

# 9 Spine

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## 9.1 RADIOGRAPHIC ANATOMY OF THE SPINE

Anatomical features of each vertebral body that can be identified radiographically (Figs 9.1, 9.2 and 9.3) include:

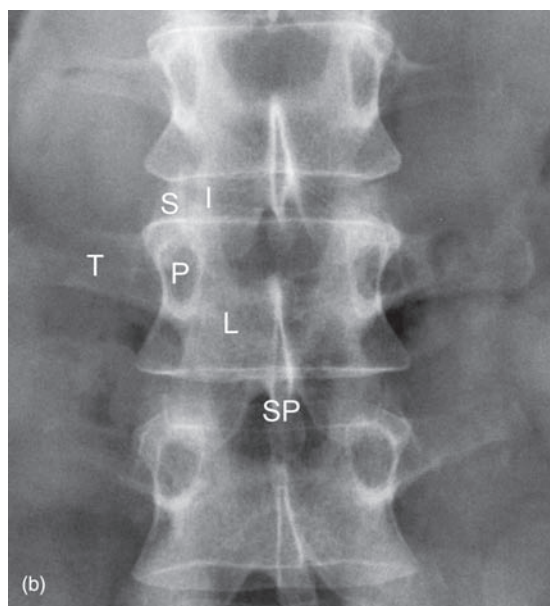
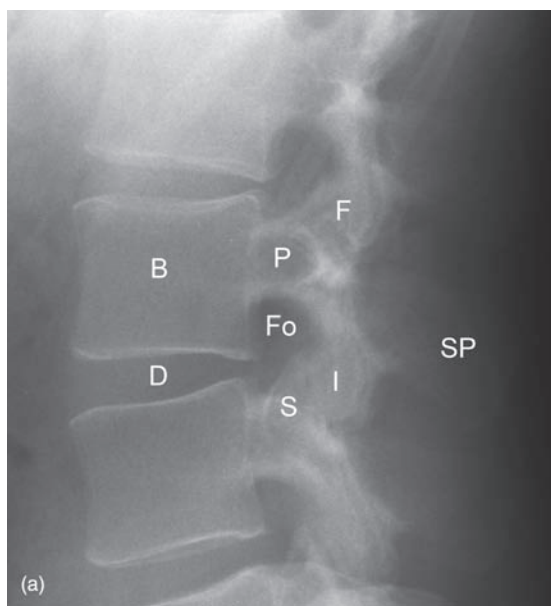
- Anterior vertebral body
- Posterior arch formed by pedicles and lamina, enclosing the spinal canal
- Pedicles: posterior bony projections from the posterolateral corners of the vertebral body
- Laminae curve posteromedially from the pedicles and join in the midline at the base of

the spinous process to complete the bony arch of the spinal canal

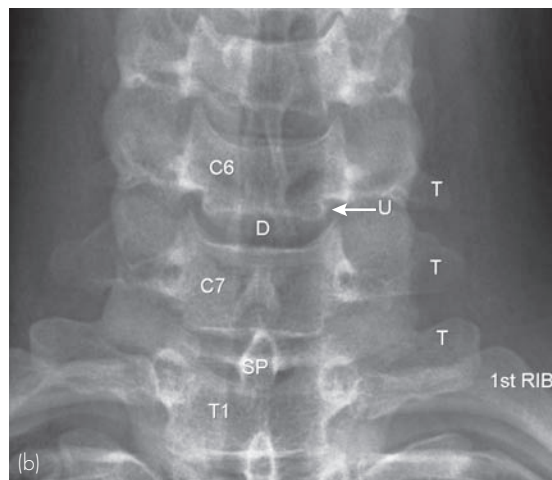
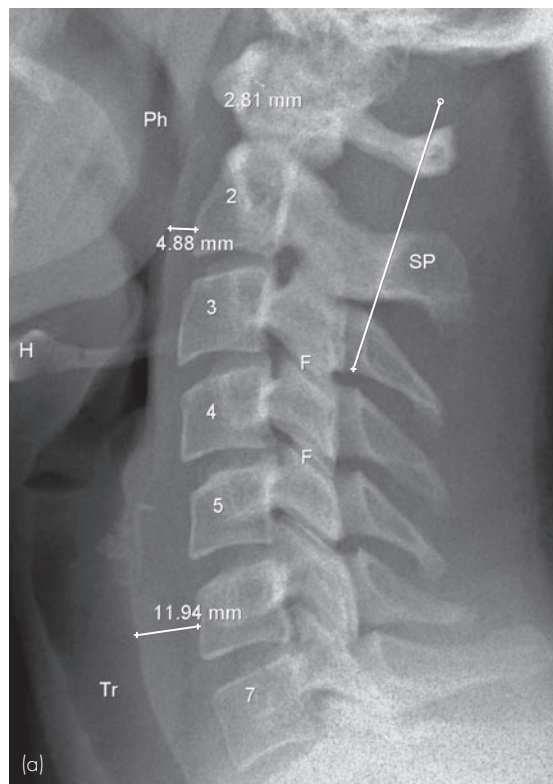
- Spinous process projects posteriorly
- Transverse processes project laterally from the junction of pedicle and lamina.

Articulations between adjoining vertebrae include intervertebral disc, zygapophyseal joints and uncovertebral joints.

- Intervertebral disc
  - Occupies the space between each vertebral body
  - Composed of central nucleus pulposus enclosed by annulus fibrosis



**Figure 9.1** Normal lumbar spine anatomy. (a) Lateral view. (b) Frontal view. Note the following features: vertebral body (B), intervertebral disc (D), pedicle (P), facet joint (F), intervertebral foramen (Fo), inferior articular process (I), superior articular process (S), transverse process (T), lamina (L), spinous process (SP).



**Figure 9.2** Normal cervical spine anatomy. (a) Lateral view. Note the following: facet joint (F), spinous process (SP), pharynx (Ph), hyoid bone (H), trachea (Tr) and posterior cervical line from C1 to C3. Note also measurements of predental space (between anterior arch of C1 and the odontoid peg), retropharyngeal space at C2 and retrotracheal space at C6. (b) Frontal view of lower cervical spine. Note the following: intervertebral disc (D), uncovertebral joint (U), transverse process (T), spinous process (SP).

- Zygapophyseal joints
  - Commonly known as facet joints
  - Formed by articular processes that project superiorly and inferiorly from the junction of pedicle and lamina
- Uncovertebral joints
  - Found in the cervical spine
  - Formed by a ridge or lip of bone that projects superiorly from the lateral edge of the vertebral body and articulates with the lateral edge of the vertebral body above.

The exception to the above pattern occurs at the first and second cervical vertebrae (C1 and C2). C1, also known as the 'atlas', consists of an anterior arch, two lateral masses and a posterior arch. Lateral masses of C1 articulate superiorly with the occiput (atlanto-occipital joints), and inferiorly with superior articular processes of C2 (atlanto-axial joints). The odontoid peg or dens is a vertical projection of bone that extends superiorly from the body of C2 and articulates with the anterior arch of C1.

## 9.2 SPINE TRAUMA

The roles of imaging in the assessment of spinal trauma are:

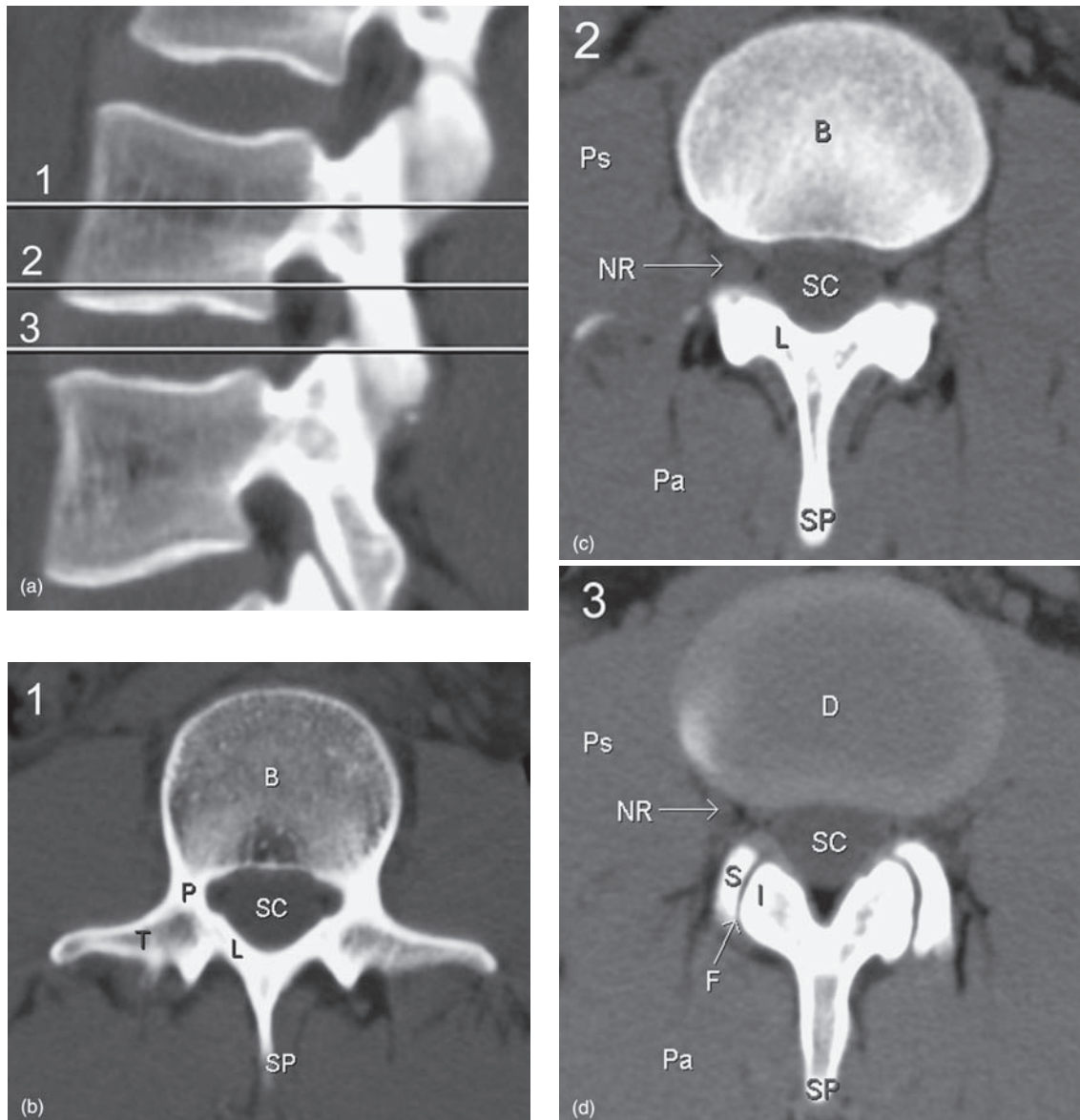
- Diagnosis of fractures/dislocation
- Assessment of stability/instability
- Diagnosis of damage to, or impingement on, neurological structures
- Follow-up
  - Assessment of treatment
  - Diagnosis of long-term complications, such as post-traumatic syrinx or cyst formation.

The principal imaging modalities used in the assessment of spine trauma are radiography, CT and MRI.

### 9.2.1 Cervical spine radiographs

Radiographic assessment of the cervical spine should be performed in all patients who have suffered major trauma as part of a trauma series that includes:

- Lateral radiograph cervical spine
- Frontal CXR
- Frontal radiograph of the pelvis.



**Figure 9.3** Normal lumbar spine anatomy: CT. (a) Reconstructed image in the sagittal plane showing the levels of the three following transverse sections. (b) Transverse section at level of pedicles. (c) Transverse section at level of intervertebral foramina. (d) Transverse section at level of intervertebral disc. In images (b), (c) and (d) note the following: vertebral body (B), pedicle (P), facet joint (F), inferior articular process (I), superior articular process (S), transverse process (T), lamina (L), spinous process (SP), nerve root (NR), spinal canal (SC), psoas muscle (Ps), paraspinal muscle (Pa).

Specific indications for cervical spine radiography in trauma patients include:

- Neck pain or tenderness
- Other signs of direct neck injury
- Abnormal findings on neurological examination
- Severe head or facial injury
- Near-drowning.

The following radiographs should be performed for suspected trauma of the cervical spine:

- Lateral view with patient supine showing all seven cervical vertebrae
  - Traction on the shoulders may be used to assist with visualization of the lower cervical spine

- Where the lower cervical vertebrae are obscured by the shoulders, a so-called 'swimmer's view' may be performed; this consists of a lateral view with one arm up and one down
- Traction on the head must never be used
- AP view of the cervical spine
- AP open mouth view to show the odontoid peg.

Oblique views to show the facet joints and intervertebral foramina may also be performed where facet joint dislocation or locking is suspected. Functional views may be performed to diagnose posterior or anterior ligament damage where no fractures are seen on the neutral views. Functional views consist of lateral radiographs in flexion and extension with the patient erect. The patient must be conscious and cooperative and must actively flex and extend their neck; a doctor or radiographer must not move the patient's head passively.

Cervical spine radiographs should be checked in a logical fashion for radiographic features that may indicate trauma. These features include vertebral alignment, bone integrity, disc spaces and prevertebral swelling:

- Vertebral alignment
  - Disruption of anterior and posterior vertebral body lines: lines joining the anterior and posterior margins of the vertebral bodies on the lateral view
  - Disruption of the posterior cervical line: a line joining the anterior aspect of the spinous processes of C1, C2 and C3; disruption of this line may indicate upper cervical spine fractures, especially of C2 (Fig. 9.2)
  - Facet joint alignment at all levels; abrupt disruption at one level may indicate locked facets
  - Widening of the space between spinous processes on the lateral film
  - Rotation of spinous processes on the AP film
  - Widening of the predental space: >5 mm in children; >3 mm in adults
- Bone integrity
  - Vertebral body fractures
  - Fractures of posterior elements, i.e. pedicles, laminae, spinous processes
  - Integrity of odontoid peg: anterior/posterior/lateral displacement
- Disc spaces
  - Narrowing or widening
- Prevertebral swelling
  - Widening of the retrotracheal space: posterior aspect of trachea to C6
    - >14 mm in children
    - >22 mm in adults
  - Widening of the retropharyngeal space: posterior aspect of pharynx to C2
    - >7 mm in adults and children.

## 9.2.2 Common patterns of cervical spine injury

### 9.2.2.1 Flexion: anterior compression with posterior distraction (Fig. 9.4)

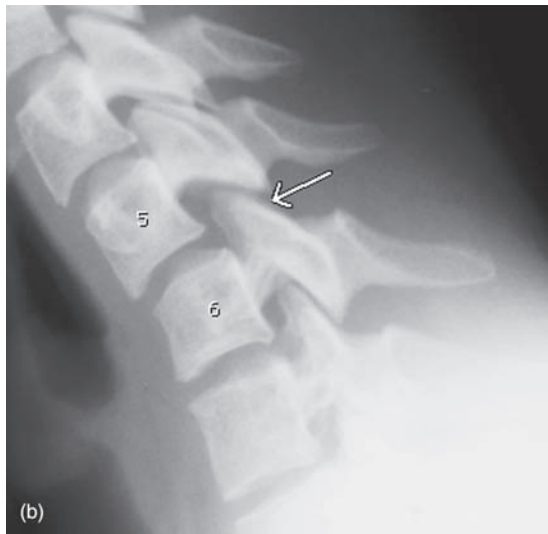
- Vertebral body compression fracture
- 'Teardrop' fracture, i.e. small triangular fragment at lower anterior margin of vertebral body
- Disruption of posterior vertebral line
- Disc space narrowing
- Widening of facet joints
- Facet joint dislocation and locking
- Widening of space between spinous processes.

### 9.2.2.2 Extension: posterior compression with anterior distraction (Fig. 9.5)

- 'Teardrop' fracture of upper anterior margin of vertebral body: indicates severe anterior ligament damage
- Disc space widening
- Retrolisthesis (posterior shift of vertebral body) with disruption of anterior and posterior vertebral lines
- Fractures of posterior elements: pedicles, spinous processes, facets
- 'Hangman's' fracture: bilateral C2 pedicle fracture (Fig. 9.6).

### 9.2.2.3 Rotation (Fig. 9.7)

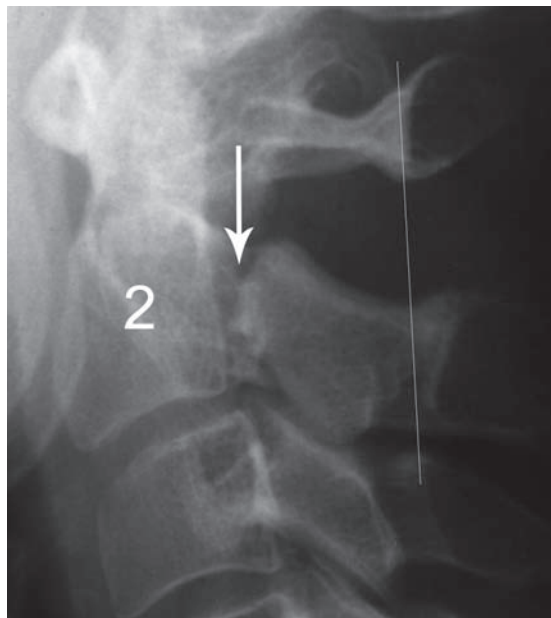
- Anterolisthesis (anterior shift of vertebral body) with disruption of posterior vertebral line
- Lateral displacement of upper vertebral body on AP view
- Abrupt disruption of alignment of facet joints: locked facets.



**Figure 9.4** Flexion injuries of the cervical spine: three separate examples. (a) Crush fracture of C7 (arrow). (b) Facet joint subluxation. The space between the spinous processes of C5 and C6 is widened. The inferior articular processes of C5 are shifted forwards on the superior articular processes of C6 (arrow) indicating facet joint subluxation. (c) Bilateral locked facets. Both facet joints at C6/7 are dislocated. The posterior corners of the inferior articular processes (I) of C6 are locked anterior to the superior articular processes (S) of C7 (arrow).

**Figure 9.5** Extension injury cervical spine. Note widening of the anterior disc space at C6/7 (arrow).





**Figure 9.6** Hangman's fracture. Fracture of the pedicles of C2 (arrow) with loss of continuity of the posterior cervical line.

### 9.2.3 Stability

As well as diagnosing and classifying cervical spine injuries, it is important to decide whether the injury is stable or not. Instability implies the possibility of increased spinal deformity or neurological damage occurring with mobilization or continued stress. Viewed laterally, the spine may be divided into three columns:

- Anterior: anterior two-thirds of the vertebral body
- Middle: posterior one-third of vertebral body and posterior longitudinal ligament
- Posterior: facet joints and bony arch of spinal canal (pedicles, laminae and spinous process).

It is generally accepted that two of these three columns must be intact for spinal stability to be maintained.

Radiographic signs of instability include:

- Displacement of vertebral body
- 'Teardrop' fractures of vertebral body
- Odontoid peg fracture
- Widening or disruption of alignment of facet joints including locked facets
- Widening of space between spinous processes
- Fractures at multiple levels.



**Figure 9.7** Flexion and rotation injury of the cervical spine: unilateral locked facet. There is widening of the space between the spinous processes of C5 and C6. Only one normally aligned facet joint is seen at C5/6. Compare this with the levels above where two normally aligned facet joints can be seen. Note the bare articular surface of one of the superior articular processes of C6 (arrow) due to dislocation of this facet joint.

### 9.2.4 Thoracic and lumbar spine radiographs

Assessment of plain films of the thoracic and lumbar spine following trauma is similar to that outlined for the cervical spine, with particular attention to the following factors:

- Vertebral alignment
- Vertebral body height
- Disc space height
- Facet joint alignment
- Space between pedicles on AP film: widening at one level may indicate a burst fracture of the vertebral body.

## 9.2.5 Common patterns of thoracic and lumbar spine injury

### 9.2.5.1 Burst fracture

- Complex fractures of the vertebral body with a fragment pushed posteriorly (retropulsed) into the spinal canal
- Multiple fracture lines through vertebral end plates.

### 9.2.5.2 Compression (crush) fracture (Fig. 9.8)

- Common in osteoporosis
- Loss of height of vertebral body most marked anteriorly giving a wedge-like configuration.

### 9.2.5.3 Fracture/dislocation

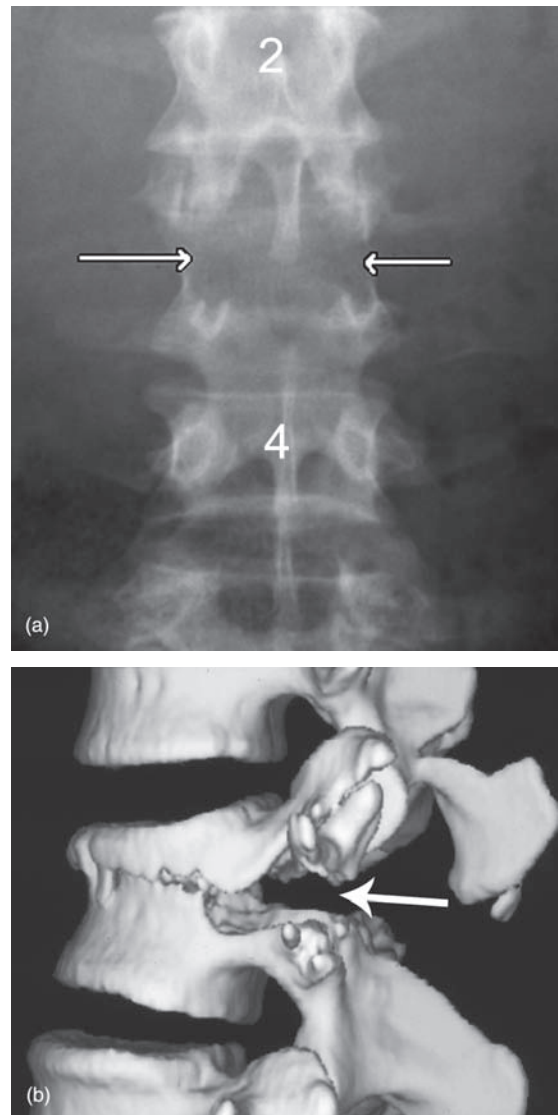
- Vertebral body displacement
- Disc space narrowing or widening
- Fractures of neural arches, including facet joints
- Widening of facet joints or space between spinous processes.



**Figure 9.8** Crush fracture lumbar spine. Lateral view showing a crush fracture of the upper body of L1.

### 9.2.5.4 Chance fracture (seatbelt fracture) (Fig. 9.9)

- Fracture of posterior vertebral body
- Horizontal fracture line through spinous process, laminae, pedicles and transverse processes
- Most occur at thoracolumbar junction



**Figure 9.9** Chance fracture (seatbelt fracture) lumbar spine. (a) Frontal view showing a transverse fracture at L3 including horizontal splitting of the pedicles (arrows). (b) Three-dimensional CT reconstructed image showing the transverse fracture of the pedicles and posterior vertebral body (arrow).

- High association with abdominal injury, i.e. solid organ damage, intestinal perforation, duodenal haematoma.

### 9.2.6 CT in spine trauma

CT is more sensitive than plain radiography in the diagnosis of bony spinal injuries. Particular advantages of CT in this clinical setting include:

- Accurate assessment of bony injuries, especially those of the neural arches and facet joints
- Retropulsed bone fragments projecting into the spinal canal and compressing neural structures are well seen (Fig. 9.10)
- Multiplanar and 3D images greatly assist in delineation of both subtle fractures and complex injuries.

CT examination of the cervical spine may be performed at the same time as a head CT in the setting of major trauma or an unconscious patient. Diagnostically adequate images of thoracic and lumbar spine may be reconstructed from

multidetector CT of the chest and abdomen; this may obviate the need for radiographic assessment of these regions in patients with mid or lower back pain following trauma.

### 9.2.7 MRI in spine trauma

MRI is the investigation of choice for assessment of suspected spinal cord damage. Signs of spinal cord trauma that may be visualized on MRI include cord transection, cord oedema and haemorrhage, plus late sequelae such as arachnoid cyst, pseudomeningocele, myelomalacia and syrinx (Fig. 9.11). Other soft tissue changes, such as post-traumatic disc herniation, ligament tear and spinal canal haematoma are also seen on MRI.

Indications for MRI of the spine in the setting of trauma include:

- Where neurological symptoms or signs are present, regardless of radiographic findings
  - The phenomenon of spinal cord injury without radiographic abnormality



**Figure 9.10** Burst fracture lumbar spine. CT in the transverse plane shows a fracture of the vertebral body with a retropulsed bone fragment (arrow) extending into the spinal canal.



**Figure 9.11** Spinal cord injury: MRI. Sagittal T2-weighted MRI of the cervical spine shows a high signal lesion associated with focal thinning of the spinal cord at C7 indicating myelomalacia (arrow).



(SCIWORA) is well described, particularly in children

- A normal radiograph should not preclude MRI where neurological injury is suspected on clinical grounds
- Suspected ligament injury and instability
- To differentiate acute crush fractures of the thoracic and lumbar spine from older healed injuries
  - This is an increasingly common indication in elderly patients with suspected osteoporotic crush fracture in whom MRI may assist with patient selection for percutaneous vertebroplasty (see Section 9.5.4).

### 9.3 NECK PAIN

Non-traumatic neck pain is an extremely common complaint. Most cases of neck pain are due to musculoligamentous strain or injury. Seventy per cent of episodes of neck pain resolve within one month. Most of the remaining 30 per cent resolve over the longer term with a small minority going on to have chronic neck problems. In the clinical assessment of neck pain, there are three major sources of diagnostic difficulty:

- Multiple structures including vertebral bodies, ligaments, muscles, intervertebral discs, vascular and neural structures are capable of producing pain
- Pain may be referred to the neck from other areas, such as shoulder, heart, diaphragm, mandible and temporomandibular joints
- Pain from the neck may be referred to the shoulders and arms.

#### 9.3.1 Osteoarthritis of the cervical spine

Osteoarthritis (degenerative arthropathy) is a major cause of neck pain, with increasing incidence in old age. The primary phenomenon in osteoarthritis of the spine is degeneration of the intervertebral disc. Intervertebral disc degeneration in the cervical spine is most common at C5/6 and C6/7. Degenerate discs may herniate into the spinal canal or intervertebral foramina, with direct compression of the spinal cord or nerve roots. More commonly, disc degeneration

leads to abnormal stresses on the vertebral bodies and on the facet and uncovertebral joints. These abnormal stresses lead to formation of bone spurs or osteophytes. Osteophytes may project into the spinal canal causing compression of the cervical cord, or into the intervertebral foramina causing nerve root compression. Cervical cord compression presents clinically with neck pain associated with a stiff gait and brisk lower limb reflexes (myelopathy).

Causes of cervical myelopathy:

- Syrinx
- Spinal cord tumours: ependymoma, glioma, neurofibroma, meningioma
- Vertebral body tumours: metastases, giant cell tumour, chordoma.

Nerve root compression produces local neck pain plus pain in the distribution of the compressed nerve. Osteoarthritis uncomplicated by compression of neural structures may cause episodic neck pain with the following features:

- Tends to be increased by activity
- May be associated with shoulder pain or headache
- Usually resolves within 7–10 days.

#### 9.3.2 Imaging of the patient with neck pain

The goals of imaging of the patient with neck pain should be to exclude conditions requiring urgent attention, to diagnose a treatable condition, and to direct management. With these goals in mind and given the fact that most neck pain resolves spontaneously, it follows that the majority of patients do not require imaging. Imaging should be reserved for those cases where symptoms are severe and persistent, or where there are other relevant factors on history or examination, such as trauma or a known primary tumour.

Initial imaging in the majority of cases consists of a plain film examination of the cervical spine. Radiographic signs of osteoarthritis of the cervical spine (Fig. 9.12) include:

- Disc space narrowing, most common at C5/6 and C6/7
- Osteophyte formation on the vertebral bodies and facet joints
- Osteophytes projecting into the intervertebral foramina.



**Figure 9.12** Osteoarthritis of the cervical spine. Note disc space narrowing at multiple levels.

MRI is the investigation of choice where further imaging is required for persistent nerve root pain, or for assessment of a possible spinal cord abnormality. CT is used in the investigation of neck pain where fine bone detail is required, such as in the assessment of vertebral body tumour.

## 9.4 LOW BACK PAIN

Low back pain refers to back pain that does not extend below the iliac crests. Pain extending to the buttocks or legs is referred to as sciatica; this is a separate clinical problem to back pain and is considered in Section 9.6. Low back pain may be classified into acute or chronic, with the term 'acute back pain' usually referring to pain of less than 12 weeks' duration. There are now well-developed evidence-based guidelines for the management and investigation of acute back pain from which

a number of consistent recommendations can be identified. Primary among these is the need for diagnostic triage of patients into three major groups:

- Non-specific low back pain, acute or chronic
- Specific low back pain
- Sciatica or radicular pain, with neurological findings such as positive straight leg raise test.

As discussed in Section 9.6, sciatica is best investigated with MRI or CT. Specific low back pain refers to back pain with associated clinical symptoms or signs, known as 'red flags', that may indicate an underlying problem. Examples of these 'red flags', some of which will be discussed below, include:

- Known primary tumour, such as prostate or breast
- Systemic symptoms: unexplained fever or weight loss
- Recent trauma
- Known osteoporosis or prolonged steroid use
- Age at onset of pain: <20 or >55 years
- Thoracic pain
- Neurological changes.

### 9.4.1 Acute non-specific low back pain

All of the evidence-based guidelines on acute back pain agree that imaging assessment, including radiography of the lumbar spine, is not indicated in patients with non-specific acute back pain. This reflects the fact that most cases of non-specific low back pain are due to musculoligamentous injury or exacerbation of degenerative arthropathy, and will usually resolve within a few weeks. Most guidelines emphasize the importance of reassurance, discouragement of bed rest, and the recognition of psychosocial risk factors that may predispose to chronic back pain.

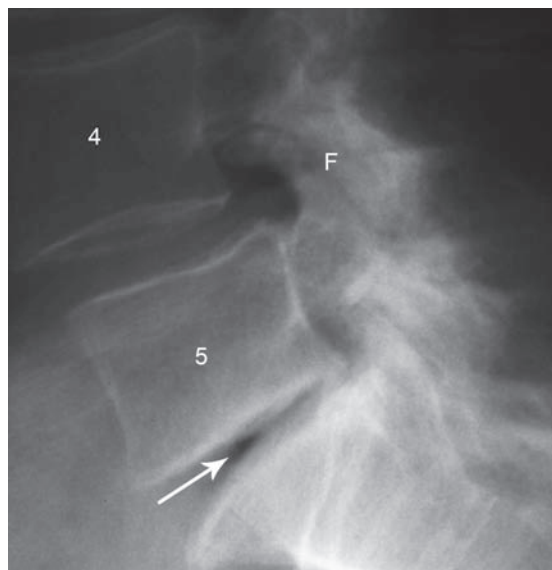
### 9.4.2 Chronic non-specific low back pain

Most of the evidence in the medical literature dealing with the problem of chronic low back pain points to the exclusion of 'red flags' (see above). A multidisciplinary approach to therapy is often required, including exercise, education and counselling. A specific diagnosis as to the cause of pain is often not required. In some cases, however, particularly when pain is severe and debilitating, or

due to other factors, such as loss of employment or depression, a specific diagnosis may be required as a guide to therapy.

Most cases of chronic back pain are due to facet joint pain, sacroiliac joint pain or internal disruption of intervertebral discs. Imaging techniques, such as radiography, CT and MRI, are able to show changes of degenerative arthropathy in a large percentage of patients examined (Fig. 9.13). A major problem with imaging in this context is that findings are very non-specific; imaging is often unable to pinpoint the cause of pain. For example, radiographs may show a narrowed disc space; this does not mean that this is definitely the cause of the patient's pain.

The only way to prove that a certain structure, such as a facet joint, is the cause of pain is to inject local anaesthetic into that structure and assess the response. Image-guided interventions are now commonplace in the management of chronic back pain and are performed under CT or fluoroscopic guidance (see below). It should be emphasized that in the absence of 'red flags', imaging is not indicated in the majority of patients with chronic non-specific low back pain.



**Figure 9.13** Osteoarthritis of the lumbar spine. Narrowing of the intervertebral disc space between L5 and S1 (arrow). Sclerosis of the facet joints at L4/5 (F) with degenerative spondylolisthesis at this level.

### 9.4.3 Image-guided interventions in the diagnosis and management of back pain

Image-guided interventions are increasingly common in the management of back pain and sciatica. Most procedures outlined in this section have the following features in common:

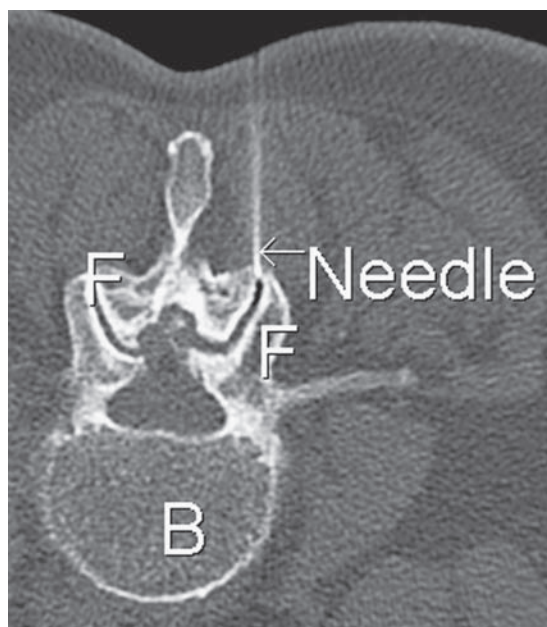
- Performed under CT or fluoroscopic guidance
- Use of fine needles, 22–25 gauge
- Injection of local anaesthetic and corticosteroid (LACS).

Complications are very rare and may include haemorrhage or infection. Contraindications are few and include severe coagulopathy and unsuitable anatomy.

#### 9.4.3.1 Facet joint injection

Facet joint injection of LACS (Fig. 9.14) has two roles:

- Diagnostic: confirm facet joint as pain generator
- Therapeutic.



**Figure 9.14** Facet joint block: computer tomography guidance. The patient is lying prone with the vertebral body (B) towards the bottom of the image. A fine needle is inserted into the facet joint (F) for injection of local anaesthetic and steroid.

#### 9.4.3.2 Medial branch block

Each facet joint receives dual innervation from medial branches of two contiguous nerve roots:

- For example, each L4/5 facet joint receives innervation from medial branches of the L3 and L4 nerve roots
- These medial branches pass across the bases of the transverse processes of L4 and L5.

For medial branch block, fine needles are positioned under imaging guidance at the bases of the relevant transverse processes; LACS or local anaesthetic (LA) alone is injected to block the nerve supply to the facet joint.

Indications for medial branch block include:

- Recurrence of symptoms following successful facet joint block.
- Confirm facet joint as pain generator
- Prior to permanent medial branch ablation.

#### 9.4.3.3 Medial branch ablation

The aim of medial branch ablation is long-term pain relief from facet joint denervation.

Facet joint denervation is usually achieved by radiofrequency (RF) ablation of the medial nerve branches supplying the joint. Following injection of LA, the RF probe is placed under imaging guidance with its tip at the known position of the medial nerve branch.

Medial branch ablation is often performed with mild intravenous conscious sedation. General anaesthetic is not used, as the patient must be able to respond to sensory and motor stimuli during the procedure.

#### 9.4.3.4 Epidural injection

Injection of LACS into the epidural space (Fig. 9.15) may be performed for various indications including:

- Back pain and/or sciatica due to spinal stenosis
- 'Discogenic' back pain due to degenerative changes in intervertebral discs.

Although common, epidural injection is a controversial procedure for a number of reasons, including uncertainty over mechanism of action.



**Figure 9.15** Epidural injection: CT guidance. Injection of a small amount of air confirms the needle tip position in the epidural space (arrow).

#### 9.4.3.5 Discography

Discography is used to prove that pain is arising from one or more intervertebral discs. Under fluoroscopic guidance, a fine needle is positioned in the centre of the intervertebral disc. A small amount of dilute contrast material is injected to 'stress' the disc. The patient's pain response is recorded. Contrast material is used to assess the actual morphology of the disc and to diagnose annular tears.

## 9.5 SPECIFIC BACK PAIN SYNDROMES

Imaging may be required for assessment of back pain associated with 'red flags' as listed above. An initial radiographic examination of the lumbar spine is reasonable in these patients. This will help exclude obvious bony causes of pain, as well as delineate any other relevant factors such as scoliosis.

Limitations of radiographs of the lumbar spine:

- Soft tissue structures such as ligaments, muscles and nerve roots are not imaged
- Relatively insensitive for many painful bone conditions such as infection



- Cross-sectional dimensions of the spinal canal are not assessed.

In many conditions, such as suspected infection or suspected acute osteoporotic crush fracture, MRI is the investigation of choice.

CT is highly accurate for assessment of bony lesions such as suspected tumours or pars interarticularis defects.

Scintigraphy with  $^{99m}\text{Tc}$ -MDP may be indicated in certain instances:

- To exclude spinal metastases where there is a known primary tumour
- Suspected pars interarticularis fractures; these may be difficult to see on plain films, particularly in young patients with subtle stress fractures.

### 9.5.1 Pars interarticularis defects and spondylolisthesis

The pars interarticularis is a mass of bone between the superior and inferior articular processes of the vertebral body. Defect of the pars interarticularis, also known as spondylolysis, may be congenital or due to trauma:

- Congenital pars interarticularis defects are often associated with other developmental anomalies of the lumbar spine, especially failure of complete bony fusion of the laminae in the midline.
- Acute trauma may produce an acute fracture through the pars interarticularis, and stress fractures may occur associated with sports such as gymnastics and fast bowling (cricket).

Regardless of aetiology, pars interarticularis defects may be unilateral or bilateral, and are most common at L5. Bilateral pars defects may be associated with spondylolisthesis, i.e. anterior shift of L5 on S1. Back pain in spondylolysis and spondylolisthesis may be due to a number of factors including:

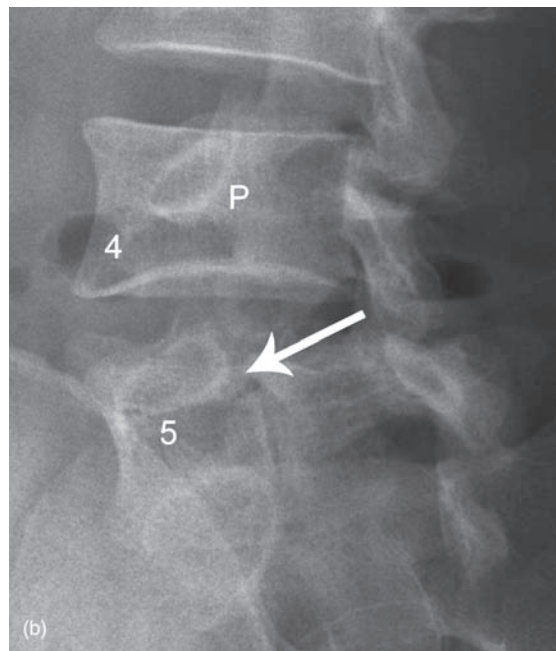
- The bony defects themselves
- Segmental instability
- Degenerative changes in the intervertebral disc.

Spondylolysis is suspected in otherwise healthy young adults presenting with back pain, particularly those participating in typical sporting

activities. Spondylolisthesis also causes narrowing of the intervertebral foramina between L5 and S1 with compression of the exiting L5 nerve roots producing bilateral posterior leg pain and a sensation of hamstring tightness. Spondylolysis and spondylolisthesis may be investigated with radiographs, scintigraphy, CT and MRI.

Radiographically, pars interarticularis defects are best seen on oblique views of the lower lumbar spine. The complex of overlapping shadows from the superior and inferior articular processes, the pars interarticularis, and the transverse process forms an outline resembling that of a Scottish terrier dog. A pars defect is seen as a line across the neck of the 'dog' (Fig. 9.16).

Scintigraphy with  $^{99m}\text{Tc}$ -MDP and single photon emission CT-CT (SPECT-CT) may be used to diagnose subtle stress fractures not able to be visualized radiographically. Pars interarticularis defects are also well shown on CT, particularly with multidetector CT, which allows multiplanar reconstructions.



**Figure 9.16** Pars interarticularis defect. Oblique view of the lower lumbar spine showing a pars interarticularis defect at L5 (arrow). Note also the intact pars interarticularis at L4 (P) and the facet joints.



When there is frank spondylolisthesis on the lumbar spine radiographs, MRI is often used. MRI provides more information on the state of the intervertebral disc and is also the best method for assessing the degree of narrowing of the intervertebral foramina and associated nerve root compression.

### 9.5.2 Vertebral infection

Most vertebral infection commences in the intervertebral disc (discitis). Discitis may spread to involve the vertebral body, causing vertebral osteomyelitis, or may invade the spinal canal to produce an epidural abscess. Discitis is usually due to blood-borne infection, may occur in children or adults, and is more common in the lower spine. Clinical features of discitis include rapid onset of back pain accompanied by fever and malaise. In young children, there may be less specific symptoms, such as limp or failure to weight bear.

Radiographic findings of discitis occur late in the disease process and include narrowing of the intervertebral disc with blurring of the vertebral endplates.

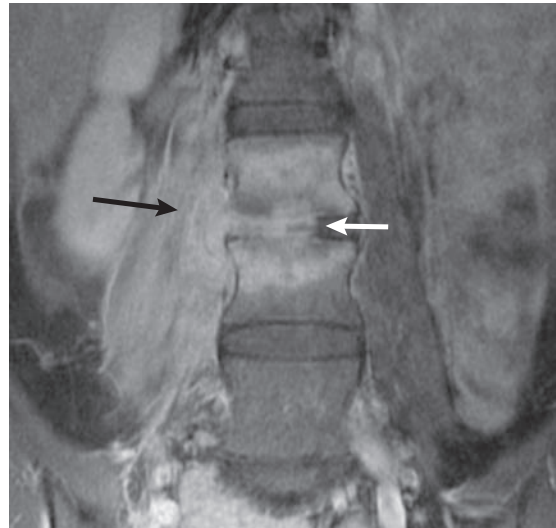
MRI is the investigation of choice for suspected vertebral infection. MRI is usually positive at the time of clinical presentation, before radiographic signs are evident (Fig. 9.17). MRI is also the best imaging method for showing the full extent of infection, including epidural abscess.

### 9.5.3 Vertebral metastases

Tumours with a high incidence of vertebral metastases include prostate, breast, lung, kidney and melanoma. Lymphoma and multiple myeloma may also involve the spine. Vertebral metastatic disease is suspected when back pain occurs in a patient with a known primary tumour. Other suspicious clinical factors include weight loss and raised PSA (prostate specific antigen).

Radiographs of the spine may show focal sclerotic (dense) lesions throughout the vertebral bodies in metastases from prostatic primary. Other primary tumours tend to produce lytic or destructive metastases that may be difficult to appreciate on radiographs (Fig. 9.18).

Scintigraphy with  $^{99m}\text{Tc}$ -MDP is generally the investigation of choice in screening for skeletal metastases, including the spine.



**Figure 9.17** Discitis: MRI. Coronal T1-weighted, fat saturated contrast-enhanced MRI of the lumbar spine in a 14-year-old female with severe back pain and fever. Enhancement of L3/4 intervertebral disc (white arrow). Note also enhancement of adjacent vertebral bodies and spread of infection into the right psoas muscle (black arrow).

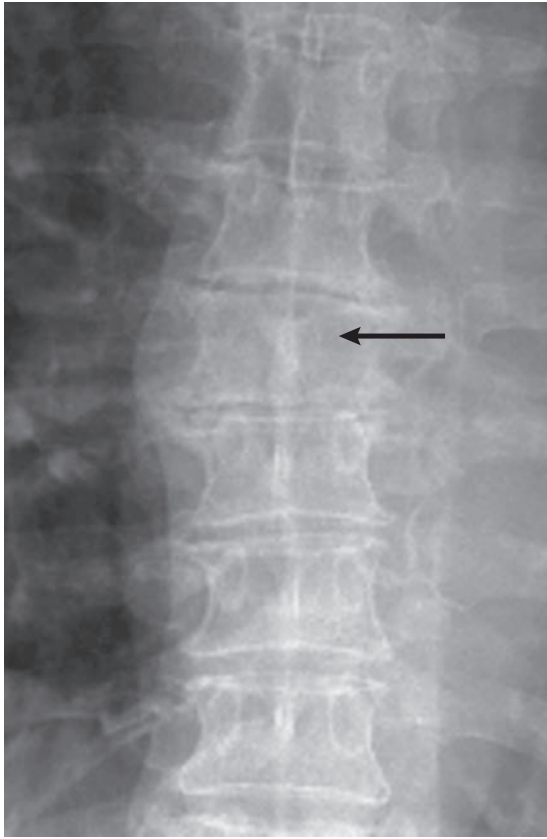
Occasionally, a vertebral metastasis may expand into the spinal canal and compress the spinal cord causing an acute myelopathy. Clinical features of myelopathy include:

- Motor problems in the legs leading to difficulty with walking
- Sensory disturbances; a band-like sensation around the abdomen
- Voiding difficulties.

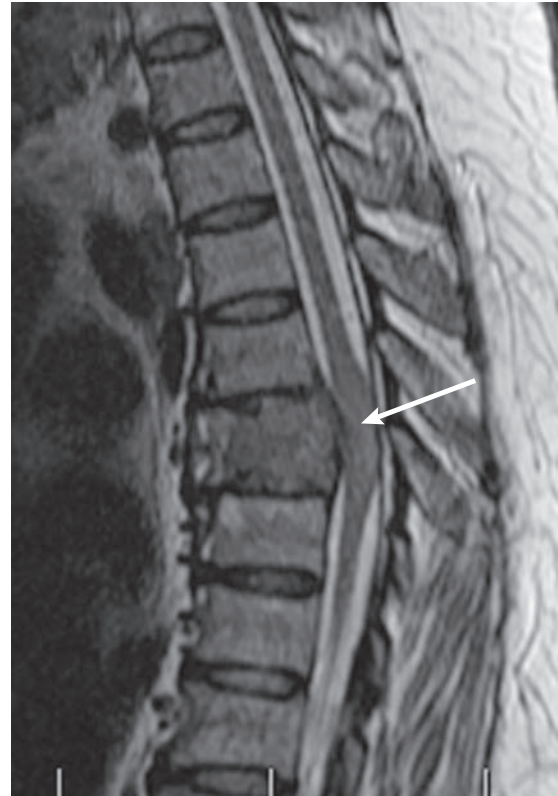
Cord compression due to metastatic disease is most common in the thoracic region and may require acute surgical decompression or radiotherapy. MRI is the investigation of choice for suspected spinal cord compression (Fig. 9.19).

### 9.5.4 Acute osteoporotic crush fracture

Individuals with osteoporosis are at an increased risk for the development of a crush fracture of the spine. Osteoporotic crush fractures may occur at any level, though are most common in the lower thoracic and lumbar spine. The patient usually presents with acute back pain that is mechanical in type, i.e. worsened by movement or activity. There may be



**Figure 9.18** Vertebral metastasis. Sudden onset back pain and leg weakness in a 62-year-old female with a history of breast cancer. Frontal radiograph shows reduced height of the T6 vertebral body. Note loss of visualization of the left pedicle due to bone destruction (arrow).



**Figure 9.19** Vertebral metastasis: MRI. Same patient as Fig. 19.18. Sagittal T2-weighted MRI shows destruction and partial collapse of T6. Neoplastic tissue is invading the spinal canal and compressing the spinal cord (arrow).

an associated band-like distribution of pain around the chest wall or abdomen, depending on the level involved. The pain associated with osteoporotic crush fracture usually settles in a matter of weeks. In some patients, however, the pain may persist and produce numerous complications:

- Reduced mobility
- Inhibition of respiration
- Difficulty sleeping
- Significant mortality and morbidity in elderly patients.

Percutaneous vertebroplasty is now a well-accepted technique for the treatment of the pain associated with acute osteoporotic crush fractures. Radiographs of the spine will usually diagnose a crush fracture (Fig. 9.8). A major limitation of

radiography is that there is no reliable way to distinguish an acute crush fracture from an older healed injury. This becomes particularly relevant where percutaneous vertebroplasty is being considered and multiple crush fractures are seen radiographically.

Prior to vertebroplasty, MRI is used to define the acute level(s), and therefore assists with patient selection and procedure planning. MRI is able to show bone marrow oedema in acutely crushed vertebral bodies (see Fig. 1.19). Older healed crush fractures show normal bone marrow signal with no evidence of oedema.

Vertebroplasty involves insertion of a large bore needle (11 or 13 gauge) into the vertebral body followed by injection of bone cement. The bone cement is mixed with barium powder so

it can be visualized radiographically. Needle placement and cement injection are performed under direct fluoroscopic guidance to avoid injury to neurological structures (Fig. 9.20). Vertebroplasty is a highly effective technique for reducing pain, restoring mobility and reducing dependence on analgesics. Complications of vertebroplasty are uncommon and include:

- Haemorrhage
- Leakage of cement into the spinal canal or intervertebral foramina with impingement on spinal cord and nerve roots
- Embolization of tiny cement fragments into the lungs: usually not clinically significant.

### 9.5.5 Scoliosis

Scoliosis refers to abnormal curvature of the spine, with a lateral component of  $>10^\circ$ . Recognized causes of scoliosis include:

- Congenital due to abnormal vertebral segmentation (Fig. 9.21a)
- Underlying syndrome, such as neurofibromatosis
- Severe degenerative disease in elderly patients
- Acute painful scoliosis may indicate the presence of vertebral infection or a tumour such as osteoid osteoma.

Most commonly, scoliosis is idiopathic. Idiopathic scoliosis is classified according to the age of onset with three major groups described:

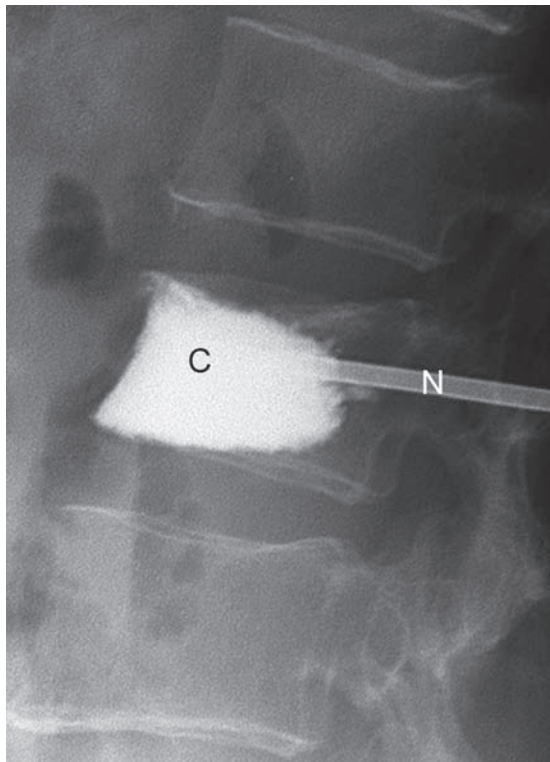
- Infantile: birth to four years
- Juvenile: four to ten years
- Adolescent: ten years or older.

Adolescent idiopathic scoliosis (AIS) accounts for 90 per cent of patients with scoliosis. The key clinical test for the diagnosis of AIS is the forward bend test. A positive forward bend test is indicated by convex bulging of the contour of the back on the side of the convexity of the spinal curve, due to rotation of the spine producing prominence of the posterior ribs on the convex side.

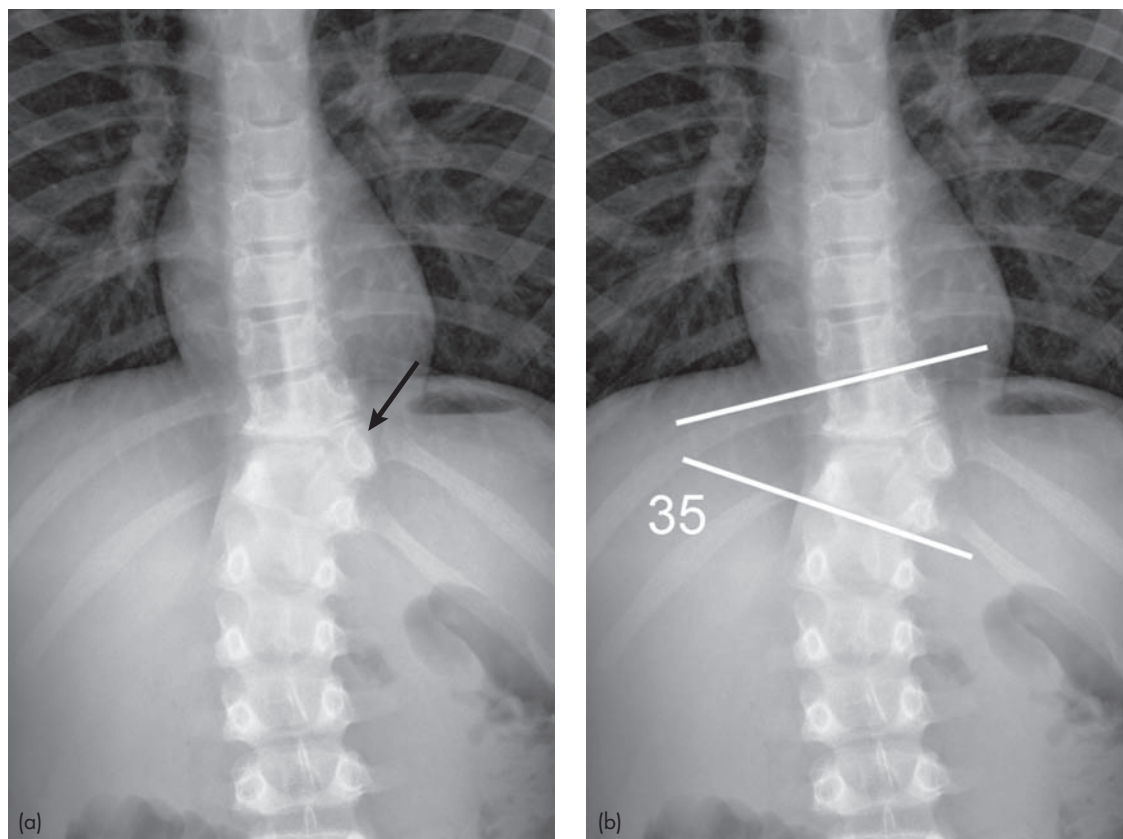
Patients with suspected scoliosis should be assessed radiographically with a single AP long film of the thoracic and lumbar spine taken with the patient standing erect. The key to radiographic diagnosis and follow-up is measurement of the Cobb angle:

- Identify the most tilted vertebral bodies above and below the apex of the curve
- Line drawn parallel to the superior vertebral end plate of the most tilted vertebral body at the upper end of the curve
- Similar line drawn parallel to the lower vertebral end plate of the lower most tilted vertebral body
- The angle between these lines is the Cobb angle (Fig. 9.21b).

A Cobb angle of  $10^\circ$  or greater is considered abnormal. Curves are described by their region, thoracic or lumbar, and by the direction of convexity, e.g. a 'right curve' is convex to the right. The largest curve is termed the 'major' or 'primary' curve. Compensatory or secondary curves occur above and/or below the primary curve; these usually have smaller Cobb angles than the primary curve. The most common pattern in AIS is a right thoracic primary curve with a left lumbar or thoracolumbar



**Figure 9.20** Vertebroplasty. Lateral view showing radio-opaque bone cement (C) being injected into the vertebral body via a large bone biopsy needle (N).



**Figure 9.21** Vertebral anomaly causing scoliosis. (a) Frontal radiograph shows a left-sided hemivertebra on the left in the lower thoracic spine (arrow). Note that the hemivertebra articulates with an unpaired left rib. (b) Cobb angle measurement: note the method of Cobb angle measurement as outlined in text.

secondary curve. A single erect radiograph is usually sufficient for the imaging assessment of AIS.

Uncommonly, further imaging with MRI may be indicated for the following:

- Neurological signs
- Certain radiographic abnormalities, e.g. bone destruction such as may indicate the presence of a vertebral tumour
- Atypical curves
  - In particular, a left thoracic primary curve may be associated with a syrinx of the cord.

## 9.6 SCIATICA

Sciatica is usually caused by herniation of intervertebral disc, or by spinal stenosis due to degenerative disease. Each intervertebral disc

is composed of a tough outer layer, the annulus fibrosis, and a softer semifluid centre, the nucleus pulposus. With degeneration of the disc, small microtears appear in the annulus fibrosis allowing generalized bulging of the nucleus pulposus. This causes the disc to bulge beyond the margins of the vertebral bodies causing narrowing of the spinal canal. Secondary effects of degenerative disc disease include abnormal stresses on the vertebral bodies leading to osteophyte formation, as well as facet joint sclerosis and hypertrophy. These changes may lead to further narrowing of the spinal canal producing spinal canal stenosis.

A common complication of disc degeneration is the occurrence of a localized tear in the annulus fibrosis through which the nucleus pulposus may herniate. Disc herniation may project into the spinal canal or posterolaterally into the intervertebral



foramen, causing compression of nerve roots. 'Free fragment' and 'sequestration' are terms that refer to a fragment of disc that has broken off from the 'parent' disc; this fragment may migrate superiorly or inferiorly in the spinal canal.

### 9.6.1 Sciatica syndromes

Sciatica refers to pain confined to a nerve root distribution, with leg pain being more severe than back pain. Sciatica may be accompanied by other neurological symptoms such as paraesthesia, and by signs of nerve root irritation such as positive straight leg raise test. Sciatica or leg pain syndromes are classified based on whether the pain is acute or chronic, unilateral or bilateral:

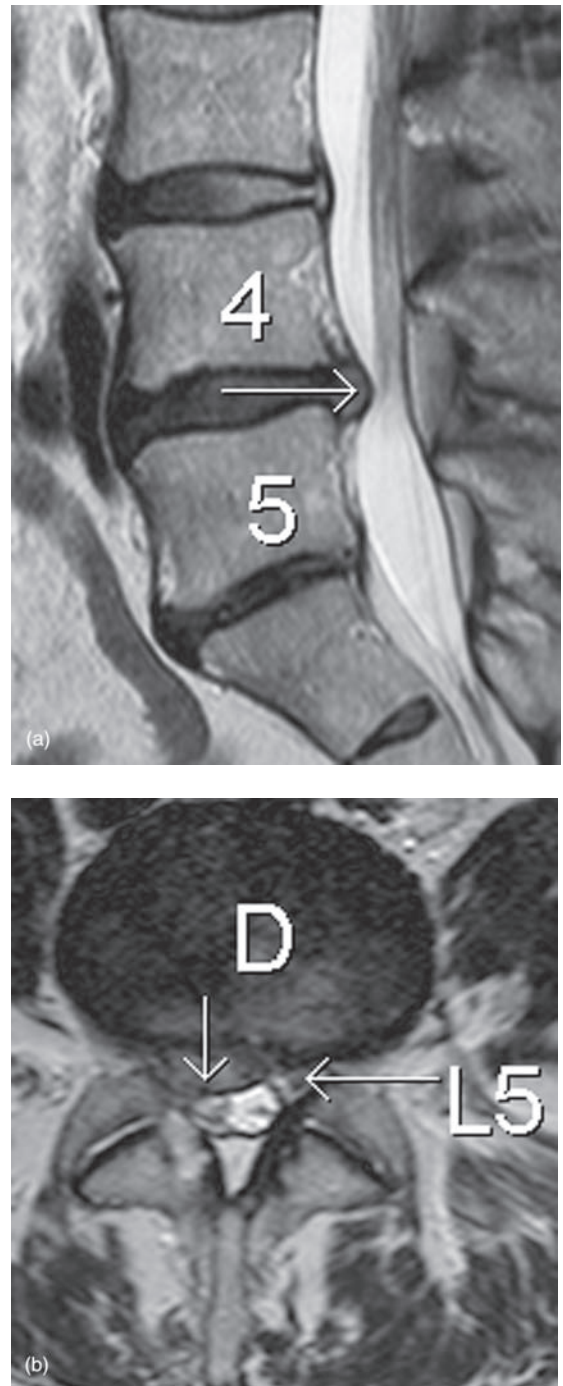
- Unilateral acute nerve root compression: 'classical' sciatica
  - Usually caused by focal disc herniation
- Bilateral acute nerve root compression: cauda equina syndrome
  - Cauda equina syndrome refers to the sudden onset of bilateral leg pain accompanied by bladder and/or bowel dysfunction
  - Usually caused by a massive disc herniation or sequestration
- Unilateral chronic nerve root compression: sciatica lasting for months
  - Unilateral chronic sciatica may be caused by disc herniation or spinal stenosis
- Bilateral chronic nerve root compression
  - Bilateral chronic nerve root compression refers to vague bilateral leg pain aggravated by walking and slowly relieved by rest
  - Usually caused by spinal canal stenosis
  - A common clinical difficulty is differentiating neural compression from vascular claudication
    - Clinical pointers that indicate a vascular cause include absent peripheral pulses, pain is in the exercised muscles, and rapid pain relief with rest.

### 9.6.2 Imaging of sciatica

#### 9.6.2.1 MRI and CT

MRI is the investigation of choice for most neurological disorders of the spine, including sciatica. Advantages of MRI in this context include:

- Better soft tissue contrast resolution than CT



**Figure 9.22** Intervertebral disc herniation: MRI. (a) Sagittal image showing posterior herniation of the L4/5 disc (arrow). (b) Transverse image through the intervertebral disc (D) showing herniation into the right side of the spinal canal (arrow). Note the normal left L5 nerve root. The right L5 nerve root is compressed and cannot be visualized.



- Nerve roots and the distal spinal cord and conus can be imaged without the use of contrast material
- Able to outline the anatomy of the spinal canal and the intervertebral discs
- Highly sensitive for the detection of spinal canal stenosis, disc herniation and narrowing of the intervertebral foramina (Fig. 9.22).

CT is a reasonable alternative for investigation of sciatica where MRI is not available.

#### 9.6.2.2 Selective nerve root block

Selective nerve root block (SNRB) is used in patients with sciatica as both a diagnostic tool and a means for giving temporary pain relief. SNRB is a relatively simple procedure in which a fine needle is positioned adjacent to the nerve root under CT or fluoroscopic guidance, and a small volume of steroid and local anaesthetic injected. SNRB may be

performed safely in the cervical, thoracic or lumbar spine.

Indications for SNRB include:

- To confirm the symptomatic level where imaging findings indicate nerve root compression at multiple levels
- Lack of imaging evidence of nerve root compression despite a convincing clinical presentation
- To provide temporary pain relief from sciatica while surgery is planned
- Surgery contraindicated due to anaesthetic risk or other factors.

Post-procedure care:

- Some patients experience transient lower limb numbness and a subjective feeling of weakness and may need to be assisted with standing and walking following the procedure
- Patients are advised not to drive a car for a few hours following the procedure.

## SUMMARY BOX

Clinical presentation	Investigation of choice	Comment
Spine trauma	Radiography CT to define bony anatomy MRI to define soft tissue complications including spinal cord injury	
Neck pain	Imaging not indicated in most cases Radiography MRI/CT for radiculopathy/myelopathy	
Back pain	Imaging not indicated in most cases Radiography MRI/CT for radiculopathy/myelopathy	Imaging indicated in neck and back pain for chronic, relapsing or unremitting pain, or in the presence of clinical 'red flags' (see above)
Spondylolysis and spondylolisthesis	Radiography SPECT-CT	MRI if sciatica is the dominant symptom
Discitis	MRI	
Vertebral metastases	Bone scintigraphy	
Acute osteoporotic crush fracture(s)	Radiography	MRI where vertebroplasty is contemplated
Scoliosis	Radiography ('long films')	MRI in selected cases
Sciatica	MRI	CT where MRI is unavailable

SPECT-CT, single photon emission CT-CT.

