Computed tomography

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There has been a great deal of development in CT technology over the last 30 years from the initial conventional CT scanners through to helical or spiral scanners and the current multi- detector machines. CT scanners consist of a gantry containing the x-ray tube, filters and detectors, which revolve around the patient, acquiring information at di ff erent angles and projec - tions. This information is then mathematically reconstructed to produce a two-dimensional grey-scale image of a slice through the body . This technique overcomes the problem of di ff erent structures, which is inherent in superimposition of conventional radiography . Improvements in gantry design, development of more sensitive detectors and an increase in the number of detectors have resulted in an increase in spatial resolution, as well as the speed at which the images are acquired. In early CT scanners, the table on which the patient was positioned moved in between the gantry revolution to allow imaging of an adjacent slice. Modern scanners allow for continuous movement of the table and the patient during the gantry revolution, thus greatly reducing the scan time. With modern equipment, it is now not only possible to obtain images of the chest, abdomen and pelvis in under 10 seconds but these axial images can also be reformatted in multiple planes with practically no degradation in image quality . In addition, CT has a far higher contrast resolution than plain radiographs, allowing the assessment of tissues with similar attenuation characteristics. As with radiographs, the natural contrast of tissues is further augmented by the use of intravenous iodinated contrast medium. Rapid scanning of a volume of tissue also allows the scans to be performed at di ff erent phases of enhancement, which is advantageous in identifying di ff erent diseases. For instance, very early scanning during the arterial phase is ideally suited to the examination of the arterial tree and hypervascular liver lesions, whereas scanning performed after a delay may be better suited to the identification of other solid organ pathology such as renal Jacques Lisfranc de St. Martin , 1790–1847, Professor of Surgery and Operative Medicine, Paris, France. contrast injection, can be used to assess the ureters and bladder (Figure 8.3) . Furthermore, it is possible to obtain scans during several phases including the arterial and venous phases in the same patient, which may aid in the identification and charac - terisation of lesions. CT is widely used in thoracic, abdominal (Figure 8.9),) and neurological (Figure 8.10), musculoskeletal (Figure 8.11 trauma imaging. The thinner collimation and improved spa - tial resolution have also resulted in the development of newer techniques such as CT angiography , virtual colonoscopy and virtual bronchoscopy . Furthermore, three-dimensional images can be reconstructed from the ra w data to aid in surgical plan - ning and to provide virtual endoluminal views in virtual colo - noscopy for example . The disadvantage of CT compared with ultrasound and conventional radiography lies largely in the increased costs and the far higher doses of ionising radiation. For instance, a CT scan of the abdomen and pelvis has a radi - ation dose equivalent to approximately 500 chest radiographs.

Figure 8.9 Axial computed tomography scan of a patient with acute pancreatitis demonstrates a swollen oedematous pancreas (arrow) with extensive peripancreatic free /f_l uid (curly arrow). Figure 8.10 Axial computed tomography scan of the head following intravenous contrast demonstrates a large mass lesion in the left frontal region (arrow) in a patient with a large left frontal meningioma. (a) (b) Figure 8.11 Coronal computed tomography (a) and axial reformats /uni00A0 (b) of the foot in a patient involved in a

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Computed tomography /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF Magnetic resonance imaging Over the last 20 years, MRI has become an integral part of the imaging arsenal with ever-expanding indications. MRI relies on the fact that nuclei containing an odd number of protons have a characteristic motion in a magnetic field (precession) and produce a magnetic moment as a result of this motion. In a strong uniform magnetic field such as an MRI scanner, these nuclei align themselves with the main magnetic field and result in a net magnetic moment. A brief radiofrequency pulse is then applied to alter the motion of the nuclei. Once the radiofrequency pulse is removed, the nuclei realign themselves with the main magnetic field (relaxation) and in the process emit a radiofrequency signal that can be recorded, spatially encoded and used to construct a grey-scale image. The specific tissue characteristics define the manner and rate at which the nuclei relax. This relaxation is measured in two ways, referred to as the T1 and T2 relaxation times. The relaxation times and the proton density determine the signal from a specific tissue. There are a large number of imaging sequences that can be used by applying radiofrequency pulses of di ff erent strengths and durations. The image characteristic and signal intensity from di ff erent tissues ar e governed by the pulse sequence employed and whether it is T1 weighted or T2 weighted. For instance, fat, methaemoglobin and mucinous fluid are bright on T1-weighted images, whereas water and thus most patho logical processes, which tend to increase tissue water content, are bright on T2-weighted images. Cortical bone, air, haemo siderin and ferromagnetic materials are of very low signal on all pulse sequences. In general, T1-w eighted images are supe rior in the delineation of anatomy , while T2-weighted images tend to highlight pathology better. For added tissue contrast, intrav enous gadolinium may be administered. Other more lymph node imaging. MRI’s exquisite contrast resolution, coupled with a lack of ionising radiation, is very attractive in imaging, particularly of tissues that hav e relatively little natural contrast. MRI also has the adv antage of multiplanar imaging, as images can be acquired in any plane prescribed. It has traditionally been used extensively in the assessment of intracranial, spinal and mus - culoskeletal disorders (Figures 8.12 , 8.13 and 8.14) , allowing a global assessment of bony and soft-tissue structures. More recent developments have resulted in new indications and applications. Today , MRI is commonly used in oncological imaging, such as staging of rectal carcinoma and gynaecologi - cal malignancies, identification and characterisation of hepatic - - -

Strengths High spatial and contrast resolution Contrast resolution enhanced by ability to image in multiple phases, including arterial, venous and delayed Rapid acquisition of images in one breath-hold Imaging of choice for the detection of pulmonary masses Allows global assessment of the abdomen and pelvis Excellent for liver, pancreatic, renal and bowel pathology Three-dimensional reconstruction allows complex fracture imaging Multiplanar reconstruction and three-dimensional imaging, e.g. CT angiography and colonoscopy Ability to guide intervention such as percutaneous biopsy and drainage Weaknesses High radiation dose Poor soft-tissue resolution of the peripheries and super /f_i cial structures Patient needs to be able to lie /f_l at and still Less readily available than plain /f_i lms and ultrasound Figure 8.12 T2-weighted axial magnetic resonance imaging scan of the head in a patient with a large left-sided oligodendroglioma (arrow). Figure 8.13 Sagittal T2-weighted magnetic resonance imaging scan of the lumbar spine demonstrates disc herniation (arrow) in a patient with acute back pain.

masses and assessment of the biliary tree (magnetic resonance cholangiopancreatography [MRCP]; Figure 8.15). MRI has become increasingly important in imaging of the small bowel, for example in Crohn’s disease, where repeated imaging with ionising radiation can incur a significant radiation dose over time. Magnetic resonance (MR) angiographic techniques allow non-invasive angiographic assessment of the cranial and peripheral circulation (Figure 8.16) and cardiac imaging. Di ff usion-weighted imaging is a relatively new type of MRI sequence that exploits the di ff erent rates of Brownian motion between di ff erent tissues. Tissues with greater cellular density have low er rates of di ff usion of water molecules, and this dif ference can be exploited to distinguish benign and malignant or inflammatory lesions in a variety of organs as malignant or inflammatory lesions tend to have greater density of cells. in comparison with other imaging techniques, and it is time-consuming with respect to image acquisition and interpretation. Images are easily degraded by motion, including respiratory and cardiac motion. T he use of respiratory and cardiac gating can minimise this, although bowel peristalsis can still be a problem. The long acquisition times require a cooperative patient who can lie very still, which can be di ffi cult especially in claustrophobic individuals or those in pain. Furthermore, because of the use of high-strength magnetic fields, patients with some metallic implants, such as some aneurysm clips and prosthetic heart valves, and those with implanted electronic devices, such as pacemakers and defibrillators, cannot be examined. Some newer implants may , however, be MRI compatible, and patients with joint replacements can be studied safely . Summary box 8.6 Magnetic resonance (MR) imaging /uni25CF Nuclear medicine In other imaging techniques using ionising radiation such as - CT and conventional radiography , the individual is exposed to ionising radiation from an external source and the radiation transmitted through the patient is recorded. In nuclear medicine, however, a radioactive element or radionuclide such

Figure 8.14 Coronal magnetic resonance imaging scan of the knee demonstrates extensive serpiginous areas of altered signal intensity in the distal femur and

proximal tibia (arrows) in a patient with bone infarcts secondary to oral corticosteroids. Figure 8.15 Magnetic resonance cholangiopancreatography image demonstrates dilated intrahepatic ducts and proximal common bile duct (CBD) secondary to multiple calculi in the distal CBD (arrow). This type of imaging has the potential to alter cholecystectomy sur gical planning. Strengths No ionising radiation Excellent soft-tissue contrast Best imaging technique for Intracranial lesions Spine Bone marrow and joint

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as technetium, gallium, thallium or iodine is administered to the patient as part of a radiopharmaceutical agent, and a detector such as a gamma camera is then used to record and localise the emission from the patient, thus forming the image. The radionuclide is chosen and coupled with other compounds such that it is distributed and taken up in the tissues of interest. Therefore, a variety of radionuclides are required for imaging of di ff erent tissues. Nuclear medicine also di ff ers from other means of imaging, which are largely anatomically based, as it also provides functional information. Radionuclide imaging is widely used in bone imaging with very high sensitivity for assessing metastatic disease, metabolic bone disease, established arthropathies and occult infection and traumatic injuries (Figure 8.17) , although many of these applica tions are being replaced by MRI. In genitourinary disease, dynamic imaging can be perfor med to assess renal perfusion and function including obstruction, to investigate renovascular hypertension and to evaluate renal transplants. Radionuclide imaging is also commonly used in thyroid and parathyroid disorders, ischaemic cardiac disease, detection of pulmonary emboli and assessment of occult infection and inflammatory bowel disease. Positron emission tomography (PET) is an extension of nuclear medicine, in which a positron-emitting substance such 18 as F is tagged and used to assess tissue metabolic characteristics. 18 The most commonly used radiolabelled tracer is F-2-fluoro 2-deoxy- /d.sc -glucose (FDG), although other tracers can also be used in order to assess metabolic functions such as oxygen and glucose consumption and blood flow. Radioisotope decay causes the emission of a positron, which subsequently, within a few millimetres, collides with and annihilates an electron to produce a pair of annihilation photons. The drawbacks have been high cost, very limited availability and relatively low spatial resolution. The last of these has been addressed by PET/CT systems combining simultaneous PET imaging and CT, allowing the two sets of images to be registered so that more precisely. This modality has significantly improved the accuracy of cancer staging for a range of malignancies and is also useful in inflammatory conditions and imaging pyrexia of unknown origin. Summary box 8.7 Radionuclide imaging /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF -

Figure 8.16 Maximum intensity projection image from a magnetic res onance angiogram demonstrates the abdominal aorta, common and external iliac arteries as well as parts of the pulmonary, mesenteric and renal vasculature. Strengths Allows functional imaging Allows imaging of the whole body Bone scan has a high sensitivity for metastatic bone disease, fractures and infection

PET scanning is valuable in the detection of metastatic cancer Weaknesses Speci /f_i c agents are required for speci /f_i c indications

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brae, the skull, pelvis and ribs.

Computed tomography

CT is the main imaging method for the investigation of intra- cranial and intra-abdominal injuries and vertebral fractures. With current multidetector scanners a comprehensive exam - ination of the head, spine, chest, abdomen and pelvis can be completed in less than 5 minutes. Traditionally the CT scanner was referred to as ‘the doughnut of death’, as imaging could lead to delays in emergency treatment. Howev er, as the avail - ability of scanners and the speed of scanning has dramatically increased, it has become standard practice to use CT early in the assessment of trauma patients. Emergency departments have CT scanners co-located to the resuscitation or trauma bays or patients can be assessed and treated while on the CT table. CT examination of the head is accurate in identifying treatable intracranial injuries (Figures 8.30 and 8.31) and should not be delayed by radiography of peripheral injuries, as there is declining success in cases of intracranial collection when treated after the initial 3–4 hours. In comparison, iden - tification of more widespread injuries, such as di ff use axonal injury , is relatively poor. Examination of facial injuries and cervical spine fractures can also be carried out at the same time as this only adds seconds to the examination. There is evidence tha t CT of the abdomen and pelvis is of benefit in multiple trauma when there is a head injury , as it often shows - unexpected abnormalities; this may a ff ect the immediate man - agement, especially if the patient deteriorates. Chest CT with intravenous contrast agent is valuable in identifying vascular and lung injuries and is the most accurate way of demonstrating haemothorax and pneumothorax. The position of chest drains can be identified, allowing adjust ment /uni00A0 of position if necessary . Abdominal and pelvic CT is usually undertaken as an extension to the chest CT . If an abdominal examination is performed, the pelvis should be included to avoid missing pelvic injuries and fr ee pelvic fluid. CT is an excellent means of identifying hepatic, splenic (Figure 8.32) and renal injuries. Delayed examination after assessment of the pelvicalyceal system in cases of renal trauma. Pancreatic and duodenal injuries may also be identified, but detection of these injuries may be more prob lematic. Using CT , the accuracy of detection of bowel or mesenteric injuries is less than it is for solid organ injury , and these injuries should be suspected when there is free intraperitoneal fluid without an identifiable cause (Figure 8.33). Close clinical follow-up and early repeat scanning with oral contrast can often reveal the bowel or mesenteric injury in patients with free fluid with no other cause identified. The image data may be reconstructed into thinner slices for the diagnosis of injuries to the thoracic and lumbar spine and for the better delineation of pelvic and acetabular frac - tures. Complex intra-articular fractures of the peripheral skel - eton, such as calcaneal and tibial plateau fractures , may be usefully examined by dedicated thin-section studies provided this does not delay the treatment of other more serious injuries (Figure 8.34) . CT angiography may be used to demonstrate vascular injuries in the limbs in those with penetrating injuries or complex displaced fractures.

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a patient with a large left frontal meningioma. (a) (b) Figure 8.11 Coronal computed tomography (a) and axial reformats /uni00A0 (b) of the foot in a patient involved in a road traf /f_i c accident demon

strates Lisfranc fracture dislocation with a comminuted fracture of the base of the second metatarsal (arrows).

Computed tomography /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF Magnetic resonance imaging Over the last 20 years, MRI has become an integral part of the imaging arsenal with ever-expanding indications. MRI relies on the fact that nuclei containing an odd number of protons have a characteristic motion in a magnetic field (precession) and produce a magnetic moment as a result of this motion. In a strong uniform magnetic field such as an MRI scanner, these nuclei align themselves with the main magnetic field and result in a net magnetic moment. A brief radiofrequency pulse is then applied to alter the motion of the nuclei. Once the radiofrequency pulse is removed, the nuclei realign themselves with the main magnetic field (relaxation) and in the process emit a radiofrequency signal that can be recorded, spatially encoded and used to construct a grey-scale image. The specific tissue characteristics define the manner and rate at which the nuclei relax. This relaxation is measured in two ways, referred to as the T1 and T2 relaxation times. The relaxation times and the proton density determine the signal from a specific tissue. There are a large number of imaging sequences that can be used by applying radiofrequency pulses of di ff erent strengths and durations. The image characteristic and signal intensity from di ff erent tissues ar e governed by the pulse sequence employed and whether it is T1 weighted or T2 weighted. For instance, fat, methaemoglobin and mucinous fluid are bright on T1-weighted images, whereas water and thus most patho logical processes, which tend to increase tissue water content, are bright on T2-weighted images. Cortical bone, air, haemo siderin and ferromagnetic materials are of very low signal on all pulse sequences. In general, T1-w eighted images are supe rior in the delineation of anatomy , while T2-weighted images tend to highlight pathology better. For added tissue contrast, intrav enous gadolinium may be administered. Other more lymph node imaging. MRI’s exquisite contrast resolution, coupled with a lack of ionising radiation, is very attractive in imaging, particularly of tissues that hav e relatively little natural contrast. MRI also has the adv antage of multiplanar imaging, as images can be acquired in any plane prescribed. It has traditionally been used extensively in the assessment of intracranial, spinal and mus - culoskeletal disorders (Figures 8.12 , 8.13 and 8.14) , allowing a global assessment of bony and soft-tissue structures. More recent developments have resulted in new indications and applications. Today , MRI is commonly used in oncological imaging, such as staging of rectal carcinoma and gynaecologi - cal malignancies, identification and characterisation of hepatic - - -

Strengths High spatial and contrast resolution Contrast resolution enhanced by ability to image in multiple phases, including arterial, venous and delayed Rapid acquisition of images in one breath-hold Imaging of choice for the detection of pulmonary masses Allows global assessment of the abdomen and pelvis Excellent for liver, pancreatic, renal and bowel pathology Three-dimensional reconstruction allows complex fracture imaging Multiplanar reconstruction and three-dimensional imaging, e.g. CT angiography and colonoscopy Ability to guide intervention such as percutaneous biopsy and drainage Weaknesses High radiation dose Poor soft-tissue resolution of the peripheries and super /f_i cial structures Patient needs to be able to lie /f_l at and still Less readily available than plain /f_i lms and ultrasound Figure 8.12 T2-weighted axial magnetic resonance imaging scan of the head in a patient with a large left-sided oligodendroglioma (arrow). Figure 8.13 Sagittal T2-weighted magnetic resonance imaging scan of the lumbar spine demonstrates disc herniation (arrow) in a patient with acute back pain.

masses and assessment of the biliary tree (magnetic resonance cholangiopancreatography [MRCP]; Figure 8.15). MRI has become increasingly important in imaging of the small bowel, for example in Crohn's disease, where repeated imaging with ionising radiation can incur a significant radiation dose over time. Magnetic resonance (MR) angiographic techniques allow non-invasive angiographic assessment of the cranial and peripheral circulation (Figure 8.16) and cardiac imaging. Di ff usion-weighted imaging is a relatively new type of MRI sequence that exploits the di ff erent rates of Brownian motion between di ff erent tissues. Tissues with greater cellular density have low er rates of di ff usion of water molecules, and this dif ference can be exploited to distinguish benign and malignant or inflammatory lesions in a variety of organs as malignant or inflammatory lesions tend to have greater density of cells. in comparison with other imaging techniques, and it is time-consuming with respect to image acquisition and interpretation. Images are easily degraded by motion, including respiratory and cardiac motion. T he use of respiratory and cardiac gating can minimise this, although bowel peristalsis can still be a problem. The long acquisition times require a cooperative patient who can lie very still, which can be di ffi cult especially in claustrophobic individuals or those in pain. Furthermore, because of the use of high-strength magnetic fields, patients with some metallic implants, such as some aneurysm clips and prosthetic heart valves, and those with implanted electronic devices, such as pacemakers and defibrillators, cannot be examined. Some newer implants may , however, be MRI compatible, and patients with joint replacements can be studied safely . Summary box 8.6 Magnetic resonance (MR) imaging /uni25CF Nuclear medicine In other imaging techniques using ionising radiation such as - CT and conventional radiography , the individual is exposed to ionising radiation from an external source and the radiation transmitted through the patient is recorded. In nuclear medicine, however, a radioactive element or radionuclide such

Figure 8.14 Coronal magnetic resonance imaging scan of the knee demonstrates extensive serpiginous areas of altered signal intensity in the distal femur and proximal tibia (arrows) in a patient with bone infarcts secondary to oral corticosteroids. Figure 8.15 Magnetic resonance cholangiopancreatography image demonstrates dilated intrahepatic ducts and proximal common bile duct (CBD) secondary to multiple calculi in the distal CBD (arrow). This type of imaging has the potential to alter cholecystectomy sur gical planning. Strengths No ionising radiation Excellent soft-tissue contrast Best imaging technique for Intracranial lesions Spine Bone marrow and joint lesions Other uses Staging MRCP MR angiography Breast malignancy Pelvic malignancy Cardiac imaging MR enterography Diffusion-weighted imaging Weaknesses Absolute contraindications Ocular metallic foreign bodies

Cochlear implants Cranial aneurysm clips Relative contraindications Pacemakers First trimester of pregnancy Claustrophobia Long scan times so patients may not be able to keep still, especially if in pain Limited availability Expensive

as technetium, gallium, thallium or iodine is administered to the patient as part of a radiopharmaceutical agent, and a detector such as a gamma camera is then used to record and localise the emission from the patient, thus forming the image. The radionuclide is chosen and coupled with other compounds such that it is distributed and taken up in the tissues of interest.

Therefore, a variety of radionuclides are required for imaging of di ff erent tissues. Nuclear medicine also di ff ers from other means of imaging, which are largely anatomically based, as it also provides functional information. Radionuclide imaging is widely used in bone imaging with very high sensitivity for assessing metastatic disease, metabolic bone disease, established arthropathies and occult infection and traumatic injuries (Figure 8.17) , although many of these applica tions are being replaced by MRI. In genitourinary disease, dynamic imaging can be perfor med to assess renal perfusion and function including obstruction, to investigate renovascular hypertension and to evaluate renal transplants. Radionuclide imaging is also commonly used in thyroid and parathyroid disorders, ischaemic cardiac disease, detection of pulmonary emboli and assessment of occult infection and inflammatory bowel disease. Positron emission tomography (PET) is an extension of nuclear medicine, in which a positron-emitting substance such 18 as F is tagged and used to assess tissue metabolic characteristics. 18 The most commonly used radiolabelled tracer is F-2-fluoro 2-deoxy- /d.sc -glucose (FDG), although other tracers can also be used in order to assess metabolic functions such as oxygen and glucose consumption and blood flow. Radioisotope decay causes the emission of a positron, which subsequently, within a few millimetres, collides with and annihilates an electron to produce a pair of annihilation photons. The drawbacks have been high cost, very limited availability and relatively low spatial resolution. The last of these has been addressed by PET/CT systems combining simultaneous PET imaging and CT, allowing the two sets of images to be registered so that more precisely. This modality has significantly improved the accuracy of cancer staging for a range of malignancies and is also useful in inflammatory conditions and imaging pyrexia of unknown origin. Summary box 8.7 Radionuclide imaging /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF /uni25CF -

Figure 8.16 Maximum intensity projection image from a magnetic res onance angiogram demonstrates the abdominal aorta, common and external iliac arteries as well as parts of the pulmonary, mesenteric and renal

vasculature. Strengths Allows functional imaging Allows imaging of the whole body Bone scan has a high sensitivity for metastatic bone disease, fractures and infection PET scanning is valuable in the detection of metastatic cancer Weaknesses Speci /f_i c agents are required for speci /f_i c indications

Often non-speci /f_i c and an abnormal result may require further imaging Generally poor spatial resolution Figure 8.17 Bone scintigraphy in a patient with carcinoma of the breast illustrates

bony metastatic deposits involving multiple verte

brae, the skull, pelvis and ribs.

Computed tomography

CT is the main imaging method for the investigation of intra- cranial and intra-abdominal injuries and vertebral fractures. With current multidetector scanners a comprehensive exam - ination of the head, spine, chest, abdomen and pelvis can be completed in less than 5 minutes. Traditionally the CT scanner was referred to as ‘the doughnut of death’, as imaging could lead to delays in emergency treatment. Howev er, as the avail - ability of scanners and the speed of scanning has dramatically increased, it has become standard practice to use CT early in the assessment of trauma patients. Emergency departments have CT scanners co-located to the resuscitation or trauma bays or patients can be assessed and treated while on the CT table. CT examination of the head is accurate in identifying treatable intracranial injuries (Figures 8.30 and 8.31) and should not be delayed by radiography of peripheral injuries, as there is declining success in cases of intracranial collection when treated after the initial 3–4 hours. In comparison, iden - tification of more widespread injuries, such as di ff use axonal injury , is relatively poor. Examination of facial injuries and cervical spine fractures can also be carried out at the same time as this only adds seconds to the examination. There is evidence tha t CT of the abdomen and pelvis is of benefit in multiple trauma when there is a head injury , as it often shows - unexpected abnormalities; this may a ff ect the immediate man - agement, especially if the patient deteriorates. Chest CT with intravenous contrast agent is valuable in identifying vascular and lung injuries and is the most accurate way of demonstrating haemothorax and pneumothorax. The position of chest drains can be identified, allowing adjust ment /uni00A0 of position if necessary . Abdominal and pelvic CT is usually undertaken as an extension to the chest CT . If an abdominal examination is performed, the pelvis should be included to avoid missing pelvic injuries and fr ee pelvic fluid. CT is an excellent means of identifying hepatic, splenic (Figure 8.32) and renal injuries. Delayed examination after assessment of the pelvicalyceal system in cases of renal trauma. Pancreatic and duodenal injuries may also be identified, but detection of these injuries may be more prob lematic. Using CT , the accuracy of detection of bowel or mesenteric injuries is less than it is for solid organ injury , and these injuries should be suspected when there is free intraperitoneal fluid without an identifiable cause (Figure 8.33). Close clinical follow-up and early repeat scanning with oral contrast can often reveal the bowel or mesenteric injury in patients with free fluid with no other cause identified. The image data may be reconstructed into thinner slices for the diagnosis of injuries to the thoracic and lumbar spine and for the better delineation of pelvic and acetabular frac - tures. Complex intra-articular fractures of the peripheral skel - eton, such as calcaneal and tibial plateau fractures , may be usefully examined by dedicated thin-section studies provided this does not delay the treatment of other more serious injuries (Figure 8.34) . CT angiography may be used to demonstrate vascular injuries in the limbs in those with penetrating injuries or complex displaced fractures.

Figure 8.30 Computed tomography of the head in a patient with head injury shows bilateral large frontal extradural collections (arrow). Figure 8.31 Computed tomography of the head following head trauma shows a skull fracture with a large depressed component (arrow).

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