**Indirect signs of trauma**

a. Soft tissue swelling due to haemorrhage is commonly associated with fractures or ligamentous injury.

b. Joint effusion due to haemorrhage or fluid displaces the extracapsular fat pads away from the bone creating what is known as the “fat pad” sign. This is useful for assessing trauma involving the wrist and elbow (fig 20.3).

c. Free fat within a joint capsule is indicative of bony injury. It is best demonstrated on a horizontal beam radiograph and appears as a fluid-fluid level due to free fat floating on top of synovial fluid or blood (fig 20.4).

---

**Pitfalls in imaging**

a. Nutrient arteries appear as radiolucent lines and can be mistaken for crack fractures. This is commonly seen in tubular bones.
b. Prior to bony maturation, the epiphyseal plate can appear irregular with sclerosis. The periphery of the epiphyses is usually the last to fuse and should not be mistaken for a fracture.

c. Bony grooves or notches can be misinterpreted as a linear fracture. This is not uncommonly seen in the bicipital groove with the humerus in internal rotation.

d. Accessory ossicles can mimic small avulsed bony fragments. Comparison views and the presence of any indirect signs of trauma, such as soft tissue swelling or joint effusion, will help to confirm or exclude a fracture.

**Stress fractures (fatigue)**

This is due to abnormal stress upon bones of normal mineralisation. It is commonly seen in the tibia and the metatarsal bones. The fracture line usually runs transversely across the bone. In the early stage, the fracture may appear as a lucent line or a dense shadow due to trabecular compression and interval callus across the fracture. Lamellar periosteal and endosteal reaction can be seen at a later stage (fig 20.5). The diagnosis can be made on bone scans and serial radiographs. A positive isotope bone scan may be obtained 3–4 weeks prior to appearance of the radiographic abnormality.

---

**Special extremity fractures**

**INTRA-ARTICULAR FRACTURE**

**Bennett fracture**

This is due to forced abduction of the thumb and appears as an oblique fracture involving the proximal articulating surface of the first metacarpal bone (fig 20.6). A small fragment of the first metacarpal bone continues to articulate with the trapezium, while the rest of the bone is dorsally and radially dislocated due to the pull of the abductor pollicis longus muscle. Failure to diagnose and treat intra-articular metacarpal fractures may lead to protracted pain, stiffness, and post-traumatic arthritis due to incongruity of the articular surface.
Barton fracture
This is due to a fall on the outstretched hand. The intra-articular oblique fracture involves the dorsal margin of the distal radius. Occasionally, there may be an associated dislocation of the wrist joint. If the fracture involves the volar surface of the distal radius, it is known as a reverse Barton's fracture. Both varieties are best seen in the lateral projection due to the coronal orientation of the fracture line.

Tibial plateau fracture
Majority of these fractures involve the lateral tibial plateau. Mechanism of injury is due to a twisting or valgus force. The fracture may occasionally not be obvious on the standard AP and lateral projections. Hence, oblique views, or tomography, may be needed to reveal the fracture and to assess its severity (fig 20.7). About 10% of the fractures are associated with ligamentous injury of the knee joint.
Ankle fracture

This fracture is due to either inversion or eversion injuries, or a combination of both mechanisms. The variety of fractures can be classified based on the types of injury or the types of fractures involved. The latter would include an unimalleolar fracture (either the medial or lateral malleolus), bimalleolar fracture, trimalleolar fracture if the posterior tubercle of the distal tibia is involved, or a complex fracture when comminuted fractures of the distal tibia and fibula occur (fig 20.8). Fracture-dislocation can occur when the ankle mortise is disrupted due to associated bone and ligamentous injury (fig 20.9).
Calcaneal fracture
This is the most commonly fractured tarsal bone. The injury is due to a fall from a height and is commonly bilateral. May be associated with spinal fractures, especially of the second lumbar vertebra. The fracture can be classified as extra-articular or intra-articular if it involves the subtalar or calcaneocuboid joint. In an intra-articular fracture, it is important to assess the degree of depression of the posterior facet of the subtalar joint. Measuring the Bohler's angle (diagram 20.1) from the lateral radiograph helps to evaluate depression. However, a CT scan can precisely demonstrate the position of the bony fragment and the extent of the depression at the posterior facet of the subtalar joint (fig 20.10).

NON-ARTICULAR FRACTURE
Four types are discussed:

Colles fracture
This is due to a fall on the outstretched hand. The radial fracture occurs in the distal shaft, usually about 2 cm from the articular surface. The distal fragment displaces dorsally and proximally, giving a "dinner-fork" deformity. There may be an associated fracture of the ulnar styloid process (figs 20.11a & 20.11b).
Smith's fracture

This is usually due to a fall on the back of the hand or a direct blow to the dorsum of the hand. The distal fragment is displaced ventrally with radial deviation of the hand giving a "garden spade" deformity (fig 20.12).
Supracondylar fracture

This is the most common type of elbow fracture in children between the ages of 3 and 10 years. Majority of fractures are due to a fall on the outstretched hand with the elbow hyperextended. The distal fragment is posteriorly displaced (fig 20.13).

Jones fracture

This is a fracture involving the base of the 5th metatarsal bone. The fracture line is transversely oriented as compared to the ossification centre, which is obliquely oriented.
FRACTURES ASSOCIATED WITH INCREASED RISK OF AVASCULAR NECROSIS (AVN)

Scaphoid bone
This is the most common carpal bone to be fractured. The majority occur in the waist followed by the proximal pole and the tuberosity. Associated injuries include perilunate dislocation and radial fracture. Complications of delayed union or non-union increase the risk of osteonecrosis, which commonly affects the proximal fragment (fig 20.14).

Neck of femur
These are intracapsular fractures, which may be subcapital, transcervical or basicervical. Non-union is a common complication of such injury, which can result in osteonecrosis (fig 20.15).

Fracture/Dislocation

Galeazzi
This results from a fall on the outstretched hand with the forearm in pronation, or a direct blow to the dorsolateral aspect of the wrist. It consists of a fracture of the distal third of the radius with associated dislocation of the distal radioulnar joint. The distal fragment is dorsally displaced and angulated. The ulna is both dorsally and medially dislocated (fig 20.16).
Monteggia
This is due to forced pronation of the forearm during a fall or a direct blow to the dorsal aspect of the proximal third of the forearm. It consists of an anteriorly-angulated proximal ulnar fracture associated with anterior dislocation of the radial head.

Transcaphoid perilunate dislocation
This is the most common fracture associated with carpal dislocation. The frontal (AP) projection clearly demonstrates the scaphoid fracture but the lateral view shows the dorsally displaced capitate in relation to the lunate, which remains in articulation with the distal radius—hence the name perilunate dislocation (fig 20.17).

Maisonneuve fracture
There is a fracture of the proximal fibula associated with a tear of the interosseous membrane and the distal tibia fibula syndesmosis. There may also be an associated tear of the deltoid ligament or a fracture of the medial malleolus resulting in widening of the medial joint compartment.

Lisfranc fracture
This commonly occurs after a fall from height or down a flight of stairs. The Lisfranc ligament between the 1st cuneiform bone and the base of the 2nd metatarsal bone is disrupted or avulsed at the site of insertion. There are 2 varieties of injuries, namely, homolateral dislocation of the 1st to 5th metatarsal and divergent lateral displacement of the 2nd to the 5th metatarsal with medial or dorsal shift of the 1st metatarsal bones.
Associated fractures include those of the base of the 2nd metatarsal and less commonly, those of the 3rd metatarsal, 1st cuneiform or the cuboid bones (fig 20.18).
Fig 20.17
AP and lateral views of the wrist demonstrate a displaced transscaphoid fracture with perilunate dislocation.

Fig 20.18
Lisfranc fracture dislocation of the foot.
JOINT SUBLUXATION/DISLOCATION

Joint injuries are commonly seen in the shoulder, wrist, knee and ankle. They can be divided into contusion, sprain, subluxation or dislocation. The joint is subluxed if the articular surface is partially displaced as opposed to complete displacement in dislocation. If a fracture is associated with either dislocation or subluxation, it is classified as a fracture-dislocation/subluxation.

Shoulder dislocation

Anterior dislocation is the most common type of glenohumeral dislocation. This is easily diagnosed on the AP and lateral shoulder views (fig 20.19).

Associated fracture of the posterolateral aspect of the humeral head produces a “hatchet” defect known as the Hill-Sachs lesion. The Bankart lesion which is a fracture of the anterior aspect of the inferior rim of the glenoid is less commonly seen on radiographs. Posterior dislocation is less common but is easily missed on the standard AP radiograph of the shoulder. The humeral head however has a “light-bulb” appearance due to forced internal rotation. Overlapping of the humeral head with the glenoid in a radiograph taken with the glenoid in profile is also diagnostic. Associated compression fracture of the humeral head, giving a double cortical density to the humeral head, can also be demonstrated (fig 20.20).
Wrist dislocation

This is due to a fall on the outstretched hand. Common types are lunate dislocation, perilunate dislocation and transscaphoid perilunate dislocation. The normal alignment of the carpal bones can be demonstrated in the standard AP and lateral views. On the frontal view, Gilula has described 3 arcs outlining the carpal bones. Arc I outlines the proximal articular surfaces of the scaphoid, lunate and triquetrum. Arc II outlines the distal concavities of the same bones. Arc III outlines the proximal convexity of the capitate and lunate (diagram 20.2). In the lateral radiograph, the longitudinal axes of the radius, lunate, capitate and the 3rd metacarpal bone form a straight line (diagram 20.3).
**Epiphyseal plate injury**

This injury is seen in the immature skeleton prior to the fusion of the epiphysis. It can be divided into 5 types based on the Salter-Harris classification.

**Type 1:** Fracture through the growth plate due to shearing force separating epiphysis from physis. The periosteum is usually intact.

**Type 2:** Fracture through the growth plate extending into the metaphysis.

**Type 3:** Fracture through the growth plate extending into the epiphysis.

**Type 4:** Fracture through the growth plate involving the metaphysis and epiphysis.

**Type 5:** Compression fracture through the growth plate due to a crush injury (diagram 20.4).
CHAPTER 21

Fractures—classification, union, complications

Lesley A. Goh & Wilfred C.G. Peh

Classification of fractures

A fracture refers to a break in the structural continuity of the bone. The fractured bone heals by a complex process of bone repair. Complications can arise both as a result of the inciting trauma, as well as during the healing process. Fractures may be broadly classified into complete and incomplete fractures. In a complete fracture, the bone is completely broken into two or more fragments. An incomplete fracture is one where only one side of the bone is broken. Complete fractures may be subdivided into transverse, oblique/spiral, impacted, comminuted, and intra-articular fractures. Incomplete fractures may be divided into greenstick fractures, which are typically seen in children, and compression fractures, which are usually seen in adults. An avulsion fracture occurs when a fragment of bone is torn away from the rest of the bone due to the pull of a strong ligamentous or tendinous attachment and is commonly seen as a result of forcible muscular contractions (fig 21.1). The pattern of some typical fractures are illustrated in the diagrams 21.1a–21.2g.

Fig 21.1
Fracture of the anterior tibial spine resulting from an avulsion injury to the anterior cruciate ligament.

Diagram 21.1
Complete and incomplete fractures:

a. Incomplete fracture—greenstick.
b. Complete fracture.
Diagram 21.2
Types of complete fracture

21.2a Transverse
21.2b Oblique
21.2c Spiral
21.2d Impacted

21.2e Comminuted
21.2f Intra-articular fracture—fracture of capitellum
21.2g Avulsion fracture—avulsion of medical epicondyle
Complete fractures

Complete fractures may be further subdivided by the orientation of the fracture line. Types of complete fractures:

a. Transverse fracture
b. Oblique/spiral: typically due to rotational stress (fig 21.2)
c. Impacted: fracture fragments are jammed tightly together (fig 21.3).
d. Comminuted: more than two fracture fragments which are usually poorly apposed.
e. Intra-articular: fracture involves a joint surface (fig 21.4).
Incomplete fractures

The bone is incompletely divided in these fractures. Types of incomplete fractures are:

Greenstick fractures (fig 21.5)
This type of fracture is commonly seen in children where the bone buckles due to its springy consistency. The periosteum is intact. These fractures are usually easy to reduce and heal well.
Compression fractures (fig 21.6)
These fractures are usually seen in adults and typically involve the vertebral bodies or the calcaneum. Complete reduction is seldom possible and the patient is likely to have a residual deformity.

**Clinical importance of classification**

It is important to classify fractures correctly. This is helpful in determining the likely prognosis and choosing the correct treatment. Fractures can be treated conservatively in a plaster cast or surgically using internal or external fixation. Surgical fixation is usually undertaken when there is failure of reduction, failure to maintain reduction, in open fractures and intra-articular fractures. External fixation is usually done for open fractures with gross contamination.

If the fracture is incomplete as in a greenstick fracture, reduction is usually easy and the child can be reassured that healing is usually quick. In contrast, compression fractures are seldom completely reducible.

Certain fractures are also less stable and correct classification can alert the clinician to fractures at risk of complications of union. Among the complete fractures, transverse fractures are more likely to remain in place following reduction unlike oblique and spiral fractures that have a tendency to displace. Displacement after reduction may give rise to delayed union, malunion or even nonunion. Similarly, comminuted fractures are usually unstable and are less likely to heal in an optimal position as reduction of the fracture fragments is often difficult to maintain. Finally, healing time tends to be longer in certain types of fractures although most fractures should unite by 16 to 18 weeks (table 1). For example transverse fractures take a longer time than spiral fractures to heal. Fractures involving children and the upper limbs (rather than the lower limbs) tend to heal more quickly. Such knowledge is useful when following up a fracture.

**Table 1. Healing times in tubular bones in adults**

<table>
<thead>
<tr>
<th></th>
<th>Upper limb</th>
<th>Lower limb</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early callus</td>
<td>2-3 weeks</td>
<td>2-3 weeks</td>
</tr>
<tr>
<td>Late consolidation</td>
<td>6-8 weeks</td>
<td>12-16 weeks</td>
</tr>
</tbody>
</table>
Special types of fractures

Stress fractures may be divided into insufficiency and fatigue fractures. The main difference is that insufficiency fractures occur in abnormal bone exposed to normal stress while fatigue fractures are seen in normal bone that has been subjected to abnormal repetitive stress. An example of insufficiency fracture would be of that typically seen in elderly patients with osteoporosis. Common fracture sites include the upper tibia, sacrum, ilium and pubic bones. Fatigue fractures occur in people with normal bones and are often seen in a younger age group. The fracture site is related to the nature of the activity producing the abnormal stress (fig 21.7).

Pathologic fractures occur secondary to pre-existing abnormality in the bone, most commonly a bone tumour. The bone is weakened by abnormality and a fracture may follow acute trauma or even normal stress (fig 21.8).

Fig 21.7
Fatigue fracture of the proximal tibia in a patient with severe osteoarthrosis of the knee joint.

Fig 21.8
Pathological fracture through a fibrous dysplasia lesion in the proximal radius.
Union
Bony union occurs as result of a complex process of bony repair that is seen radiographically as callus formation.

Early callus formation
At the early stages, the callus only contains radiolucent fibrous tissue and the fracture line would be seen radiologically. At a slightly later stage, immature callus forms. This typically forms “a soft cotton-wool appearance”. The callus may be seen to bridge the fracture though the fracture line remains visible even when clinical union has occurred. There is no motion at the fracture site under stress.

Late consolidation
The soft callus is gradually converted into hard mature bone. This is the late consolidation stage and radiographic consolidation is said to have occurred when the bony callus is seen to bridge the fracture and obliterate the fracture line. Bone remodelling follows. The marrow cavity eventually becomes continuous and the cortices are reformed.

Complications
Complications arising from fractures may be systemic or localised to the fractured bone, adjacent soft tissue or joints. Local complications involving bone include: complications of union, infection, avascular necrosis, reflex sympathetic dystrophy and growth disturbances in children when the growth plate is involved.

Non-bony local complications may involve the soft tissue and adjacent joints. Among the soft tissue injuries, trauma to the vessels adjacent to the fracture site, compartment syndrome as well as injury to nerves and adjacent viscera are among the more commonly encountered conditions.

Complications involving the joints include haemarthrosis and joint stiffness due to oedema and fibrosis. Post-traumatic osteoarthritis can result from damage to the articular cartilage and joint surface or to abnormal stress subsequent to malunion of a shaft fracture.

Complications of bony union
Bony union usually occurs within 16 to 18 weeks depending on the age of the patient, the fracture site and the type of fracture. Complications of union are delayed union, non-union and malunion. Certain fractures such as oblique fractures and comminuted fractures are less stable. Therefore correct classification is important. Early diagnosis allows the cause to be determined and correct treatment to be instituted before there is permanent disability.

- Delayed union
  The fracture fails to unite within a reasonable amount of time (16–18 weeks). Possible causes are inadequate blood supply, infection, insufficient splintage and excessive traction. Failure to diagnose and treat delayed union at its early stages may lead to non-union.

- Non-union
  The fracture fails to unite. Causes of delayed union may also cause non-union. Interposition of soft tissue between the fracture fragments may also prevent bone union. Radiographically, the fracture ends are separated by a gap. Motion between the two ends may be demonstrated under fluoroscopy or between consecutive stress films.
CHAPTER 21. FRACTURES—CLASSIFICATION, UNION, COMPLICATIONS

There are two main types of non-union: reactive and nonreactive.

- **Reactive/hypertrophic**: exuberant bone reaction with hypertrophy and sclerosis of the bone ends, and abundant callus is present (fig 21.9).

- **Nonreactive/atrophic**: bone ends are atrophic, have a tapered appearance and there is a lack of surrounding callus (fig 21.10).

Conservative treatment may not produce union and surgical fixation is therefore needed. In a hypertrophic pseudarthrosis, stabilization of the fracture is often all that is required as potential for healing is still present, while in an atrophic nonunion, stabilization in combination with additional bone grafting is required to stimulate bone healing.

- **Malunion** (fig 21.11)
  The fracture fragments join in an unsatisfactory position. This may occur when the fracture is not reduced adequately or if the fracture reduction is not maintained during healing. Angulation in a long bone may result in obvious deformity, limb shortening and osteoarthritis of the adjacent joints. An osteotomy can be performed in cases of malunion to prevent premature deterioration of the joint and subsequent osteoarthritis but this only possible if malunion is recognised and treated early.
Infection

Wound infection may complicate open fractures or surgically treated fractures. Osteomyelitis needs to be recognised and treated early as it can lead to inadequate healing. This results in delayed union or non-union. Radiographically there is soft tissue swelling, bony destruction associated with periosteal new bone formation, rarefaction and sequestration of non-viable bony fragments.

Avascular necrosis (fig 21.12)

Avascular necrosis occurs when the bone dies due to lack of blood supply. The fracture fails to unite and the ischaemic bone may collapse. This typically manifests radiographically as areas of rarefaction and sclerosis. Certain fractures are particularly associated with avascular necrosis. Careful follow-up of these fractures enables early diagnosis and treatment. These fractures are listed below:
Site of fracture | Site of avascular necrosis
---|---
Femur-neck | Femur-head
Scaphoid-waist | Scaphoid-proximal fracture fragment
Talus-neck | Talus-body
Humerus-neck | Humerus-head

**Growth disturbances**
This is seen in children. Fractures which cross the epiphyseal growth plate may lead to abnormal growth. If only part of the growth plate is damaged then this may lead to asymmetrical growth, resulting in angulation. If the entire growth plate is involved, there may be premature fusion and cessation of growth resulting in limb length discrepancy.

**LEARNING POINTS: FRACTURES**
- **Fractures**—may be treated conservatively or surgically depends on the type of fracture, hence need for correct radiological classification
- **Fracture**—complete-transverse, oblique, spiral, impacted, comminuted
  - incomplete-greenstick, compression
- **Complications**—systemic
  - local-bone, soft tissue, joints
- **Complications of union**—delayed union (bone fails to unite in 16-18 weeks)
  - non-union (fails to unite)
  - malunion
  Important to identify abnormal union and its cause (mechanical, blood supply, infection) and institute appropriate treatment promptly.
- **Other local complications** involving bone also benefit from early diagnosis and treatment.
  - infection
  - bony destruction, sequestra, soft tissue swelling
  - avascular necrosis
  - areas of patchy rarefaction and sclerosis
  - typical sites
  - femoral head, scaphoid, talus
  - reflex sympathetic dystrophy
  - patchy, rapidly progressive rarefaction
  - growth disturbances
  - angulation, cessation of growth
CHAPTER 22

Spinal trauma

Wilfred C.G. Peh

Biomechanics and classification

Spinal trauma is conventionally classified based on the mechanism of injury. These mechanisms include flexion, extension, rotation, compression, distraction and shear forces and often, a combination of these forces. In general, the vertebral end-plates are vulnerable to compression forces while supporting ligaments are prone to damage by rotation and shear forces. The resulting injuries produced by these forces may be further classified into stable and unstable categories.

The concept of stability is controversial with the definition of clinical instability being generally accepted as being the inability of the vertebrae to maintain their relationships such that spinal cord and nerve root damage are avoided, and deformity and excessive pain do not develop. Although instability is regarded as a clinical concept, radiological imaging has a useful role in demonstrating signs that support the clinical diagnosis of spinal instability. In the "three-column theory", disruption of two out of three columns is highly suggestive of instability. The anterior column consists of the anterior longitudinal ligament, anterior disc annulus and anterior vertebral body. The middle column consists of the posterior vertebral body, posterior disc annulus and posterior longitudinal ligament while the posterior column comprises all the bony and ligamentous structures posterior to the vertebral body (diagram 22.1).

Radiographic projections

The initial routine examination for the traumatised spine consists of conventional radiographs in the anteroposterior and lateral projections. The lateral projection is done at a FFD of 180cms. An open-mouth radiograph to show the C1/2 vertebrae should be added for symptomatic patients with neurological signs or symptoms of cervical injury or for patients with impeded consciousness or head injury. It is essential not to move the patients head or neck to avoid inadvertent spinal injury. All seven cervical vertebrae should be included on the lateral radiograph. Special projections such as a swimmer’s view should be performed if the C7/T1 junction cannot be visualised (figs 22.1a & 22.1b). Flexion and extension radiographs are useful in symptomatic patients in which ligamentous injury is suspected and where standard radiographs are normal. Radiographs may be supplemented by specialised modalities such as tomography, computed tomography (CT), myelography, CT myelography and magnetic resonance imaging.
Interpretation of cervical spine radiographs

The lateral cervical spine radiograph is the single most useful projection. Obvious fractures or dislocation may need further characterisation by CT or tomography if available. More subtle injuries may be detected by systematic radiographic evaluation, enhanced by knowledge of the mechanism of injury. The 5 spinal “lines” to be assessed (diagram 22.2) are as follows:

- Initial lateral radiograph demonstrates C1-6 only (a). Repeat radiograph with the shoulders pulled down reveals a C6/7 bilateral facet dislocation. A C6 clay shoveller’s fracture is also present (b).
Line 1: Pre-vertebral soft tissue line.
Pre-vertebral haematoma resulting from vertebral body or ligamentous injuries may produce a soft tissue swelling. Anterior to the upper four cervical vertebrae, the maximum pre-vertebral soft tissue width is 5 mm while in the lower cervical spine, the soft tissue width should not exceed the anteroposterior width of the adjacent vertebral body.

Line 2: Anterior spinal line.
This line links the anterior cortices of the cervical vertebral bodies, and should form a smooth gently curved line.

Line 3: Posterior spinal line.
This links the posterior cortices from the cervical vertebral bodies, and should form a smooth gently curved line.

Line 4: Spinolaminar line.
The line links the junctions between the laminae and base of the spinous processes of the cervical vertebrae. It should form a smooth curved line.

Line 5: Spinous process.
The spinous process should be examined for the presence of fractures.

Spinal trauma patterns
These may be classified according to anatomical region, mechanism of injury and stability. A few distinctive types of fractures are listed and illustrated.

Cervical spine: Jefferson fracture
This fracture results from axial loading of C1 vertebra. Jefferson fracture consists of ipsilateral disruption of both the anterior and posterior C1 arches. The injury may be unilateral or bilateral. This injury is best seen on the open mouth radiograph where there is lateral displacement of the lateral masses of the atlas (C1) relative to those of the axis (C2) (fig 22.2). CT is useful for confirming the fracture.
Cervical spine: Odontoid fracture

The mechanism of injury of the odontoid fracture is not well understood. There are three types:

**Type 1** odontoid tip fracture (stable)

**Type 2** fracture at junction of the odontoid peg and C2 body (unstable)

**Type 3** fracture through C2 body extending into cancellous bone (stable)

Type 2 fractures are associated with non-union hence the importance of recognising the odontoid fracture types. Fractures of the odontoid are best demonstrated on the open mouth radiograph. This fracture may be difficult to see on the lateral radiograph if it is undisplaced. Tomography is useful for detection and characterisation of odontoid fractures (fig 22.3).

![Fig 22.3](image)

Odontoid peg fracture. Lateral radiograph shows forward displacement of the odontoid peg with disruption of the anterior and posterior spinal lines and spinolaminar line (a). Lateral tomogram shows a type 2 fracture optimally (b).
**Cervical spine: Hangman’s fracture**

This fracture is due to vertical compression and hyperextension. It consists of bilateral avulsions of the neural arches from the vertebral body, and is also known as traumatic spondylolisthesis (fig 22.4). This injury is best seen on the lateral radiograph, particularly if there is fracture displacement. Associated C2/C3 posterior element retrolisthesis is often present.

**Cervical spine: Clay shoveler’s fracture**

This fracture results from avulsion by the infraspinatus ligament due to hyperflexion. It refers to an oblique fracture of the C6 or C7 spinous process. This injury is stable and is of no clinical significance (fig 22.5).

**Cervical spine: Flexion teardrop fracture**

This fracture is due to combined flexion and axial loading. It typically involves the lower cervical spine. The affected vertebral body is divided into a smaller anteroinferior fragment (teardrop) and a larger posterior fragment. The teardrop fragment remains aligned with the vertebral body below while the posterior fragment is displaced posteriorly but remains aligned with the upper cervical vertebrae. Associated posterior structural injuries may be seen as interspinous widening, facet widening and lumbar fractures (fig 22.6). This unstable injury produces the anterior cord syndrome.
CHAPTER 22. SPINAL TRAUMA

Cervical spine: Bilateral facet dislocation (or lock)
This injury occurs secondary to severe hyperflexion. The inferior articular processes of the superior vertebra are dislocated and locked anterior to the superior articular processes of the inferior vertebra. On the lateral radiograph, the superior vertebra is anteriorly displaced greater than half the width of the vertebral body (fig 22.7).

Cervical spine: Unilateral facet dislocation (or lock)
This injury results from a combination of flexion and rotation. Due to interspinous ligament and facet joint capsule rupture, the inferior articular process of the superior vertebra dislocates and locks anterior to the superior articular process of the ipsilateral...
inferior vertebra. On the lateral radiograph, the superior vertebral body is anteriorly displaced, typically one third or less than the width of the vertebral body width. There is abrupt rotation of the facet joints at the level of the injury, producing the "bow-tie" sign. The anteposterior radiograph may show rotation of spinous processes at the site of the dislocation. Oblique radiographs are useful in confirming the fracture dislocation (figs 22.8a & 22.8b).

**Upper thoracic fractures**

Fractures affecting the upper 4 thoracic vertebrae are uncommon but when they occur, are usually due to major traumatic forces. The characteristic injury is a fracture-dislocation involving two adjacent vertebrae. There is typically an associated facet joint disruption, anterior displacement of the superior vertebra and a compression fracture of the superior end-plate. The components of these complex injuries, namely: malalignment, degree of displacement and spinal canal compromise, is best assessed on CT.
Thoraco-lumbar spine: Chance fracture

This fracture (also known as seatbelt fracture) is due to a hyperflexion force with the fulcrum of motion located anteriorly at the level of the anterior abdominal wall. This force results in compression of the vertebral body and distraction of the posterior body and ligamentous structures, typically at the thoraco-lumbar junction. On radiography, a horizontal fracture extending transversely through the body, pedicles and posterior elements is seen. As all three columns are disrupted, this fracture is unstable (figs 22.9a & 22.9b).

Fig 22.9a & 22.9b
Chance fracture through L2 vertebra (arrows).
**Burst fracture**
This fracture results from axial loading of the vertebral body combined with flexion. Centripetal vertebral body disruption produces posterior displacement of the posterior vertebral margin and loss in height of the posterior vertebral body. There may be associated fractures of the posterior elements. The fractures typically occur at the thoracolumbar junction and are often associated with deficit. CT is the best method for showing the presence of posterior element fractures and retropulsed bony fragments.

**Wedge compression fracture**
This may occur anywhere in the spine and is due to a flexion force with the fulcrum located within the vertebral body. The typical simple wedge compression fracture results in loss of anterior vertebral body height with preservation of the middle and posterior columns. These fractures are stable and are commonly encountered in the osteoporotic spine (fig 22.10).

**LEARNING POINTS**
- Spine trauma may result in spinal cord and nerve root damage and should be diagnosed promptly.
- Radiological imaging is useful in demonstrating signs that support the concept of instability.
- Radiographs, especially those of the lateral cervical spine, should be interpreted in a systematic manner.
- The types of spinal fractures or dislocations are generally classified according to the predominant mechanism of injury.
CHAPTER 23

Facial and pelvic trauma

Swee-Tian Quek & Wilfred C.G. Peh

Introduction

Facial and pelvic injuries are commonly encountered with patients with multiple injuries. Due to the complex anatomy of these areas, there is often superimposition of the bony structures on the radiographs rendering radiographic assessment challenging. As a result of this, cross-sectional imaging by CT is often useful in the further evaluation of these injuries.

Facial trauma

Radiographic assessment of facial trauma can be daunting due to the complex anatomy of this region as well as the number of different projections available for evaluation. The projections employed depend largely on the suspected pathology although routinely this usually includes at least an occipitomental (OM) or (Waters) and a lateral view. Of particular importance is the OM view (fig 23.1) where a number of lines have been described to aid assessment of the bony structures (diagram 23.1).

Diagram 23.1

OM view.

Trace McGrigor's lines.

Line 1 crosses the zygomaticofrontal suture to run along the superior orbital margin and across the frontal sinus to the opposite side.

Line 2 runs along the superior border of the zygomatic arch and follows the inferior orbital margin and superior contour of the nose to the other side.

Line 3 follows the inferior border of the zygomatic arch down the lateral wall of the maxillary sinus and across the maxilla to the opposite side.

Look for breaks in the continuity of these lines or opacification of the sinuses where they cross as clues to facial fractures.
Nasal fracture

This is the most common facial fracture. Imaging is however not required for routine clinical management. Where indicated, the lateral nasal and OM views are helpful. It is important to specifically request for the lateral nasal view (figs 23.2a & 23.2b) rather than rely solely on the routine lateral skull radiograph as the latter tends to be too overpenetrated for proper assessment of nasal fractures.
Fractures are clearly seen as a break in the bony cortex. Sometimes however, suture lines or vascular markings may be confused with a fracture. In general, fracture lines tend to be more radiolucent and more clearly defined than suture or vascular grooves. Furthermore the latter do not extend into the nasal ridge.

**Mandibular fracture**

Radiographic evaluation for mandibular fractures may include PA (postero-anterior) and lateral oblique views, reverse Towne's view and a pantomography. Although the latter is often regarded as the best view in the assessment of mandibular injuries, it has its limitations in the emergency setting. It requires the patient to sit or stand still during the exposure and hence cannot be used for the unconscious or the critically ill patient who cannot keep still. Furthermore, the equipment required for the examination may not be available in the emergency department. Fractures of the mandibular body and symphysis are often easily diagnosed on the PA view while fractures of the ramus and mandibular angle are usually better seen on the lateral oblique view. Condylar or subcondylar fractures which not uncommonly occur in combination with fractures of the body and symphysis (fig 23.3) may be difficult to detect on routine PA and lateral oblique views especially if undisplaced and are often better assessed on the reverse Towne's or panoramic views. In addition to identification of the fracture, it is also important to assess displacement of the fractured segments and note possible involvement of the teeth and inferior alveolar canal by the fracture as these factors have bearing on the clinical management.
Fig 23.3
Mandibular fractures. The fracture of the body is well visualised on the PA view but the left condylar fracture is more subtle and may be better demonstrated on a panoramic or reversed Towne's view.

Zygomatic and malar fractures
The classical malar or tripod fracture involves the zygomatic arch and the orbital process of the zygoma. It extends to the lateral wall of the orbit, the orbital floor and the lateral maxillary wall (fig 23.4). This is again best assessed on the OM view where the findings include fracture of the zygomatic arch, diastasis of the zygomaticofrontal suture, a step deformity of the infraorbital margin and opacification or an air-fluid level in the maxillary sinus due to haemorrhage within it. Isolated zygomatic arch fractures can also occur and are usually the result of a direct blow posterior to the malar prominence. This is usually seen on the OM or submento-vertical (SMV) view (fig 23.5).

Fig 23.4
Tripod fracture. Note the fracture lines. The orbital floor fracture is not as well seen but there is secondary evidence of the fracture with opacification of the right maxillary sinus.

Fig 23.5
SMV view of a left zygomatic arch fracture.
Maxillary fracture

Maxillary fractures have been traditionally divided according to the level of the fracture for convenience and classified by the Le Fort system (diagram 23.2):

- **Le Fort I** (low transverse) fractures are horizontal fractures through the maxilla that separate the alveolar segment of both maxillae and leave the orbits and nose intact.

- **Le Fort II** (pyramidal) fracture are fractures that cross the nasal bridge and extends across the orbits and lateral maxillary walls to the pterygoid plates.

- **Le Fort III** (high transverse) fractures are fractures that extend from the orbital floor to the lateral maxillary wall and separates the facial skeleton from the cranium.

Although these fractures can be assessed on the OM and OF (occipital-frontal) views, further imaging by CT is often helpful in the preoperative evaluation.

Orbital fracture

These may represent isolated orbital injuries or be associated with other more complex fractures e.g. tripod or Le Fort fractures.

Blow-out fractures are the result of direct trauma to the orbit causing it to fracture at its weakest points namely the thin orbital floor and its medial wall. The OM view is useful in detecting these fractures.

Radiographic findings include:

1) a break in the cortex of the orbital floor or rim,

2) herniation of the orbital contents e.g. inferior rectus muscle through the orbital floor fracture into the roof of the maxillary sinus (teardrop sign),

3) opacification or an air-fluid level in the maxillary sinus, and

4) intra-orbital emphysema due to air entering the orbit through the maxillary or ethmoid sinus (fig 23.6).

Fractures of the superior orbital rim require a significant amount of force as these involve thick cortical bone. They are therefore frequently associated with other injuries such as fractures of the frontal sinus or anterior cranial fossa. While they may be visualised on the standard OM, PA and lateral views, they sometimes require additional views such as oblique or tangential view to better demonstrate the injury. As with maxillary fractures, the true extent of the injury may be difficult to assess on radiographs alone and further evaluation with CT may be required.
Pelvic fractures

The spectrum of pelvic fractures ranges from avulsion injuries to more severe life-threatening ones. They can be broadly classified into stable and unstable injuries. Identification of the type of injury is important as the key issue in their management revolves around the stability of the fracture. The routine radiographic projection for assessment is the AP view.

- **Stable fractures** are those which:

  1) do not involve the pelvic ring e.g. avulsion fractures (fig 23.7), isolated fractures of the iliac wing (fig 23.8) or
2) involve the ring but result in little bony displacement (fig 23.8) leaving the soft tissues largely intact. Usually these fractures involve the pelvic ring in only one place.

- **Unstable fractures** are generally those which involve the pelvic ring in two or more sites. Depending on whether there is significant disruption of the posterior sacroiliac ligamentous complex, these can be further subdivided into fractures which are rotationally unstable but vertically stable (partially stable fractures) or those which are both rotationally and vertically unstable (fig 23.9).

Pelvic fractures are an important group of injuries to diagnose and manage both in terms of mortality and morbidity. It is pertinent to remember that the pelvis does not merely comprise of a number of bones but also contains many major vessels as well as a number of important viscera and damage to these structures may be as important as or even more important than the bony injuries sustained. These associated injuries should be therefore carefully sought for and managed.

**Acetabular fractures**

Several classification systems have been proposed. Whichever system is used, proper fracture assessment requires good quality radiographs with AP and two oblique (Judet) views. CT is also often employed to better demonstrate the fracture pattern as well as look for intra-articular involvement or loose bodies. Accurate classification is important in determining which patients will benefit from surgical intervention (fig 23.10).
### KEY LEARNING POINTS: FACIAL AND PELVIC FRACTURES

**Facial fractures**
- A number of projections are available. In general, the OM view is particularly useful.
- In the OM view, follow McGrigor’s lines. Also look for fluid/opacification of the sinuses and for intra-orbital emphysema.
- Imaging nasal fractures is not usually required for clinical management
- CT is often useful in the further evaluation of the more complex fractures. Remember the review areas on the OM skull radiograph.

**Pelvic fractures**
- Often associated with other injuries which must be actively sought for and managed
- Recognise stable fractures; everything else is unstable!
Bone infection is a common cause of morbidity in many developing countries. Diagnosis of osteomyelitis is often delayed resulting in persistent infection and disability especially in children. For effective treatment early diagnosis is essential. Plain film radiography is usually normal in early acute bone infection. Over-reliance on radiography without examining the patient carefully can lead to a delay in diagnosis.

Osteomyelitis

Bone infection is particularly common in the 5-15 year age group. Infection usually follows blood borne spread from a focus of infection elsewhere especially from the skin or lung. In childhood a long bone, such as the femur, is the commonest site of infection, while in adults the spine is more commonly involved. Staphylococcus aureus is the most common organism in children, followed by streptococcal and haemophilus influenzae. In neonates streptococcal and E coli infection are common. With patients who are immunosuppressed gram negative organisms, tuberculosis and fungal infection can occur. Osteomyelitis is more common in children because of the excellent blood supply to the metaphyseal regions of long bones. In the metaphysis infection starts in the bone contiguous to the growth plate where blood flow is slow. Abscess formation and bone marrow oedema causes the infection to penetrate the cortex and elevate the adjacent periosteum. Bone necrosis follows thrombosis of the metaphyseal arteries and stripping of the periosteum by the abscess.

The first radiographic signs are soft tissue swelling and effacement of tissue planes adjacent to the focus of bone infection that appears after 3 days. Periosteal reaction and bone destruction is detected as lytic “holes” (permeative pattern) in the bone appear after 10 days. Necrotic cortex forms sequestra that are bony debris detached from the live bone. The dead bone is a culture medium for infection (fig 24.1). With bone necrosis, there is an attempt at healing and new bone formation from the periosteum. This is called involucrum (fig 24.2). It is important to remember that osteomyelitis may mimic malignant long bone sarcomas in children, especially Ewing’s sarcoma and osteosarcoma.

In the chronic phase of osteomyelitis a localised abscess can become walled off in the bone. This is called a Brodie’s abscess. The Brodie’s abscess appears as a localized lucency in the metaphysis with sclerotic borders (fig 24.3).
**Fig 24.1**
Child with acute osteitis demonstrating periosteal reaction, cortical destruction, and permeative lytic destruction of the right femur.

**Fig 24.2**
Infant with chronic osteitis of the femur with extensive new bone formation (involucrum).
CHAPTER 24. BONE INFECTIONS

Septic arthritis

Septic arthritis is a very important diagnosis to make in children where the hip and knee joints are most commonly affected. Delayed diagnosis will result in a destroyed joint and life long disability. The infection is usually due to staphylococcus aureus or haemophilus influenzae. Spread is usually blood borne to the synovial lining of the joint and then into the synovial fluid and cartilaginous epiphysis. Infection rapidly destroys the epiphyseal cartilage. On radiographs soft tissue swelling around the joint is noted initially with a joint effusion (fig 24.4). As the cartilage is destroyed there is joint space narrowing and articular erosions. There is usually an associated osteitis. In the chronic phase bony ankylosis will be noted.

Tuberculous arthritis

Tuberculous arthritis occurs in large joints especially the hip joint, but also in the sacroiliac joints. Granulomatous infection starts in the synovium. Initially focal osteopaenia (decreased bone density compared to the opposite normal hip) and soft tissue thickening around the joint are detected on plain radiographs. As the disease progresses, articular cartilage destruction occurs with joint space narrowing and irregularity of the joint margins (fig 24.5). The sacro iliac joints are commonly involved with erosion of the joint margins and joint space widening (fig 24.6). In children a cystic form is not uncommon involving the metaphyses of long bones. Dactylitis (spina...
ventosa) occurs in childhood with fusiform swelling of the phalanges with periostitis. With AIDS patients multifocal skeletal involvement is common.

**Infective spondylitis**

The clinical diagnosis of spinal inflammatory disease is often delayed as the symptoms and signs are non-specific. Imaging therefore has an important role in diagnosis.

**Pyogenic discitis and spondylitis**

Pyogenic infections, especially staphylococcus aureus, spread via the blood from other foci of infection in the body such as the skin to the vertebral body end plates and the intervertebral discs (in children). Intervertebral discs are well vascularised in children and are far more susceptible to infection than in adults. There may be a history of a
recent surgical procedure in adults, such as cystoscopy, particularly if gram negative organisms such as E coli, pseudomonas or proteus are detected. Diabetics and patients who are immunosuppressed (HIV, on steroids) are more susceptible to infection. Clinical symptoms of non-specific backache and fever may be present.

Initially the radiographs are normal for the first week, although Tc99m isotope bone scans are positive. In the second and third week erosion of the subchondral bone and destruction of the disc occurs with loss of disc height (fig 24.7). There may be paraspinal soft tissue swelling or rarely an abscess. After 2 to 3 months regenerative osteoblastic response occurs and sclerosis dominates. Isolated intervertebral disc involvement in children is not uncommon and although the infected disc does not often culture any organisms, staphylococcus aureus is the most likely cause.

**Tuberculous spondylitis**

Spinal tuberculosis is extremely common in sub-Saharan Africa and is endemic in South Asia. It represents 50% of all bone and joint cases of TB. The common sites of involvement are the thoraco lumbar spine, followed by the cervical spine and lower lumbar spine. Infection starts in the anterior subchondral region of the vertebral body end plate where there is initial lysis and erosion of the cortical margin. The intervertebral disc is infected relatively late compared to pyogenic infection of the disc. The anterior and posterior longitudinal ligaments are displaced by abscess produced by the infection resulting in spread of infection to adjacent vertebral bodies. Pus spreads posteriorly to displace the dura in the extradural space with resultant spinal cord compression. Plain radiographs demonstrates bony erosion of the vertebral end plates, followed by disc space narrowing (fig 24.8). As the longitudinal ligaments become involved angulation and gibbus formation occurs. Posterior element involvement is uncommon, occurring in approximately 10% of patients. With patients with HIV infection, multifocal spinal tuberculosis is often found together with foci in other organs.
Brucellosis

Brucellosis is an important cause of spondylitis especially in the Middle East. The cause is brucella melitensis which is an intracellular infection and very difficult to culture or to detect on biopsy. The lower lumbar spine and sacroiliac joints are commonly involved. Infections start in the vertebral end-plates with contiguous disc destruction. Plain radiographs demonstrate vertebral end plate erosion, sclerosis with prominent anterior osteophytes in the healing phase. Soft tissue paravertebral abscess formation is uncommon unlike tuberculosis.

<table>
<thead>
<tr>
<th>LEARNING POINTS: BONE INFECTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Osteomyelitis common involves the metaphyses of long bones of children</td>
</tr>
<tr>
<td>• Radiographs are normal for the first three days following infection</td>
</tr>
<tr>
<td>• Early signs of osteomyelitis are soft tissue swelling and loss of tissue planes</td>
</tr>
<tr>
<td>• Periosteal reactions are detected at 7 days</td>
</tr>
<tr>
<td>• Brodie’s abscess is a localised osteitis</td>
</tr>
<tr>
<td>• Septic arthritis is common in the hip and knee joints of infants</td>
</tr>
<tr>
<td>• Joint space widening and displaced tissue fat planes are the first sign of septic arthritis</td>
</tr>
<tr>
<td>• Pyogenic spondylitis is more common in diabetic and immunosuppressed patients</td>
</tr>
<tr>
<td>• Tuberculous spondylitis is more common in the vertebral end-plates of the thoracolumbar spine</td>
</tr>
<tr>
<td>• Multifocal tuberculous involvement is common in patients with AIDS</td>
</tr>
</tbody>
</table>
PART 4

GASTROINTESTINAL AND URINARY TRACT PATTERNS
Interpretation of plain abdominal radiographs is often difficult, but as with reading chest radiographs, a systematic approach is helpful. A good knowledge of the radiographic anatomy is essential.

**Radiographic anatomy (fig 25.1)**

The abdomen extents from the diaphragm to the pelvis. Only the stomach and colon normally have intraluminal air. The small bowel normally does not have any air within it. Air fluid levels are normal in the stomach, duodenum and colon however it is unusual to have air fluid levels in the small bowel. The liver, gall bladder and spleen are intra-peritoneal solid organs that are located in the right and left subcostal regions respectively. The retroperitoneum contains the kidneys and perirenal fascia, the adrenal glands, lymph nodes, the pancreas, the aorta, inferior vena cava, and psoas muscles.

**Interpretation of the abdominal radiograph**

With the application of ultrasound and CT scanning, investigation of the abdomen has become much easier. However the plain abdominal radiograph remains an extremely useful imaging investigation especially in patients presenting with an acute abdomen.

- **Assess quality**: correct patient name, good exposure, without rotation and anatomical marker (L or R) on the film. An abdominal series will include a supine (AP) radiograph. To detect fluid levels a decubitus abdomen or an erect abdomen is required. To detect free intraperitoneal air an erect chest is useful or a left side down decubitus abdomen.

- **Assess bowel gas pattern**: normally the stomach and large bowel contain gas. The only normal fluid level is in the stomach and occasionally in the proximal duodenum.

- **Determine position of the stomach in the left upper quadrant and the colon “frames’ the edges of the abdomen in the supine film**. In the erect film, colon is attached by the hepatocolonic and phrenicocolic ligaments at the hepatic and splenic flexures respectively that are constant.

If there is gas in the small bowel or small bowel dilatation is suspected a **decubitus or erect film of the abdomen** to demonstrate fluid levels is recommended.

The jejunum is dilated if >3.5 cm diameter, mid small bowel if >3 cm diameter and the
ileum if >2.5 cm diameter. Dilated jejunum has valvulae coniventes or folds transversely across the diameter of the jejunum.

If the colon appears dilated check for the presence of haustra to confirm that it is the colon dilated. Haustra interdigitate and do not cross the diameter of the colon unlike the valvulae coniventes in the jejunum. The colon is dilated if the transverse colon diameter >5.5 cm or the caecal diameter at its base >8 cm.

Check the psoas outlines bilaterally: should be symmetrical with slightly concave lateral borders.

Check the renal outlines that should normally be 10–12 cm long or 3.5 vertebrae in longitudinal length.

Check the outline of the liver and spleen. The inferior border of the liver is well defined especially laterally.

Check for free intraperitoneal fluid or collections. The properitoneal fat line is displaced laterally by free fluid.

Look for radiopaque calculi and calcification in the region of the gall bladder, kidneys and ureters. Beware of pelvic vein phleboliths that may be confused with calculi. Phleboliths are oval, smooth and have a small internal lucency. Calculi appear dense with irregular margins. Pancreatic calcification is stippled and crosses the midline in an oblique axis. Vascular calcification is commonly seen in the aorta of older patients, diabetics and patients with aortitis from takayashu’s disease.

Look for soft tissue masses and extraluminal gas.
The supine AP abdomen and erect chest radiographs are the best imaging investigation of the acute abdomen. The erect abdomen is used for detecting fluid levels, although it can be replaced by a decubitus view if the patient is too ill to stand. **Plain radiographs are useful in detecting:**

- free intraperitoneal air
- retroperitoneal and intramural gas
- small and large bowel obstruction
- radiopaque calculi
- detect soft tissue masses and free fluid

**Free intraperitoneal air pattern** (figs 26.1a & 26.1b)

The erect chest radiograph and left side down decubitus abdomen radiograph are very sensitive for detecting small volumes of free intraperitoneal air (<5 mls). The commonest causes are: bowel perforation from penetrating ulcers or trauma, and bowel wall infarction.

On the erect chest a crescent of air is noted under the hemidiaphragm. It is important not to confuse subdiaphragmatic air with subpulmonic pneumothorax. If you are unsure whether there is free intraperitoneal air, a left side down decubitus view of the upper abdomen will demonstrate free air as a low density crescent lateral to the lateral margin of the right lobe of the liver. On the supine abdomen detection of free air can be difficult. There are two signs that can help: Rigler’s sign of gas on either side of the

**Fig 26.1a**

Supine abdomen demonstrates free intraperitoneal air. Note the falciform ligament in the right upper quadrant, and the visualization of both sides of the bowel wall centrally.
bowel wall, and the sign of outlining the falciform ligament of the liver in the right upper quadrant by free air.

**Intramural gas pattern** (fig 26.2)

Gas in the bowel wall appears as linear lucencies within the wall. It is usually from bowel wall infarction. In premature babies intramural gas is detected in necrotising enterocolitis (NEC). Often these neonates also have gas in the portal veins.
Gas outside the bowel (fig 26.3)

Gas may be detected in the wall of the gall bladder in emphysematous cholecystitis and in the gall bladder lumen if there is a fistula with the bowel or if there has been an anastomosis with the biliary tree.

Gas in the renal parenchyma is caused by empysematous pyelonephritis. This is usually due to a severe E coli infection of the kidneys in diabetics.

Bowel obstruction pattern

The diagnosis of bowel obstruction is made clinically and confirmed by plain film radiographs. Supine, erect or decubitus abdomen views are usually required. With small bowel obstruction, the commonest causes are adhesions from previous surgery or peritonitis, followed by small bowel tuberculosis, appendicitis and tumours. Normally the small bowel is not visualised and there are no fluid levels present. With obstruction there is dilatation of the bowel with fluid and gas- the jejunum has valvulae convinentes while the ileum is featureless (fig 26.4a). On the erect or decubitus radiograph multiple fluid levels are present. Occasionally the obstructed bowel contains only fluid and no gas and the diagnosis can be missed. In such cases give the patient 50mls of diluted water-soluble contrast agent orally. This will opacify dilated bowel and confirm the diagnosis (fig 26.4b).

In large bowel obstruction, the commonest cause is carcinoma of the colon, followed by inflammatory strictures and sigmoid volvulus. The colon can be identified because the haustra do not cross the lumen like valvulae convinentes of the jejunum. Usually the level of obstruction can be detected on decubitus films or a single contrast barium enema. In sigmoid volvulus there is disproportionate dilatation of the sigmoid colon with a twist (volvulus) at the rectosigmoid junction. On barium enema there is “bird of prey” appearance to the obstruction (figs 26.5a & 26.5b).
Fig 26.4a
Small bowel obstruction from adhesions. Note dilated jejunum with valvulae coniventes centrally. Calcification of the bladder noted from schistosomiasis.

Fig 26.4b
Small bowel study confirms the site of the adhesive obstruction (arrow).
**Paralytic ileus**

Paralytic ileus is generalised bowel dilatation with multiple fluid levels. Paralytic ileus is found post abdominal surgery, trauma, infection, metabolic states and certain drugs. It is particularly common in children following severe gastroenteritis.

**Cholecystitis**

Acute inflammation of the gall bladder is usually due to calculi obstructing the cystic duct. On plain film radiographs radiopaque calculi are detected in approximately 20% of patients (fig 26.6). Ultrasound is usually diagnostic: a distended gall bladder >4 cm diameter, gall bladder wall thickening >4 mm, fluid around the gall bladder and echoes from calculi. Non-calculous cholecystitis is found in ill patients in high care settings, ICU, burns, parenteral nutrition but the cystic duct remains patent on HIDA scan.
Pancreatitis

In acute pancreatitis a generalised or localised ileus is found. If there is an abscess or phlegmon a localised mass is detected. In chronic pancreatitis localised calcification is noted along the duct system of the pancreas (fig 26.7). Complications of acute pancreatitis include abscess formation, haemorrhage, pancreatic necrosis, pseudocyst formation and biliary obstruction.

Abdominal collections and abscesses

Abscesses appear as soft tissue masses which may contain gas. Abscesses can be confused with the colon patterns on plain films. Both ultrasound and CT will usually establish the diagnosis. Intraperitoneal fluid and abscesses collect in the most dependent regions of the peritoneal cavity: the subphrenic spaces (fig 26.8), subhepatic space (between the right lobe of the liver and kidney) and in the pelvis in the rectovesical pouch or Pouch of Douglas (rectouterine pouch).
Amoebic liver abscess

Amoebic liver abscess is common in many regions of the world. Patients present with right upper quadrant pain and marked tenderness in the intercostal spaces of the lower right ribs. Imaging is important in the diagnosis. The right hemidiaphragm is elevated and there is basal linear atelectasis in the right lower lobe because of the enlarged liver. The diagnosis is confirmed by ultrasound examination of the liver that will detect a hypoechoic lesion in the liver (fig 26.9).

Appendicitis

Appendicitis is a diagnosis that is increasingly being made in many developing countries. The classic symptoms and signs of appendicitis are not always present especially in young children and the elderly. The diagnosis may be confused with gynaecological causes in young woman. Imaging has an increasingly important role in the diagnosis. Plain radiographs may demonstrate a localised ileus in the right lower quadrant with dilated bowel loops and fluid levels, or a soft tissue mass suggesting an inflammatory mass. Very rarely will calcified appendicoliths be detected. Ultrasound will usually confirm the diagnosis. A swollen appendix with a distended lumen is detected. With patients where the appendix has perforated there is usually matted bowel loops around the appendix forming an inflammatory mass.
### LEARNING POINTS: ACUTE ABDOMEN

- In suspected perforation, the supine abdomen and erect chest film or left side down decubitus abdomen are the most sensitive investigation to detect free air.
- Intramural gas usually indicates bowel wall infarction.
- Gas in the perirenal tissues and kidneys is found in acute renal infections in diabetics.
- In suspected small bowel obstruction the supine abdomen is more sensitive than the erect film. Beware of fluid filled dilated loops with no fluid levels; give the patient a water soluble contrast agent to confirm the diagnosis. Common causes: adhesions, inflammatory bowel disease.
- In suspected large bowel obstruction the supine abdomen and decubitus abdominal radiographs are especially sensitive. If unsure of the site of obstruction perform a dilute 1:6 single contrast barium enema to demonstrate the site of obstruction. Common causes: carcinoma, inflammatory disease, volvulus. In volvulus there is disproportionate bowel dilatation.

### Reference

CHAPTER 27

Gastrointestinal contrast studies

Peter Corr

Contrast media

Barium sulphate
The most common oral contrast used in the gastrointestinal tract is barium sulphate. It is an inert powder that is reconstituted into a suspension with water. Barium is safe to use for many investigations except:

- when there is a suspicion of bowel perforation
- when there is a likelihood of aspiration of barium into the lungs
- in the presence of complete bowel obstruction

Non-ionic water soluble contrast media
These agents are especially useful in detecting bowel perforation and when there is total oesophageal or bowel obstruction. Non-ionic contrast agents that are iso osmolar are the preferred agents in neonates and very ill infants.

Barium swallow (fig 27.1)
A barium swallow is indicated with patients with dysphagia or suspected oesophageal reflux. If total oesophageal obstruction from oesophageal cancer is suspected it is best to
use 5–10 mls of non-ionic water soluble contrast initially to detect the site of obstruction and so prevent aspiration of contrast into the lungs.

A swallow can be performed on a conventional erect bucky unit without fluoroscopy if you keep to the above rule. It is important to always have at least two views of the oesophagus in the AP and oblique planes. Always include the cervical oesophagus and oesophagogastric junction and stomach in the study.

**Barium meal (fig 27.2)**

A barium meal is performed for dyspepsia, epigastric pain or mass. It is important to give an antiperistaltic agent such as hyoscine 10–20 mg IV a few minutes before the procedure, in addition to granules that produce carbon dioxide gas to distend the stomach (eruvase fruit salts will also work!). A cup fill (250 mls) of high-density barium suspension is given orally to the patient. The patient is rotated anticlockwise to coat the stomach. Spot films of the stomach are taken using a fluoroscopy table. The following views are especially important: fundus, subfundal, antrum, duodenum, and stomach body.

**Small bowel follow through (fig 27.3)**

This technique is used to visualize the small bowel from the duodenojejunal junction to the ileocaecal valve. Always obtain a plain abdominal radiograph first to exclude bowel obstruction. Then give the patient a cocktail of 500 mls dilute barium suspension with
50 mls of water-soluble contrast medium (sodium diaztriote contrast) to drink. Lie the patient in the lateral position on their right side and take spot radiographs at 30, 60 and 90 minutes after drinking the contrast, by which time the contrast should have reached the terminal ileum. Adequate visualisation is obtained using high kv techniques (100–120 kvp).

**Barium enema** (fig 27.4)

Barium enema studies, using >100 kvp, are used to assess the colon for strictures, masses and polyps. The most important point is the preparation of the colon. An effective laxative must be given 24 hours before the procedure to clean the colon. Barium enemas are either single or double contrast. To detect obstruction in the presence of possible large bowel obstruction, a single contrast study is adequate. Single contrast studies involve using dilute barium sulphate (300 mls to 1800 mls of tap water). Double contrast studies require 200 mls of high-density barium and air insufflation. Double Contrast studies are used to demonstrate the mucosal surface of the colon to detect polyps or colitis.

---

**Gastrointestinal tract patterns**

**THE OESOPHAGUS**

The oesophagus extends from the pharynx to join the stomach at the oesophago gastric junction. In the cervical region at C3 there is an anterior impression on the lumen from a small venous plexus which must not be confused with a lesion. In the thoracic oesophagus there is a smooth impression due to the aorta and pulmonary artery. At the oesophago gastric junction there is a physiological sphincter.

**OESOPHAGEAL PATTERNS**

**Ulcer patterns**

Fold thickening and diffuse ulceration is common in monilial (candidial) infection. This is especially common in immunosuppressed patients (AIDS, patients on steroids or cytotoxic drugs) and malnourished children. Discrete longitudinal ulcers with
oedematous edges are common in herpes simplex infection. Deep punched out ulcers are found both in HIV and cytomegalovirus infections with patients with AIDS. Cytomegalovirus ulcers can be very large and perforate the oesophageal wall.

**Reflux oesophagitis pattern** (fig 27.5)

Peptic oesophagitis results from oesophageal reflux of gastric contents and may or may not be associated with a sliding hiatus hernia. There are often fine mucosal ulcers and if severe, can result in smooth stricturing of the distal oesophagus. **Patterns of oesophageal narrowing:**

- **oesophageal webs:** these are smooth webs in the anterior wall of cervical oesophagus. They are associated with patients with iron deficiency anaemia.
- **carcinoma:** these are irregular strictures, usually with proximal shouldering, most commonly in the middle third of the thoracic oesophagus (figs 27.6a & 27.6b).
- **benign stricture:** following reflux oesophagitis-these are usually smooth strictures in the lower third of the thoracic oesophagus (fig 27.5).
- **corrosive strictures:** particularly from caustic soda ingestion.
- **extrinsic compression:** from mediastinal lymph nodes, mediastinal tumours and aneurysms
Fig 27.6a
Lateral barium swallow in a patient with an extensive oesophageal carcinoma with proximal obstruction.

Fig 27.6b
Barium swallow in a patient with an oesophageal tracheal fistula from an oesophageal carcinoma.
Carcinoma of oesophagus (figs 27.6a & 27.6b)
Most carcinomas are common in the middle third of the thoracic oesophagus, followed by the lower third and then the upper third. Complications are common and must be searched for. Complications include: total obstruction, perforation and fistula formation into the tracheobronchial tree (fig 27.6b). A barium swallow will confirm the diagnosis of oesophageal carcinoma. Always give the patient a tablespoon full (15 mls) of barium to swallow first. This is to prevent aspiration of barium into the lungs in the present of severe obstruction. Usually the level of obstruction is evident on fluoroscopy. If fluoroscopy is unavailable, take erect PA and lateral chest radiographs after each swallow of barium.

Oesophageal varices (fig 27.7)
Today the diagnosis of oesophageal varices is established by endoscopy. However a barium swallow with the patient in a prone position on a fluoroscopy table will demonstrate multiple vertical serpiginous mucosal filling defects due to varices. It is important to search for varices in the undistended empty oesophagus as they can easily be compressed and be undetectable during if the oesophagus is distended by air or barium bolus.

Oesophageal web (fig 27.8)
Webs are a cause of dysphagia in the cervicial oesophagus. They occur on the anterior oesophageal wall. Patients often have associated iron deficiency anaemia. They must not be confused with a small submucosal venous plexus on the anterior wall.
**Hiatus hernia** (fig 27.9)

Hiatus hernia is a common finding of herniation of the stomach through the oesophageal hiatus (sliding). It may be associated with oesophageal reflux in some patients. It is best demonstrated by placing the patient in a prone oblique position and

**Fig 27.8**

Oesophageal web on the anterior border of the cervical oesophagus at the C5 level.

**Fig 27.9**

Barium meal of a sliding hiatus hernia.
asking the patient to take a deep inspiration after swallowing a mouthful of barium. Sliding hiatus hernia can be complicated by ulceration and bleeding. A rolling or para oesophageal hernia is where the oesophago-gastric junction remains in its normal anatomical position however a cuff of stomach wall herniates around the sphincter into the chest. It is important to detect as incarceration can occur in rolling hernias but is rare in the more common sliding variety.

STOMACH

The stomach mucosa and lumen are well visualized by barium meal. By rotating the patient on the fluoroscopy table, you will achieve a double contrast effect of the mucosa from the barium and carbon dioxide gas. Remember to achieve maximum distension of the stomach lumen with carbon dioxide gas powder or tablets after the patient has swallowed the barium.

STOMACH MASS LESIONS PATTERNS

Single gastric mass (figs 27.10, 27.11, 27.12)

A mass can originate from the stomach muscle layer, submucosa, mucosa or in the lumen of the stomach or be due a mass extrinsic or invading the stomach. Masses are
identified as filling defects on barium meal or soft tissue densities. **Common causes of solitary mass in the stomach are:**

- Polyp: adenomatous or carcinoma (primary or secondary)
- Leiomyoma or leiomyosarcoma (fig 27.12)
- Bezoar
- Extrinsic tumour: pancreas adenocarcinoma

**Multiple gastric masses**

- polyps
- fundal varices (fig 27.14)
- gastric cancer
- lymphomas
- Kaposi’s sarcoma (fig 27.13)
  —metastases

Early stomach cancer may be difficult to detect if is plaque-like. With all masses it is important to determine the cancer’s extent, especially to determine whether the oesophagogastric junction and duodenal cap are involved which may preclude gastrectomy. With antral tumours you must mention whether there is any gastric outlet obstruction. Multiple masses are common in lymphoma, metastases and Kaposi’s sarcoma (fig 27.13).

Fundal varices are seen after splenic vein thrombosis and appear as serpiginous filling defects in the fundus (fig 27.14). Varices change size on changing position from supine to erect and decrease with distension of the stomach with gas. It is important not to confuse them with a mass as inadvertent biopsy of fundal varices can be fatal.
Thickened stomach folds

The rugae or stomach folds are especially prominent along the greater curvature and body of the stomach. Rugae that are greater than 1 cm in diameter are considered to be enlarged or thickened. Causes of rugal thickening include:

- inflammatory: gastritis, Zollinger Ellison syndrome
- tumours: lymphoma, adenocarcinoma
- Menetrier’s disease

Linitis plastica pattern (“bald stomach”) (fig 27.10)

The stomach appears contracted with a featureless flat mucosal surface. This is called linitis plastica or “water bottle” stomach. Important causes for this are: adenocarcinoma, lymphoma, breast metastases, battery acid ingestion (fig 27.15), tuberculosis, Crohn’s disease, and eosinophilic gastroenteritis.
The main causes in Africa are primary stomach cancer and battery acid ingestion. With adenocarcinoma, it may be very difficult to get a positive biopsy of the stomach as the cancer spreads in the deep submucosa and the overlying mucosa is often normal. There is usually a bald stomach pattern with gastric outlet obstruction from antral stenosis and swollen mucosal folds in the small bowel (fig 27.15).

**Ulcers**

Stomach ulcers are common on the lesser curve and antrum. They appear as collections of barium outside the line of the stomach lumen (fig 27.16). You cannot differentiate between a benign or malignant ulcer on barium meal alone. However ulcers on the greater curvature are invariably benign. Duodenal ulcers appear as irregular deformed duodenal caps. Normally the first part of the duodenum has a triangular appearance but after ulceration the cap becomes deformed (fig 27.17). It is impossible to decide on a barium meal whether an ulcer is active or inactive without assessing the patient for clinical signs of ulcer activity first. Complications of ulcers are bleeding and perforation. Barium studies play no role in the diagnosis of gastrointestinal haemorrhage, the diagnosis is made usually by endoscopy and barium will only interfere with the endoscopic study.
SMALL BOWEL PATTERNS
There are only three patterns of small bowel disease: strictures or narrowing, mucosal fold thickening or multiple nodules or masses.

Small bowel stricture pattern
Strictures can be single or multiple. Causes of small bowel strictures are:

- fibrous adhesions from previous abdominal surgery or peritonitis are the commonest cause
- inflammatory: tuberculosis and Crohn’s disease
- neoplastic: adenocarcinoma, lymphoma
- radiation strictures especially following irradiation of pelvic cancer

To detect the level of the stricture and its extent, a barium follow through examination is the best investigation. Always take a control supine abdomen radiograph first as this may demonstrate dilated small bowel and give you an idea where the stricture is. Often it is difficult to differentiate between the various causes however both TB and Crohn’s disease tend to occur more commonly in the ileocaecal region.

Terminal ileum
Strictures here are common in two inflammatory conditions that are radiological indistinguishable: Crohn’s disease and tuberculosis. Tuberculosis usually causes stricturing of the caecum as well as the terminal ileum which becomes small and conical with the terminal ileum becoming straight and vertical at the level of the ileocaecal valve (figs 27.18 & 27.19).
Small bowel fold thickening

Fold thickening is best visualized on barium follow through studies. There are many causes:

- ischaemia: acute from mesenteric infarction
- ischaemia: chronic from vasculitis or radiation injury
- oedema: hyproteinaemia
- inflammatory: TB, Crohn's
- venous: Budd Chiari, cirrhosis

Fig 27.18  Barium enema of a patient with ileocaecal tuberculosis demonstrates deep ulcers in the terminal ileum and caecum with circumferential narrowing.

Fig 27.19  Barium enema of a patient with tuberculosis of the colon demonstrates multiple aphthoid ulcers throughout the colon.
lymphatic obstruction

- infiltration: lymphoma, carcinoma, metastases, eosinophilic enteritis.

The causes can be divided into two groups: focal and diffuse fold thickening.

Focal causes include ischaemia, inflammatory, and tumours while diffuse causes include oedema, lymphatic obstruction and infiltrative processes.

**Nodular small bowel pattern**

This usually represents an infiltrative process either inflammatory or neoplastic. Nodular lymphoid hyperplasia is a hyperplasia of the Peyer’s patches in the ileum and can be a normal variant. Multiple nodules are found in small bowel lymphoma, metastases, and eosinophilic enteritis.

**THE COLON**

Barium enema examination remains the easiest method of imaging the colon. It is important to tailor the examination to the patient and the suspected pathology. In young patients it is usually possible to obtain good mucosal coating of the colon with a double contrast study while in older patients who have suspected large bowel obstruction a more limited single contrast study will determine the site of obstruction.

**Colon stricture pattern**

Colon stricture is an important pattern to identify on barium enema. There is a focal narrowing of the colon with proximal dilatation of the normal colon. If there is “shouldering” at either end of the stricture a carcinoma must be suspected (“apple core” lesion) (fig 27.20). Assessing the mucosa for destruction is very inaccurate hence it is best to consider all strictures to be malignant until proved otherwise. Inflammatory lesions tend to be longer than malignant strictures and may have fistulae present in diverticular disease. It is important to appreciate that a malignant and inflammatory stricture can coexist in diverticular disease. **Common causes for colon stricture are:**

- neoplastic: adenocarcinoma, lymphoma
- inflammatory: diverticular disease, ulcerative colitis, Crohn’s, amoebiasis,
- tuberculosis
- radiation
- ischaemia
- extrinsic compression from tumours or inflammatory masses

![Fig 27.20](Barium_enema_of_a_patient_with_a_transverse_colon_carcinoma_demonstrates_an_apple_core_circumferential_narrowing_of_the_transverse_colon_from_a_carcinoma.)
Colonic masses pattern

Focal masses or polyps appear as filling defects on a single contrast enema or as soft tissue densities on double contrast studies (fig 27.21). Polyps than are more than 2 cm in diameter should be removed because of the risk of malignancy. If multiple polyps are present in the colon polyposis coli is a possible cause (fig 27.22). This is an autosomal dominant condition, which will lead to multifocal carcinoma by the 4th decade. It is important to screen other members of the family for polyps. Inflammatory polyps are

Fig 27.21
Barium enema of a patient with rectal bleeding demonstrates an ulcerated polyp in the sigmoid colon.

Fig 27.22
Barium enema of a patient with multiple polyposis coli. Note multiple small polyps throughout the colon.
detected after colitis either amoebiasis or ulcerative colitis, they tend to be filiform in appearance. **Causes of polyps:**

- polyps: adenomas, hamartomas
- carcinoma
- lymphoma
- post inflammatory following colitis

**Carcinoma of the colon** (figs 27.23a & 27.23b)

This diagnosis can be made with double contrast barium enema with a sensitivity of 76%. Patients with caecal or ascending colon cancers present with chronic blood loss.
and anaemia while patients with descending colon and sigmoid colon cancers present with symptoms of obstruction. Important points to remember are that 15% of patients will have a second tumour at presentation, so that you must be able to clearly visualize the whole colon especially the caecum and sigmoid colon where most cancers occur. Cancers present either as a mass or polyp or focal circumferential narrowing ("apple core" lesion). Polyps appear as a filling defect in a pool of barium or as soft tissue mass density if coated by barium. It is important to distinguish a polyp from faecal residue: faeces generally tend to have irregular sharp edges while polyps are smooth. Any polyp that is more than 2 cm diameter at the base should be viewed with suspicion as possibly malignant and removed by endoscopy.

**Colonic “thumb printing” pattern** (fig 27.24)

Thumb printing is an important observation on both plain radiographs and barium enema. Thumb printing usually represents oedematous or ischaemic colonic mucosa. **It is found in:**

- Amoebiasis
- Ischaemic colitis
- Crohn's disease
- Ulcerative colitis

**Colitis pattern** (fig 27.24)

Colitis is an inflammation of the colonic mucosa. On barium enema it appears either as discrete ulcers or diffuse ulceration. The most important colitis in many developing countries is amoebic dysentery. Amoebic colitis is often indistinguishable from ulcerative colitis. In severe cases there may be thumb-printing of the colon, megacolon and colon perforation with intraperitoneal abscess formation. Crohn's colitis and tuberculous colitis appear similar with discrete deep asymmetrical ulcers, often with fistulas and stricture formation.
Megacolon

Megacolon occurs when the diameter of the transverse colon exceeds 5.5 cm. Causes are: colon obstruction, colon pseudo obstruction, severe colitis, ischaemic colitis, and amoebiasis. When there is associated thumb-printing and the patient is ill it is termed toxic megacolon. In severe colitis this may be a precursor of colonic perforation. Serial supine abdominal radiographs are required to detect gas in the bowel wall or free intraperitoneal gas to indicate perforation.

Diverticular disease (fig 27.25)

Diverticula are out pouches of the mucosa and submucosa through hypertrophied smooth muscle in the wall of the colon. Although considered uncommon in developing countries, there is an increasing incidence from a change in diet from unrefined to refined carbohydrates. Patients may be asymptomatic, but if the diverticula become infected, form abscesses and or fistula in the sigmoid colon. Ascending diverticula may be a cause of active large bowel bleeding. The pattern is easy to recognise, however beware of confusing polyps for diverticula. Polyps have increased soft tissue density.
LEARNING POINTS: GASTROINTESTINAL CONTRAST STUDIES

- Common oesophageal strictures are from oesophageal carcinoma and following peptic oesophagitis
- Complications of oesophageal carcinoma are: tracheal oesophageal fistula, perforation with mediastinitis, aspiration and total obstruction
- Important causes of oesophagitis in AIDS patients are monilial oesophagitis, herpes simplex, CMV and HIV infections
- Causes of a solitary gastric mass are: polyps- adenomas, carcinomas, leiomyomas or sarcomas, bezoars, and extrinsic tumours (pancreas) invading the wall
- Causes of multiple gastric masses are: polyps, fundal varices, adenocarcinoma, lymphomas, Kaposi’s sarcoma and metastases.
- Causes of gastric fold thickening: gastritis, Zollinger Ellison syndrome, lymphoma, Menetrier’s disease
- Causes of a “bald stomach” linitis plastica; adenocarcinoma, lymphoma, metastases, battery acid ingestion
- Causes of small bowel strictures: fibrous adhesions, inflammatory-TB, Crohn’s, tumours-adenocarcinoma, lymphoma, ischaemic/radiation damage
- Causes of colon strictures are: tumours-adenocarcinoma, lymphoma, metastases, inflammatory-diverticular, amoebiasis Crohn’s, TB, ulcerative colitis, ischaemia/radiation, extrinsic compression by tumours
- Causes of colon polyps: adenomas, hamartomas, carcinoma, lymphoma, post inflammatory
- Causes of “thumb printing” of the colon: amoebiasis, ischaemic colitis, Crohn’s, ulcerative colitis

Reference

Neonatal abdomen

Imaging the ill newborn infant requires that radiographs are taken with a mobile X-ray unit while the neonate is in the incubator. Often only the supine chest and abdomen radiograph are all that is required to make a diagnosis. When further studies are required it is very important to keep the baby warm throughout the procedure and to return the baby to the incubator immediately after the procedure.

Oesophageal atresia (fig 28.1)

Usually there is a history from the mother of sucking difficulties from birth and a nasogastric tube cannot be passed more than 11–12 cm. Babies present with bubbly saliva on their lips because they cannot swallow. It is extremely important not to give this neonate any oral contrast as this will be aspirated immediately into the lungs. Air in the distended upper oesophagus, to the level of the atresia with the nasogastric tube stopping at this site is diagnostic. There is usually no air in the stomach in pure oesophageal atresia, however in 85% of babies there is an associated tracheo-oesophageal fisula which allows air into the stomach with each breath. Associated rib and vertebral anomalies are commonly detected.
Neonatal bowel obstruction (figs 28.2a & 28.2b)

Bile stained vomiting in the newborn is indicative of intestinal obstruction. A supine chest and abdomen film will define the site of obstruction. Upper intestinal obstruction is characterised by a few fluid levels on the abdominal radiograph. In duodenal obstruction there are usually only two fluid levels called the double bubble sign. Duodenal obstruction is due to midgut volvulus until proved otherwise and it is extremely important not to miss this life threatening condition. Mid gut volvulus results from the small bowel twisting on itself. A non-ionic water soluble contrast agent such as iohexol will identify the volvulus. The critically important observation to make is whether the duodenum has a normal C shape with the duodenojejunal junction to the left of the midline which is found in normal babies or whether the duodenojejunal junction to the right of the spine as seen in mid gut malrotation. With mid gut volvulus there is often a “cork screw” appearance to the mid-gut. Jejunal and ileal atresia will present with distended featureless bowel loops with multiple fluid levels. It is impossible to distinguish between small and large bowel radiologically in neonates.

Fig 28.2a
Barium meal of an infant with malrotation of the duodenum. Note the inverted “C” of the duodenum.

Fig 28.2b
Barium meal of a child with bile stained vomiting demonstrating mid gut volvulus with a “cork screw” appearance to the duodenum.
Anorectal malformations
The diagnosis of anorectal malformation is made by examining the child’s perineum. The treatment depends on the level of the malformation. In females the level can be assessed by visual inspection but this is impossible in males to determine whether the abnormality is above or below the levator muscle. Babies should be placed in the genu pectoral position and left in this position for several minutes. This will allow gas to rest in the distal bowel and outline the malformation. A lateral shoot through abdomen film allows one to identify low malformations below the pubococygeal line.

Nectrotising enterocolitis (NEC)
This condition, found in very ill premature babies, results in bowel wall ischaemia and infarction. Linear lucencies are noted in the bowel wall with gas in the portal vein branches of the liver. The diagnosis is made by carefully looking daily for the streaky lucencies in the bowel wall on the supine abdominal film.

Acute abdomen in infants
Abdominal radiographs are essential for the diagnosis of intestinal obstruction in children, although it is important to remember that gastroenteritis, hypokalaemia can cause multiple fluid levels due to paralytic ileus.

Intussusception (figs 28.3a & 28.3b)
Acute abdominal pain in infants has many causes. It is important to establish whether there is bowel obstruction. Intussusception is common in infants who present with episodes of colicky abdominal pain and bloody diarrhoea. The diagnosis should be considered on supine abdomen radiographs with bowel dilatation and in some patients a soft tissue mass from the intussuception. Usually the diagnosis is more easily made by ultrasound where a “doughnut” or “target” mass is detected. An air enema is used to...
detect the intussusception and can also be used to reduce it at the same time. It is important to perform this procedure only if the child is well sedated, and fully resuscitated, and the history is less than 48 hours.

**Worm bolus obstruction** (figs 28.4a & 28.4b)

Ascaris worm boluses are a common cause of small bowel obstruction in patients in many developing countries. The child presents with severe colicky abdominal pain and vomiting. Often the abdominal radiograph will demonstrate a mass of worm bodies
with bowel dilatation and fluid levels proximal to the obstruction. The worms also ascend the common bile duct and cause cholangitis and liver abscess. The diagnosis is usually established by ultrasound, where the worm bodies are seen as echogenic masses in the bile duct.

**Learning Points**

- Bile stained vomiting in neonates is indicative of intestinal obstruction
- Malrotation of the mid gut is diagnosed if the DJ flexure is to the right of the spine and the duodenum C-loop is not formed
- Midgut volvulus is diagnosed in the presence of malrotation and a "cork screw" appearance of the duodenum
- Oesophageal atresia is diagnosed by a dilated proximal oesophagus with the nasogastric tube at the level of the atresia
- Never feed oral contrast media to a baby with oesophageal atresia
- Fluid levels are commonly seen in gastroenteritis
- Ascaris infestation is a common cause of bowel obstruction. The diagnosis is made by detecting the worm bolus on the plain radiograph
- Intussusception can be diagnosed on plain films and ultrasound and confirmed by an air enema that can be used to reduce it
- It is good practice to minimise radiation to the child during procedures
- It is always good practice to minimise radiation dose during procedures
CHAPTER 29

Urinary tract imaging

Malai Muttarak, Peter Corr & Wilfred C.G. Peh

Introduction

The main imaging methods for investigation of the urinary tract are radiography, intravenous urography (IVU), micturating (or voiding) cystography (MCU) and ultrasonography (US) of the kidneys and bladder.

Anatomy

An understanding of the normal anatomy and normal anatomical variants of the kidneys and collecting systems is essential to interpret imaging (fig 29.1). The kidneys are situated in the retroperitoneum with the hila located at the level of L1 vertebra. In adults, both kidneys measure 10-12 cm long from pole to pole. Kidneys are approximately 5.5 cm in length in the neonate, and grow to reach adult size by 8 years of age. The adult renal parenchyma should measure at least 2 cm in thickness. It is important to understand the position and orientation of the kidneys. The upper poles are deviated medially, and the lower poles are deviated laterally at an angle of 30 degrees from the vertical axis. Due to their anterior location relative to the psoas muscle, the upper poles are more posteriorly located poles. Each renal hilum contains the renal vein, renal artery, renal pelvis and proximal ureter. The ureters descend along

---

Fig 29.1
Diagram of the normal urinary tract.
a line linking the tips of the transverse processes of the lumbar vertebrae, and insert into the bladder at the ureterovesical junctions. The bladder is an extraperitoneal pelvic organ situated anterior to the uterus in females and to the rectum in males. The male urethra is divided, from proximally to distally, into prostatic, membranous and bulbular portions. The female urethra is a much shorter structure. Due to the complex embryology of the urinary tract, there are a number of normal anatomical variants, which should not be confused with pathological conditions. Recognition of these variants is therefore important (table I).

**Table I.** Variants and developmental anomalies of the urinary tract

<table>
<thead>
<tr>
<th>Anomalies in number</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Renal agenesis (single kidney)</td>
<td></td>
</tr>
<tr>
<td>Supernumerary kidney</td>
<td></td>
</tr>
<tr>
<td>Anomalies in size</td>
<td></td>
</tr>
<tr>
<td>Hypoplasia</td>
<td></td>
</tr>
<tr>
<td>Hyperplasia</td>
<td></td>
</tr>
<tr>
<td>Fusion anomalies</td>
<td></td>
</tr>
<tr>
<td>Horseshoe kidney</td>
<td></td>
</tr>
<tr>
<td>Cross ectopy with fusion</td>
<td></td>
</tr>
<tr>
<td>Anomalies in position</td>
<td></td>
</tr>
<tr>
<td>Ectopic kidney (sacral or pelvic kidney)</td>
<td></td>
</tr>
<tr>
<td>Cross ectopy without fusion</td>
<td></td>
</tr>
<tr>
<td>Other anomalies</td>
<td></td>
</tr>
<tr>
<td>Foetal lobulation</td>
<td></td>
</tr>
<tr>
<td>Large column of Bertin</td>
<td></td>
</tr>
<tr>
<td>Ureteropelvic obstruction</td>
<td></td>
</tr>
<tr>
<td>Duplication of renal pelvis and ureter</td>
<td></td>
</tr>
<tr>
<td>Retrocaval ureter</td>
<td></td>
</tr>
<tr>
<td>Ureterocele</td>
<td></td>
</tr>
<tr>
<td>Aberrant renal arteries</td>
<td></td>
</tr>
</tbody>
</table>

**"KUB" film**

The imaging examination of the urinary tract should start with a conventional radiograph of the kidney, ureter and bladder, which is commonly called a "KUB" film. It is essential the KUB film be taken before any intravenous contrast agent is injected so as not to obscure calcified structures.

**Technique**

Careful radiographic technique in obtaining a KUB is important. The patient is placed in a supine position. The radiograph should be exposed soon after the patient has voided and at the end of full expiration. Upper margins of the radiograph should include the suprarenal area, while the lower margin should include the pubic rami (fig 29.2). For good visualisation of the renal outlines exposure factors of 70-80Kvp for an adult patient are required.
Normal KUB

The renal outlines should be seen unless they are obscured by overlying bowel gas. The size, shape and position of the kidneys should be noted. The ureter is not visualized but if a radiopaque calculus is present it may be seen along the course of the ureter (fig 29.3). The presence of vertebral scoliosis or obliteration of normal psoas shadows may suggest the possibility of renal or perirenal inflammation.

- The renal size is normally 3–4 lumbar vertebral bodies in length (12–14 cm long, 5–7 cm wide)

![Fig 29.2 Normal KUB radiograph.](image1)

![Fig 29.3 Staghorn calculus in the lower pole of the left kidney.](image2)
Differences between the right and left renal sizes should not be more than 1 cm
- The right kidney is usually 1–2 cm more caudally located than the left kidney
- The renal axis should be parallel to the axis of the psoas muscle

**Intravenous urography (IVU)**

Although IVU has been replaced by spiral computed tomography and ultrasound (US) for certain indications, it remains an important imaging investigation and is able to provide a general overview of the whole urinary tract. Patient preparation is important, as is the technique of performing the IVU.

**Patient preparation**
- One day before examination: castor oil at 6 pm
- Nothing by mouth 6–12 hours before the examination
- Day of examination: one dulcolax suppository at 6 am

For children no preparation is required although for children under 2 years a drink of a “fizzy” cool drink before the IVU will distend the stomach and improve visualisation of the kidneys.

**IVU technique**

1. **KUB:** To detect radio-opaque renal and or ureteric calculi
2. Injection of 300–350 mg Iodine (I)/ml contrast agent
   - Dosage for adult is usually 50 ml
   - Dosage of child is 1.5 ml/kg body weight (300 mg/ml)
3. 1 minute coned radiograph of both kidneys to show the “nephrogram” phase of contrast opacification. Gonads to be shielded by lead strips.
4. 5 minute coned radiograph of both kidneys to show the pelvicalyceal system. Distension of the upper collecting system can be achieved by compression of the mid-abdomen by a compressor band (fig 29.4).
5. 15 minute full length “release” radiograph to show the ureters and the bladder. This is obtained following release of the compressor band. The entire length of the ureters may not be seen in a single radiograph due to peristalsis (fig 29.5).
6. 30 minute coned radiograph of the opacified bladder

*Fig 29.4*

Normal 5 minutes coned nephrogram.
7. Post-micturition full length radiograph to show the kidneys, ureter and fully or partially emptied bladder.

**Indications**

1. Suspected congenital anomalies
2. Persistent urinary tract infection
3. Renal colic
4. Haematuria
5. Renal trauma
6. Renal, ureteric or pelvic tumours

**Contraindications**

1. Renal failure. This is a relative contraindication as renal excretion of contrast is delayed.
2. Hypersensitivity or allergy to contrast agent

**NEPHROGRAPHIC PATTERNS**

**Unilateral small smooth kidney** (fig 29.6)

The kidney is similar in shape and outline to a normal one. However, it is more than 2 cm shorter in length compared to the normal contralateral kidney (table II). In renal artery stenosis, the collecting system is normal; while a dilated collecting system is seen in post-obstructive atrophy.
Table II. Causes of unilateral small smooth kidney

<table>
<thead>
<tr>
<th>Cause</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renal infarction</td>
</tr>
<tr>
<td>Radiation nephritis</td>
</tr>
<tr>
<td>Congenital hypoplasia</td>
</tr>
<tr>
<td>Post-obstructive atrophy</td>
</tr>
<tr>
<td>Post-inflammatory atrophy</td>
</tr>
</tbody>
</table>

Unilateral small irregular kidney (fig 29.7)

Focal scarring in a small kidney is due to reflux nephropathy and recurrent renal infection (table III). The upper pole is usually involved. Tuberculosis is a common
cause of renal infection in many developing countries. In tuberculosis, focal calcification may be seen on the KUB film.

**Bilateral small kidneys** (fig 29.8)

Bilateral small smooth kidneys are usually due to post-obstructive atrophy, chronic glomerulonephritis, chronic papillary necrosis and chronic arteriosclerosis due to ageing (table IV). Bilateral small irregular kidneys are due to bilateral reflux nephropathy or chronic renal infection.

**Table III. Unilateral small irregular kidney**

- Reflux nephropathy
- Lobar infarction

**Table IV. Bilateral small kidneys**

- Chronic arteriosclerosis
- Chronic renal infection
- Chronic glomerulonephritis
- Chronic papillary necrosis
- Post obstructive atrophy
- Hereditary nephropathies

**Bilateral large smooth kidneys** (fig 29.9)

The most common cause is bilateral hydronephrosis. Acute glomerulonephritis, acute tubular necrosis and AIDS focal glomerulonephritis are also important causes (table V).

**Table V. Bilateral large smooth kidneys**

- Bilateral hydronephrosis
- Acute glomerulonephritis
- Acute tubular necrosis
- Acute cortical necrosis
- Infiltrative renal diseases
  - leukaemia
  - lymphoma
  - amyloidosis
  - multiple myeloma
Unilateral large smooth kidney (fig 29.10)

The commonest cause is unilateral hydronephrosis in which the renal pelvis and calyces are dilated. Acute pyelonephritis manifests as a swollen enlarged kidney with decreased opacification (table VI). Congenital anomalies may mimic a large smooth kidney, and conditions to consider include incomplete duplex kidney and or crossed-fused ectopia.

Table VI. Unilateral large smooth kidney

<table>
<thead>
<tr>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydronephrosis</td>
</tr>
<tr>
<td>Renal vein thrombosis</td>
</tr>
<tr>
<td>Acute pyelonephritis</td>
</tr>
<tr>
<td>Compensatory hypertrophy</td>
</tr>
<tr>
<td>Duplicated pelvocalyceal system</td>
</tr>
</tbody>
</table>
Renal masses (fig 29.11)
These may be divided into unilateral and bilateral renal masses (tables VII and VIII). Focal calcification is present in 15% of patients with hypernephroma. Tuberculosis may produce an inflammatory mass. A congenital cause of focal renal mass is obstruction of the upper moiety of a duplex kidney.

![Hypernephroma involving the upper pole of the left kidney.](image)

Table VII. **Unilateral renal mass**

| Benign and malignant solid renal tumours |
| Simple cyst |
| Inflammatory mass (abscess) |
| Focal hydrenephrosis |

Table VIII. **Bilateral renal masses**

| Polycystic kidney disease |
| Acquired cystic kidney disease |
| Lymphoma |
| Metastases |

**PELVICALYCEAL PATTERNS**

*Hydrenephrosis*
This refers to gross dilatation of the renal pelvis and calyces. A negative pyelogram is often detected in an enlarged kidney. Supplementary US, if available, is useful to demonstrate the dilated pelviccalyceal system, and whether the obstruction is proximal or distal. Causes of proximal obstruction include pelviureteric junction obstruction, calculus, tuberculosis and tumour. Distal obstruction may be due to schistosomiasis, calculus, and tumours such as carcinomas of the uterine cervix and bladder.

*Ulcers* (fig 29.12)
Ulcers are found in early tuberculosis and papillary necrosis.
Clubbing (fig 29.13)

Clubbing is found in hydronephrosis where it is usually generalised and resembles “mickey mouse ears”. Localised clubbing is found in reflux nephropathy or chronic pyelonephritis where there is associated focal cortical scarring, usually located at the upper pole.

Displacement (fig 29.14)

The pelvicalyceal system may be displaced by a mass lesion within the renal pelvis or by an adjacent mass.
CHAPTER 29. URINARY TRACT IMAGING

Filling defects (fig 29.15)

In the differential diagnosis of a pelvicalyceal filling defect, lesions to consider include carcinoma, calculus and blood clot. Radio-opaque calculi are usually visible on the preliminary control KUB film. Some extrinsic impressions, such as those caused by vessels, may simulate the appearance of filling defects.

Ureter patterns (figs 29.16 & 29.17)

Ureteric obstruction may be due to intraluminal, mural, and extramural causes. The commonest intraluminal cause is calculus, with occasional causes being blood clot and sloughed papilla. Mural causes include tuberculosis, schistomiasis and ureterocele.
Extramural causes are usually due to pelvic tumours such as carcinoma of the uterine cervix. In acute obstruction, there is an increasingly dense nephrogram and delayed contrast opacification of the collecting system. The level of obstruction is best evaluated on delayed films taken at 60 or at 120 minutes intervals. The level of obstruction may give a clue to the cause. Displacement of the ureters is seen with retroperitoneal masses and aneurysms.
BLADDER PATTERNS

In a normal urinary bladder, a uterine impression on the bladder vertex may be seen. A small or contracted bladder may be seen in neurogenic bladder (fig 29.18), tuberculous cystitis and schistosomiasis. Prostatic enlargement may produce an elevated bladder base, superior bladder diverticula, trabeculation due to thickening of the bladder wall muscle, dilated ureters due to back pressure, and large post-micturition residue. Bladder filling defects may be due to calculus, blood clot, tumour and inflammatory polyp (fig 29.19).

Fig 29.18
Triangular trabeculated small volume neurogenic bladder.

Fig 29.19a
Calcified bladder wall and left distal ureter from chronic schistosomiasis.

Fig 29.19b
Post micturition cystogram demonstrated multiple submucosal granulomas from Schistosoma haematobium (bilharziasis).
Renal ultrasonography

**Technique**

A 3.5 MHz transducer is generally used to scan the adult kidney. The liver and spleen act as acoustic windows for evaluation of the right kidney and left kidney, respectively. The kidneys are scanned in all planes. The patient should be in placed in the supine or decubitus position.

**Indications**

1. Renal mass.
2. Haematuria.
3. Flank pain.
4. Elevation of blood urea.
5. Poor or non-functioning kidney on IVU.
6. To guide biopsy and interventional techniques.

**Normal anatomy** (fig 29.20)

The normal kidney is easily recognised as an organ with a smooth outer contour surrounded by reflective fat. The normal renal cortical echogenicity is usually less than that of the liver and spleen. The renal medulla consists of hypoechoic triangular pyramids, separated by bands of intervening parenchyma that extend toward the renal sinus. These bands of intervening parenchyma, called “columns of Bertin”, may be prominent and hence simulate a tumour. The renal sinus is composed of fibrous tissue, fat, lymphatic vessels, and renal vessels. It is seen as hyperechoic structures in the centre of the kidney. The normal ureter is not visualised on US. The bladder is seen as an ovoid fluid-filled structure in the longitudinal plane and rectangular in the transverse plane (fig 29.21). For accurate evaluation of the bladder, it should be adequately distended and the patient may need to drink additional water.
US PATTERNS

Hydronephrosis (fig 29.22)

Obstruction of the urinary tract leads to dilatation of collecting system, which may be generalised or localised depending on the site of obstruction. The hyperechoic renal sinus is displaced around the dilated renal pelvis. In severe obstruction, there may be associated cortical thinning.

Pitfalls

1. An overdistended urinary bladder can produce dilatation of a normal pelvicalyceal system. One should make sure that the bladder is empty before making a diagnosis of hydronephrosis.
2. A prominent extrarenal pelvis, a parapelvic cyst, a renal artery aneurysm, reflux and congenital megacalycites may mimic hydronephrosis.

**Renal stone** (fig 29.23)

A stone is seen as a hyperechogenic focus with acoustic shadowing.

---

**Pyonephrosis**

Hydronephrotic fluid that is either infected or replaced with pus is known as pyonephrosis. The pus-filled renal pelvis is seen as fluid with various degrees of reflectivity within the dilated pelvicalyceal system. Debris may layer in the dependant portion and appears as a fluid-fluid level.

**Renal mass** (fig 29.24)

US is the investigation of choice for evaluation of a renal mass detected on IVU. It is highly sensitive for differentiating cystic from solid lesions, and has a reported accuracy rate of as high as 97%.
Simple renal cyst (fig 29.25)
Simple renal cysts are common in elderly patients. The US features of cysts are similar to cysts elsewhere in the body. They are typically well-defined, have a smooth outline, are round or oval in shape, anechoic and produces acoustic enhancement. They may be single or multiple.

Fig 29.25
Longitudinal ultrasound of the kidney demonstrates a simple cyst of the lower pole.

Polycystic disease (fig 29.26)
Adult polycystic disease is transmitted as an autosomal dominant trait. There are multiple cysts of various size scattered throughout the renal parenchyma. IVU shows enlarged kidneys, round radiolucent nephrogram defects and irregular distorted collecting systems. On US the kidneys are enlarged with multiple cysts.

Fig 29.26
Longitudinal ultrasound of the kidney demonstrates multiple cysts replacing the parenchyma in a patient with adult polycystic disease.

Renal abscess
An abscess appears on US as a focal mass with varying internal echoes. An early abscess is seen as a slightly hypoechoic area. Eventually, the abscess becomes markedly hypoechoic to anechoic, with variable acoustic shadows.

Renal angiomyolipoma
Angiomyolipoma (AML) is a benign tumour composed of varying amount of fat, muscle and blood vessel. It may be seen on the KUB film if it is large and contains a significant amount of fat. On US, it is seen as a well-defined hyperechoic mass.

Malignant renal tumour (fig 29.24)
Hypernephroma or renal adenocarcinoma is the most common malignant tumour of the adult kidney. The characteristic US features of the tumour are based on its solid nature. The echogenicity of the tumour may vary from being hyperechoic to anechoic, in comparison to the renal parenchyma.
**Lymphoma**

Renal involvement mainly occurs with non-Hodgkin lymphoma. The tumours usually appear as solitary or multiple hypoechoic masses with poor sound transmission.

**Increased renal parenchymal echogenicity** (fig 29.27)

Hyperechoic renal parenchyma is due to chronic renal processes such as chronic glomerulonephritis and end-stage renal diseases from any cause. The kidney is usually small and may be almost impossible to visualise.

**Bladder ultrasonography**

**Technique**

The patient is scanned in the supine position using a 3.5 MHz transducer. A full bladder is necessary for the study.

**Indications**

1. Determination of residual urine volume
2. Detection of bladder tumour and intravesical masses
3. Detection of bladder wall lesions

**US PATTERNS**

**Normal pattern**

The urinary bladder lies posterior to the pubic symphysis when empty and high in the pelvic cavity when full. Its size and shape varies with the amount of filling by urine. The urinary bladder appears round to nearly square in shape on the transverse scan, and round to oval shape on the longitudinal scan. The mucosal lining is smooth and stretched when it is full (fig 29.21).

**Bladder tumour**

Ninety-five percent of bladder tumours are of urothelial origin. Transitional cell carcinoma (TCC) is the most common type of malignant bladder tumour. Painless haematuria is the most common presenting symptom. The tumour appears as a smooth or irregular homogeneous or inhomogeneous mass (fig 29.28). The mass is adherent to the wall. Invasion through the bladder wall muscle may be seen if there is interruption of the sharply-defined echogenic bladder wall. However staging of bladder tumours is more accurately achieved by CT or magnetic resonance imaging. The US appearance of TCC is not specific and must be differentiated from benign papilloma, adherent blood
clot, adherent stone, invasive carcinoma of the prostate, cystitis and wall thickening secondary to chronic bladder outlet obstruction.

**Diverticulum**

Bladder diverticula are sac-like protrusions from the bladder wall. They are urine-filled and most are acquired in association with long-standing bladder outlet obstruction.

**Cystitis**

Cystitis occurs more commonly in female than in male patients. Acute cystitis is usually caused by gram negative organisms such as E. Coli, Proteus and klebsiella and most of the cases show no abnormality on US. However, with severe cystitis the bladder wall becomes thickened, either focally or diffusely, and may mimic a tumour. The US appearances of cystitis are similar whether the cause is infection, irradiation or secondary to cyclophosphamide therapy.

Schistosoma haematobium causes cystitis and ureteritis. It is characterised by granulomas, superficial mucosal ulcerations and formation of polypoid masses. With chronicity, the bladder becomes fibrosed with reduced capacity. There is an increased risk of development of bladder carcinoma.

**Micturating cystography (MCU)**

MCU is performed by filling the bladder with contrast agent introduced via a urethral catheter. It is important to have fluoroscopy available to perform this study if possible. 250 ml of contrast usually used in an adult patient, or until the patient feels the need to void urgently. A preliminary film is always recommended for detection of calcifications or calculi. Following filling of the bladder to capacity, spot radiographs in the anteroposterior and lateral projections are taken (fig 29.29). MCU is useful for detection of vesicoureteric reflux and bladder rupture. To detect reflux, the patient should micturate during fluoroscopy as reflux may be intermittent (fig 29.30). In suspected
29.29b normal ascending urethrogram in the same patient.

**Fig 29.30a**
MCUG in an infant male demonstrates urethral valves in the proximal urethra causing proximal dilatation. B-there is severe reflux up the right ureter to the right renal pelvis.
bladder trauma, fluoroscopy should be performed and early spot radiographs should be obtained after instillation of 50ml of contrast in order to detect early extravasation (fig 29.31).

**Cystogram patterns**
- **Normal appearance**: note uterine impression on the vertex of the bladder.
- **Small bladder**—seen in neurogenic bladder, tuberculous cystitis, schistosomiasis
- **Large bladder** with irregular outline-neurogenic bladder
- **Prostate enlargement** causes elevated bladder base with a convex superior border, bladder diverticula, trabeculation (due to thickening of the bladder muscle), dilated ureters from back pressure, large post micturition residue.
- **Filling defects** are due to calculi, blood clot, tumour, inflammatory polyps

**Urethrography**
The urethra may be visualised as part of a MCU or by ascending urethrography. The main indications are trauma and stricture following gonococcus urethritis. Urethritis produces strictures in the bulbar urethra while traumatic strictures are found in the membranous urethra (fig 29.32). In infants, congenital valves can be seen during MCU, particularly on the lateral projection (fig 29.30).
**Learning Points: Uroradiology**

- Always remember to ask for a control KUB before an IVU or cystogram study to detect radiopaque calculi.
- Congenital anomalies of the kidneys and ureters are common.
- Adult kidney size is from 12-14 cm in length.
- Kidneys are considered small if less than 9 cm in length in adults.
- More than 2 cm difference in longitudinal height between both kidneys is significant.
- Always consider renovascular disease if one kidney is 2 cm smaller than the other and the contour is smooth.
- A small kidney with an irregular border is usually due to reflux nephropathy or tuberculosis.
- Bilateral small kidneys are due to chronic renal disease such as chronic glomerulonephritis, papillary necrosis or chronic arteriosclerotic disease.
- Commonest cause for a large unilateral kidney is hydronephrosis or acute pyelonephritis. Ultrasound will confirm hydronephrosis.
- Common causes of renal “masses” are renal cysts, hypernephromas, renal abscess or inflammatory masses.
- Common causes of ureteric obstruction are calculi, tuberculosis, pelvic tumours especially carcinoma of the cervix.
- A small contracted bladder is seen in neurogenic lesions, tuberculosis and schistosomiasis.
- Bladder filling defects are due to calculi, blood clot, tumour or inflammatory polyps.
- Commonest cause of a urethral stricture is gonococcal urethritis and pelvic trauma.
Acknowledgements

Thank you to Leonie Munro for proof reading and Marianne Singh for organizing the manuscript.