as they can move if not watched closely. It is important to work quickly, without compromising patient care. If a CT exam takes too long, these patients may become more restless which may cause movement artefacts which may require repeat scanning.

Restless psychiatric patients should never be left unsupervised as they can injure themselves or wander and may get lost. This will be tantamount to negligence and may result in litigation. Sedation should only be considered once all efforts to immobilise or scan restless patients have been exhausted.

Transfer of patients

Patients who are being transferred to and from the scanner bed are at risk of physical injury and this should be prevented at all costs. It is therefore important that practitioners apply safe transferring techniques. Paraplegic or quadriplegic patients, or those who have undergone neurosurgery, should be transferred carefully as any physical injury to their skull or body will be exacerbated. A safe way of preventing any injury to their heads is to support their heads when transferring them to or from the scanner bed. This will prevent their heads from knocking the scanner bed or head rest during the transfer, which may cause further intracranial or extracranial damages. The same would apply for their limbs. (For more tips on how to transfer patients, please refer to Chapter 14, Moving and handling.)

Transfer of the patient with confirmed or suspected spinal injuries

Remember that patients with any confirmed or suspected spinal injuries should be treated with the outmost care. Patients with unconfirmed spinal injuries should be treated the same as patients with confirmed injuries, as the possible risk of causing damages to the spinal cord is equally high for unconfirmed spinal injuries.

Every effort should be made to maintain spinal stability during patient transfer.

- As a rule, patients with spinal injuries should never be turned unless it is absolutely necessary. Even if there is clinical justification, the transfer of these patients, should be done by experienced staff. (Refer to Chapter 14, Moving and handling, for guidelines on how to transfer patients safely.)

Physical risks during interventional CT procedures

Biopsies of small lesions (e.g. lymph nodes, pulmonary nodules, focal liver lesions) require precise needle placement to attain a secure position for therapeutic or diagnostic purposes.[5] Interventional procedures in CT such as conventional fine needle aspiration biopsy (FNAB), facet joint injections, and CT fluoroscopy assisted biopsies, pose potential risks to the patient. Even though the practitioner is not directly

responsible for the execution of these interventional procedures, they do have some responsibilities with regards to the success of the examination and the patient's wellbeing.

FNAB of the thorax

FNABs are performed to obtain cells from lesions within the thorax. FNABs are thus done so that these cells can be analysed by cytology in order to establish the type of lesion present. These procedures can be long, especially if the lesion is small, or are located at odd anatomical sites. Practitioners should ensure that the patient is comfortable on the bed, to ensure cooperation. Practitioners should ensure that once the needle is advanced, the correct table position is selected. This can be done by matching the light marker to the site at which the needle enters the skin, to prevent scanning at the incorrect level. If the needle cannot be introduced parallel to the scan plane, compensation should be made for the angle at which the needle is placed.

There is always a potential risk of causing a pneumothorax or haemothorax during passing of the needle into the thorax. Practitioners should encourage patients to hold their breath when the needle is passed through the chest wall to minimise possible injury to the pleural membranes or soft tissue. Once the needle is *in situ*, patients should be encouraged to maintain shallow breathing, as deeper irregular breathing may cause the needle to shift out of position, or even break with subsequent risk of haemorrhage or damage to underlying soft tissue. A broken needle will need to be removed by surgery.

Practitioners should further ensure that an aseptic technique is applied during all interventional procedures. No contamination of any of the accessories should occur during the procedure. Care should be taken that the needle does not touch the gantry, as this too may cause shifting of the needle and will in addition increase the risk of cross infection to the patient. Remember that even although local anaesthetics are used to anaesthetise the skin, underlying structures such as the lungs and deep thoracic wall muscles cannot be anaesthetised due to their relative deep anatomical location. Repositioning of the needle is inevitably painful.

Practitioners should ensure that all patients who underwent a FNAB of the chest, should have a chest radiograph within an hour after the procedure, to rule out any pneumothorax or haemothorax.

Facet joint injections

Facet joint pain is attributed to segmental instability, inflammatory synovitis, or degenerative arthritis.[6] The use of CT in management of facet joint pain has become routine in clinical practice. CT guided techniques has brought about an increase in the precision of these procedures and help to confirm needle placement. The patient is placed in the prone position, and several images are obtained at the level of interest to determine entry site and angle of approach. The entry site is marked on the skin, and a 22-gauge needle is advanced into the joint.

Possible complications of facet joint injections include inter alia: infection, haemorrhage, pneumothorax, anaphylactic (idiosyncratic), reaction to iodinated contrast material or anaesthetic and nerve damage. The practitioner role in minimising the risk would be similar to that described for FNABs, above.

BIOLOGICAL RISKS IN CT – RADIATION DOSES

Regardless of scanner model or make, all CT scanners consist of a gantry, X-ray tube and detectors. When X-rays pass through the body part, the incident beam is attenuated in a manner dependent on the local tissue composition. Tissue with higher densities such as bones or calcifications absorbed more of the beam than soft tissue organs such as the liver or spleen. The beam exiting the patient will fall on a set of detectors. These detectors will generate a signal that is used to reconstruct the image. The X-ray beam energy (determined by tube potential) and photon fluence (determined by the product of tube current times the tube rotation), are important factors that affect radiation exposure to the patient.[7]

Studies have shown that CT examinations account for only a small percentage of all imaging examinations but contribute to a very large percentage of the total medical radiation dose to the population.[8] This can be ascribed to the fast growth in the clinical use of this imaging modality, brought about by the improved volume coverage, improved z-axis resolution and the speed of the latest multislice scanners.[10] It is imperative for practitioners to ensure that the 'As Low As Reasonably Achievable' (ALARA) principle is upheld when performing CT examinations.

Bio-effects associated with radiation exposure can be divided into two main groups: the deterministic risk which relates to the death of cells and the stochastic risk which relates to cancer induction or genetic damage (see Chapter 9, Ionising radiations, for more information). Recently, deterministic effects of CT radiation have been reported, where patients have suffered temporary hair loss after undergoing multidetector CT (MDCT) brain perfusion studies.[11] The estimated lifetime risk of cancer death for those undergoing CT of the abdomen has been estimated to be about 12.5/10 000 population for each CT abdominal scan in adults.[12] Risks for children are higher.

Dose reduction in CT

Even although practitioners are not always directly responsible for vetting requests for CT examinations, they can play a role in ensuring that where CT examinations are not clinically justified, that they are not performed.

Establishment of clinical guidelines to advise referring doctors, radiologists and practitioners about the appropriateness and acceptability of CT examinations helps eliminate inappropriate requests for CT.

CT examinations should not be repeated without clinical justification. Imaging modalities such as ultrasound and magnetic resonance imaging (MRI), should be used for appropriate clinical indications when equal or greater diagnostic information can be obtained. Once a CT examination has been clinically justified, each examination should be optimised for each patient. The principle of optimisation should be applied on an individual basis, so as to achieve an image quality sufficient for a particular patient, in order to obtain diagnoses with the minimum dose to the patient.[13]

Optimal use of CT scanning is governed by:

- The diagnostic quality of the examination
- The radiation dose to the patient
- The choice of CT technique.[14]

The benign condition of complicated acute pancreatitis is thought to be responsible for the largest cumulative radiation dose from CT, and imaging thereof, may be substituted by MRI.

CT images are often acquired before, during and after intravenous administration of contrast material. When medically appropriate, multiphase studies should be kept to a minimum and where possible, pre-contrast sequences should be eliminated. This may be relevant in the evaluation of liver and bowel wall conditions, where pre-contrast sequences can frequently be omitted without affecting the interpretation of the imaging study.[7]

Practitioners also need to ensure that repeat examinations due to double booking of patients, or lost CT results, does not occur. Practitioners should also ensure that topograms (scout views) are only covering the area of interest and do not extend beyond the anatomical area to be examined. In addition, CT sequences should also only include the anatomical area of interest and should not be acquired purely out of curiosity.

Use of appropriate CT parameters

Various CT parameters can be manipulated by practitioners to minimise the dose to patients. These are:

- Low dose CT
- Automatic exposure control
- Tube rotation
- Section thickness
- Pitch and dose.

Low dose CT

Low dose CT protocols are now routine in many CT departments. Studies have shown that the dose delivered to patients can be lowered by lowering the tube potential (kV) or tube current (mA) during image acquisition, without reducing image quality. A 50% reduction in tube current is considered to reduce radiation dose by half. Other studies have shown that a four-fold decrease in the radiation dose occurs when the kilovoltage is dropped from 140 to 80 kVp, for both body and head CT protocols.[15] Reduction in the tube current is the most practical means of reducing CT radiation dose. Practitioners should, where possible, reduce the tube current (milliamperes, mA) in order to reduce the dose to patients. For example, when scanning for abdominal aortic aneurysms, the tube current can be lowered as low dose protocols will not influence the ability to diagnose aneurysms.

Automatic exposure control (AEC)

AEC is analogous to acquisition timing in general radiography. All scanners employ AEC. The user determines the image quality requirements (with regards to the noise or the contrast-to-noise ratio), and the CT system automatically determines the right tube milliampere-seconds (mAs).[16] Various tube current modulation strategies have been developed by CT manufacturers to reduce dose to patients during image acquisition. The two modulation strategies were developed in response to large variations in patient body diameter and subsequent variation in radiation absorption along certain anatomical regions. Tube current modulation is therefore aimed at ensuring even image quality (noise reduction) along the full sequence, with a lowered dose.[16]

Longitudinal (z-axis) modulation

Longitudinal modulation involves variation of dose (mA) between anatomical regions in the z plane, e.g. between shoulders versus abdomen versus pelvis. The aim of varying the tube current along this plane is to ensure uniform noise levels (with lower dose) across the various anatomic regions. The operator chooses a desired level of image quality for input to the algorithm that will calculate the required mAs.[16]

Angular (x–y) modulation

The purpose of angular current modulation strategies is similar to the z-axis modulation, i.e. to ensure uniform dose over areas of varying thickness. The diameter of the lateral plane at the shoulder region is much larger then the antero-posterior (AP) diameter of the same region. Angular current modulation ensures that the exposure during image acquisition is automatically lowered for areas with shorter diameters (in this case the AP plane of the shoulder region). This angular modulation occurs in real time as the tube rotates about the patient. The use of angular (x–y) or longitudinal (z-axis) current modulation is a valuable tool that can reduce doses to patient.

Tube rotation

The longer the tube rotates around the patient, the higher the dose will be and vice versa. Where a shorter tube rotation is selected, anatomical structures will be exposed to radiation for a shorter time. There has been a dramatic decrease in tube rotation times with recent technologic innovations, most notably with the development of sixty-four slice scanners. If the tube rotation time is decreased (faster gantry rotation), the radiation exposure decreases, and tube current may thus have to be increased to maintain constant image quality.[17] Practitioners should therefore always select a shorter tube rotation, provided that this will not automatically increase the mA. Practitioners should therefore be knowledgeable about their scanner configurations in order to reduce dose without compromising the diagnostic quality of CT examinations.

Section thickness

Section thickness in CT refers to the thickness of the slice obtained. Thin collimation can lead to a higher dose, especially if tube current is increased to maintain image noise at a level similar to that of thicker sections.[7] Thinner slices further require more rotations around the patient for the same volume coverage compared with larger slices, which increases the dose imparted. Thus, it is important to employ thicker beam collimation where possible, in order to reduce dose.

Pitch

With MDCT scanners, beam collimation, table speed, and pitch are interlinked parameters that affect the diagnostic quality of an imaging study. In MDCT, detector pitch can be defined as the distance in table movement (in mm) divided by the detector width in mm.[18] Increasing the pitch is another useful method for reducing radiation dose. Faster table speed for a given collimation, resulting in higher pitch, is associated with a reduced radiation dose (especially if other scanning parameters, including tube current, are held constant) because of a shorter exposure time, whereas narrow collimation with slow table speed, resulting in a longer exposure time, is associated with a higher radiation dose. In other words, an increase in the pitch decreases the duration of radiation exposure to the anatomic part being scanned. Studies have shown that increasing the pitch from 1.0 to 1.5 can decrease the radiation dose by 33%, without any apparent loss of diagnostic information.[17]

Shielding of superficial organs

Superficial radiosensitive organs, such as the eye lens, thyroid gland and breast can be shielded using bismuth material or the more commonly available lead apron. The aim of using shielding is to prevent scatter radiation to sensitive organs.[11]

CT radiation risks in children

Radiation risks to children in CT are far greater than for adults. This can be attributed to three factors:

- The increased organ radiosensitivity of children relative to adults
- The longer lifetime risk for radiation-induced cancer
- Lack of adjustment of paediatric CT parameters based on size or region of scanning.[9]

Most manufacturers now incorporate dedicated paediatric protocols into their scanners, and these act as a useful guide for children's dose reduction.[11] Practitioners should employ paediatric protocols when examining children as the exposure (dose) required is far less than for adult protocols.[19] Adult protocols should under no circumstances be used when scanning children. Use of dedicated paediatric protocols and large beam collimation is strongly recommended. The use of thin slice beam collimation when scanning children should be kept to an absolute minimum.

Body weight and habitus

Body weight and habitus are used in some clinical departments to choose appropriate CT parameters in order to reduce dose.[3] Some experts believe that using patient diameter will provide the best approximation of tissue length traversed during the examination because body weight alone does not account for body habitus or height, which can vary with identical body weight, resulting in incorrect selection of parameters and thus dose imparted.[20]

CT in pregnancy

CT is often used for emergency indications such as suspected pulmonary embolus, abdominal perforation, renal colic or trauma among pregnant patients.[21] CT examinations on pregnant females should only be performed where strong clinical justifications exist. Where possible, other imaging modalities such as ultrasound and MRI should be employed as the risks to the unborn child are much lower with these modalities, compared to CT imaging.

The fetal dose delivered by MDCT for pulmonary embolism in pregnant females is mainly attributed to scatter radiation and is lower than direct scanning of the uterus in the first trimester. The major risks to the fetus, with direct scanning of the uterus using MDCT, is that of neurologic deficit and carcinogenesis.[21]

Optimal CT parameters should be selected such as scanning only the anatomical part in question. The use of larger beam collimation, higher pitch and or low dose protocols should be selected. Applying the ALARA principle in pregnant patients are therefore crucial as dose to the unborn fetus can be potentially harmful and should be applied with care. Lead protection of sensitive organs such as of the uterus, breast and thyroid is strongly recommended.

KEY POINTS

- Patient care in the CT department is aimed at enhancing the wellbeing of patients
- All patients should be treated with respect and dignity, irrespective of their social status, race, gender, mental or physical status, sexual orientation, religion or beliefs
- Before a CT examination, practitioners need to correlate the identity of patients
- Practitioners should ensure that the clinical history justifies the CT examination
- Patients should always be informed about the procedure, namely: how long the examination will take or whether any breathing or other instructions will be requested
- Informed consent is needed for invasive procedures prior to starting the examination
- Patients undergoing CT of the abdomen need to have bowel free from barium or faecal matter
- Patients should be made comfortable on the scanner table
- The 10-day rule should be applied to escorts accompanying patients in the scanner room
- Critically ill patients must be given preference in any CT department and should be examined upon arrival
- Restless patients need to be immobilised on the scanner bed using immobilisation straps
- Radiation dose in CT can be minimised by the following:
  1. Performing only CT examinations that are clinically justified
  2. Using low dose protocols
  3. Using tube current modulation strategies
  4. Faster pitch
  5. Larger beam collimation
  6. Shielding of sensitive organs
  7. Using dedicated paediatrics protocols when examining children.