The abdominal radiograph: a pictorial review

C Cook, TA Campbell-Smith, R Hopkins

The plain abdominal radiograph is one of the most frequently requested X-ray examinations by junior surgical and accident and emergency staff. Interpretation is often difficult, but this review outlines normal appearances, suggests a strategy for evaluation, and covers the common pathological appearances seen in hospital practice.

Dr C Cook is Consultant Radiologist, Weston General Hospital, Weston super Mare BS23 4TQ, **Mr TA Campbell-Smith** is Surgical Registrar, Crawley General Hospital, Crawley, and **Dr R Hopkins** is Consultant Radiologist, Cheltenham General Hospital, Cheltenham

Correspondence to: Dr C Cook

This article begins by suggesting a methodical approach to abdominal X-ray (AXR) interpretation. A series of commonly encountered AXR films is then discussed.

INTERPRETATION: BASIC PRINCIPLES

Interpretation of the AXR requires a methodical assessment of all aspects of the film including not only the bowel gas pattern, but also the soft tissue and bone (Armstrong and Wastie, 1992). Each of these will be considered in turn.

BOWEL GAS PATTERN

The initial AXR assessment invariably involves evaluation of the bowel gas pattern. The distribution, calibre and mucosal pattern of the bowel are all important in determining whether a particular loop is small bowel or colon but this can still be difficult to differentiate (*Table 1*).

There is rarely enough gas in the small bowel to see more than short segments of mucosal outline but the transverse mucosal folds (valvulae conniventes) of the small bowel are closer together and cross the entire bowel lumen. This can sometimes give rise to a 'stack of coins' appearance. The distal ileum can appear smooth when dilated which may further complicate interpretation. Small bowel is generally centrally positioned and the loops are more numerous, and demonstrate tighter radius of curvature than large bowel (Sutton and Young, 1990; Armstrong and Wastie, 1992; Grainger et al, 2001).

The presence of solid faeces is an indicator of large bowel, which can also be recognized by the incomplete haustral band crossing the colonic gas shadow. Haustra are usually present in the ascending and transverse colon but they may be absent from the splenic flexure and descending colon (Sutton and Young, 1990; Armstrong and Wastie, 1992; Grainger et al, 2001).

When a loop has been assessed to be small bowel or colon, the direct measurement of the bowel diameter will give a reasonable assessment of the degree of dilatation. The maximum calibre of the small bowel is 3.5 cm in the jejunum and 2.5 cm in the ileum. The large bowel calibre can measure up to 5.5 cm in diameter (Chapman and Nakielny, 2000). Diameters significantly greater than this may be at risk of perforation. Caecal perforation is at risk when the diameter of the caecum is greater than 9 cm.

Using these simple basic principles this article will now describe the salient features of several of the more frequently encountered abdominal pathologies which result in abnormal bowel gas pattern (Sutton and Young, 1990; Armstrong and Wastie, 1992; Morris and Wood, 2000; Grainger et al, 2001). These usually result in a degree of abnormal bowel dilation; other features of the film then lead to the correct diagnosis.

TABLE 1.
Differentiation of small from large bowel

	Small bowel	Large bowel
Distribution	Central	Peripheral
Mucosal pattern	Valvulae conniventes crossing the width of the bowel	Haustra do not cross the entire width
Calibre	Jejunum 3.5 cm (max) Ileum 2.5 cm (max)	5.5 cm (max)
Number of loops	Many	Few, rarely seen
Presence of solid faeces	Absent	Present
Radius of curvature	Small	Large

ABNORMALITIES OF BOWEL GAS PATTERN

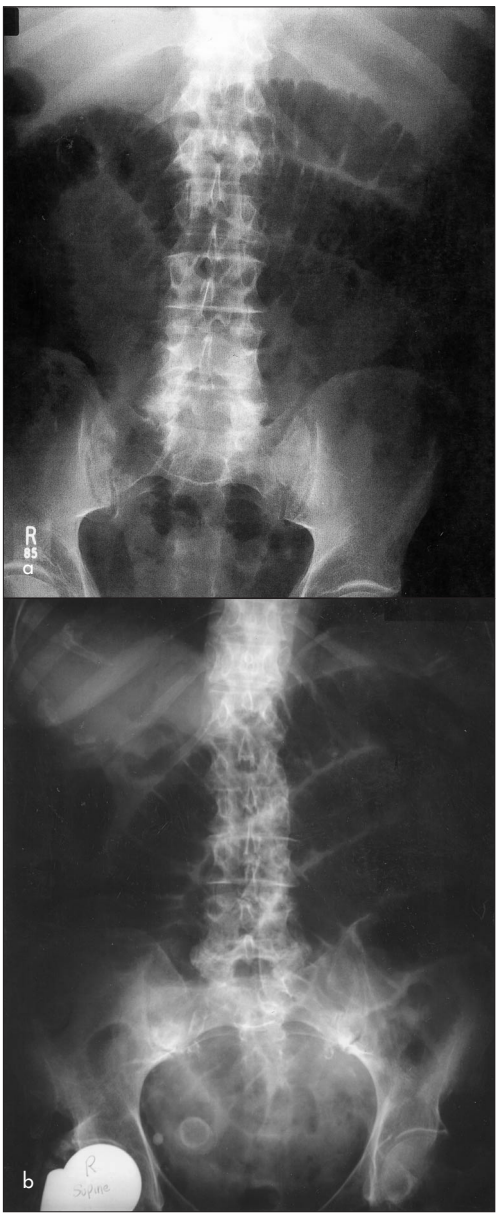
The following patterns may be recognized.

Mechanical small bowel obstruction

Mechanical small bowel obstruction (SBO) results in multiple loops of dilated, centrally positioned bowel (*Figure 1a*), often with tight radius of curvature. These changes are seen within 3–5 hours after complete SBO, and are marked at 12 hours (Grainger et al, 2001). The dilated bowel loops are clearly seen when gas filled, but can be very much more subtle should they be fluid filled; in these cases an erect film will clearly demonstrate multiple air–fluid levels. If loops are predominantly fluid filled then only a few scattered gas bubbles may be seen trapped against the mucosal surface. This is known as the 'string of beads' sign and is a useful sign in confirming SBO in the otherwise gasless AXR. A paucity of large bowel gas may also be a helpful sign – this is caused by collapse of the bowel lumen distal to the site of obstruction.

Although SBO usually occurs as a result of postsurgical adhesions (look for surgical clips) or inguinal hernia (look for gas overlying the inguinal canals), numerous other aetiologies will give similar appearances and these cannot be easily differentiated on the plain AXR. Gall-stone ileus is a rare cause of SBO, which can give a classical appearance on AXR. Gall-stone ileus occurs when a large gall-stone passes from the biliary tree into the small bowel where it comes to rest at the ileocaecal valve causing SBO. If the stone is calcified then it may be seen in the right iliac fossa. In addition, the stone's passage or erosion from the biliary tree into the duodenum may allow reflux of gas back into the biliary tree. This gives a branching low density pattern in the right upper quadrant overlying the central part of the liver (*Figure 1b*).

Figure 1. a. Supine abdominal X-ray demonstrating multiple gas-filled loops of small bowel – small bowel obstruction. b. Small bowel obstruction in which a gall-stone is visible in the right inguinal region, and there is gas in the biliary tree. The diagnosis is gall-stone ileus.



Large bowel obstruction

This is shown in *Figure 2* and gives rise to distention of the large bowel down to the level of

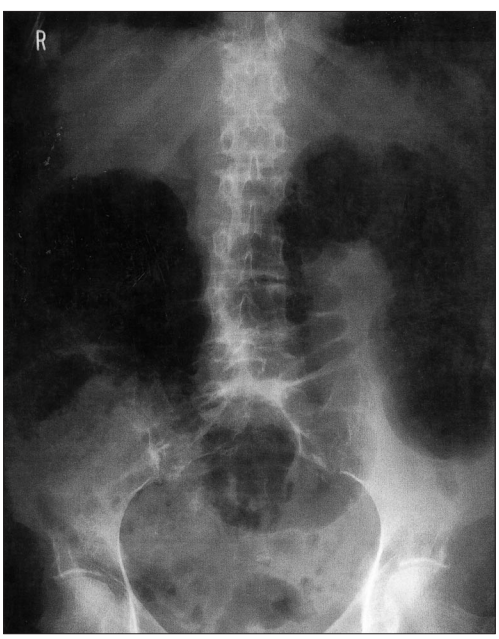


Figure 2. Large bowel obstruction. Dilated transverse and descending colon caused by obstructing lesion (not visible) in mid-descending colon.

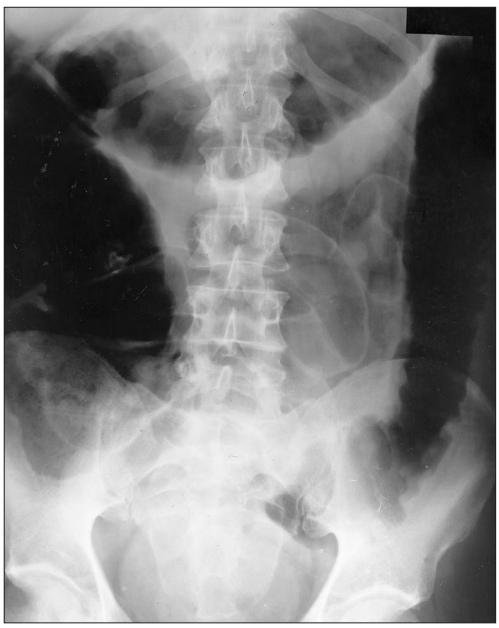


Figure 3. Toxic megacolon. The mucosa of the transverse and descending colon is thickened as a result of ulcerative colitis and there is the typical underlying thumb-printing as a result. Perforation has occurred, resulting in Rigler's sign outlining the small bowel in the central abdomen.

obstruction, sometimes with accompanying small bowel dilation if the ileocaecal valve is incompetent. Indeed, valve incompetence may result in some caecal decompression, thus reducing the probability of caecal perforation.

Toxic megacolon

This may be the diagnosis when the diameter of the colon exceeds 5.5 cm, with blurring of the mucosal outline and thumb-printing indicating mucosal oedema and ulceration (*Figure 3*). Toxic megacolon most commonly occurs in inflammatory bowel disease or ischaemic bowel, and this may have been revealed in the history. If the patient is in atrial fibrillation this should be noted, as this is a risk factor for arterial emboli.

Paralytic ileus

Both the large and small bowel can become dilated which can extend down into the sigmoid colon and rectum. Differentiation from low large bowel obstruction may be difficult. A water-soluble unprepared ('instant') enema is of great value in distinguishing large bowel obstruction from pseudo-obstruction (Chapman and Nakielny, 2001). Local peritonitis from acute cholecystitis or pancreatitis can lead to a single dilated loop of bowel (a sentinel loop).

Sigmoid volvulus

Sigmoid volvulus (*Figure 4*) gives a hugely dilated loop of bowel extending from the pelvis. The inverted 'U' loop or 'coffee bean' appearance is commonly devoid of haustra and is seen to extend as far as the liver in the right upper quadrant, and to the 10th thoracic vertebra superiorly. The inferior convergence of the two limbs of the loop is seen in the left iliac fossa. There may be some secondary loops of dilated large bowel associated with these appearances.

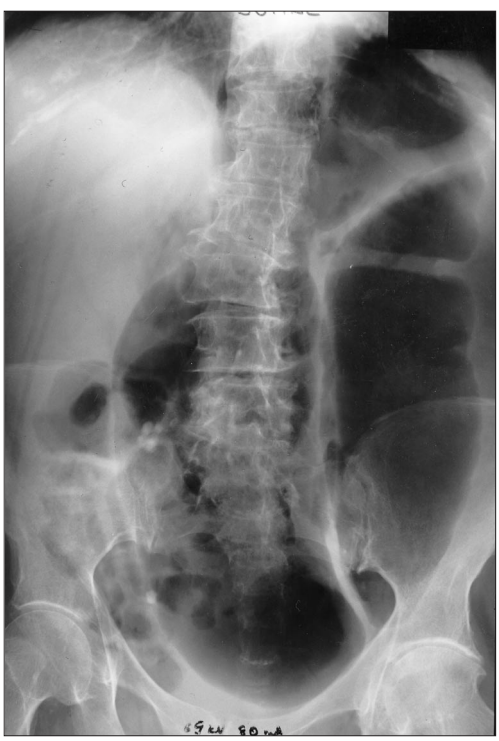
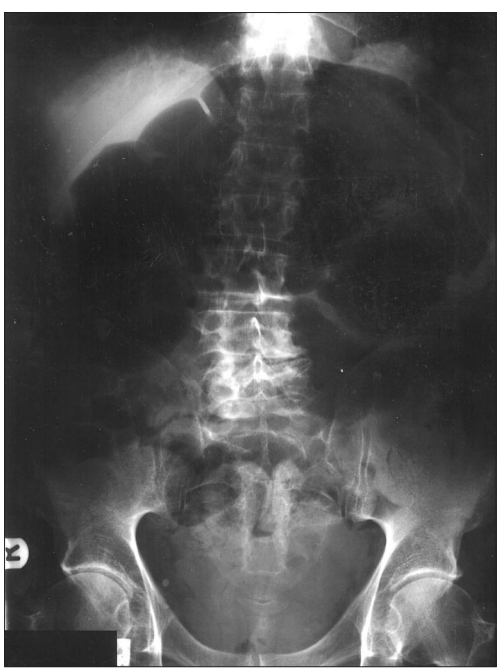


Figure 4. Sigmoid volvulus. 'Coffee bean' appearance arising from the left iliac fossa.

Figure 5. Caecal volvulus. The caecum is seen to have twisted about its axis to lie across the midline in the upper/central abdomen. In this case the small bowel remains undilated.



Caecal volvulus

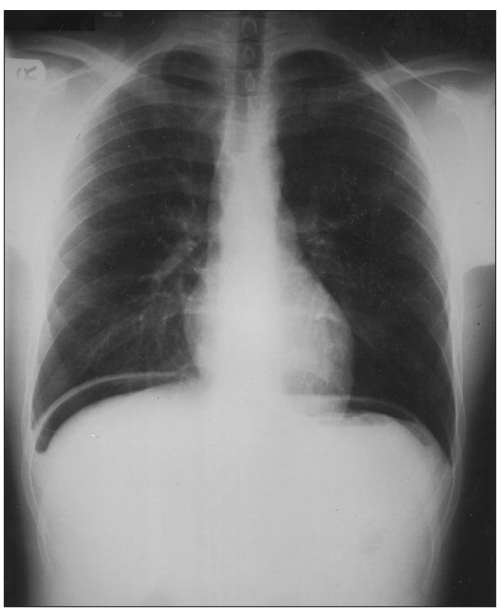
Caecal volvulus (*Figure 5*) is far less common than sigmoid volvulus, since the caecum is usually a retroperitoneal structure. In some patients the caecum and ascending colon hang on a mesentery and are therefore at risk of twisting about their axis to lie across the midline in the upper/central abdomen, or sometimes around its axis to remain in the right iliac fossa. There is usually associated SBO, and distal colonic collapse (Grainger et al, 2001). If the diameter of the caecum exceeds 9 cm there is risk of imminent perforation.

Although gas is usually seen within bowel loops, the film must be scrutinized for evidence of gas outside these anatomical structures and thus free within the peritoneal space.

EXTRALUMINAL GAS

This occurs as a result of leakage of gas from a gas-containing viscus, i.e. bowel, into the peritoneal space. Gas is best demonstrated as a lucent arc under the hemi-diaphragms on an erect chest radiograph (CXR) or erect AXR (*Figure 6*). The importance of the erect CXR in a patient with an acute abdomen cannot be overstressed. The CXR should be performed after the patient has sat erect for 10–15 minutes and can show as little as 1 ml of free gas under the hemidiaphragms. If the erect CXR fails to clearly show free gas, or if the patient is unable to sit upright, a right side up lateral decubitus film or a lateral erect CXR may allow diagnosis (Grainger et al, 2001).

Figure 6. Erect chest X-ray showing free sub-diaphragmatic gas.



On the supine AXR, gas is only seen within the bowel lumen. This results in a clear inner margin of bowel because of the air–mucosa interface. The outer margin (the serosal surface), however, is not clearly seen since the serosal surfaces merge with those of adjacent loops. However, perforation results in free intraperitoneal gas forming an interface with the serosal surface which then becomes radiographically visible, giving the appearance of a thin 'pencilled' line of the bowel wall with gas on either side. This appearance is known as Rigler's sign (*Figure 7*). On the supine film peritoneal folds may also be outlined by gas, including the falciform ligament, the median, medial and lateral umbilical ligaments (peritoneal folds caused by the urachus, the inferior epigastric vessels and obliterated umbilical arteries respectively).

Free gas may be seen after bowel perforation or following laparotomy or laparoscopy, and even following prolonged gastrointestinal endoscopy. In adults postlaparotomy pneumoperitoneum persists for up to 7 days but air is absorbed very much more quickly in children, usually by 24 hours. Repeat films can be very helpful in determining if there is an anastamotic leak or perforation present. However, clinical correlation, and possibly computed tomography (CT) is often important in these cases, when postoperative collections will also be demonstrated.

Pneumatosis coli gives a characteristic appearance with air-containing spaces visible in the wall of the bowel. It is associated with obstruc-

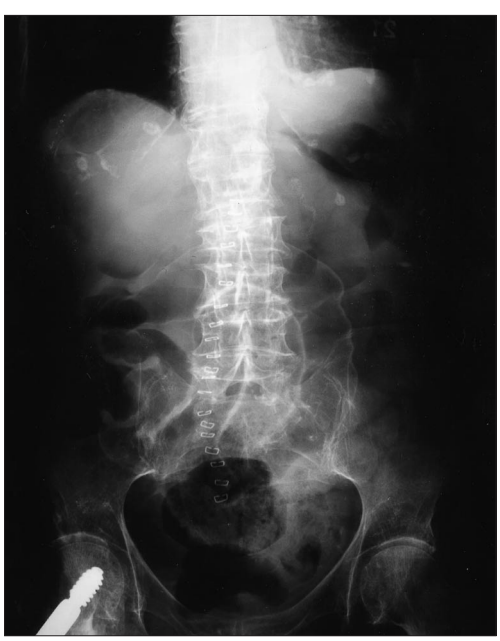


Figure 7. Pneumoperitoneum: Rigler's sign on supine film. The wall of the small bowel in the centre of the abdomen is seen clearly because it is outlined on both sides by air. The cause in this case is postsurgical (note surgical clips).

tive airways disease but the mechanism of this association is not clear.

Subsequent evaluation of the AXR should involve a survey of soft tissue outlines.

SOFT TISSUE OUTLINES

The normal visceral anatomy of liver edge, renal outlines and splenic tip may be seen. These structures are particularly well outlined if the patient has a significant amount of intraperitoneal fat, which helps to demarcate soft tissue planes. The aortic wall is seen if it is calcified and its normal diameter (even allowing for radiographic magnification) rarely exceeds 2.5 cm. Further vascular calcification may be seen, particularly within the splenic vessels, as serpiginous tramlines of calcific density in the left upper quadrant. Calcified renal tract stones or more rarely gall-stones may also be seen.

An abnormal soft tissue mass or abscess may be seen in addition to these structures. If there is a suspicion of an abnormal soft tissue mass, an ultrasound or CT scan may be indicated. The most appropriate scan is often chosen on an individual basis, but ultrasound is particularly useful for evaluation of right upper quadrant pain, pelvic pain, and in patients with low body fat (Armstrong and Wastie, 1992; Royal College of Radiologists, 1998).

An abscess classically has a rather heterogenous density because of the gas, pus and necrotic tissue within it. In addition, the position of displaced bowel within the abdomen may be indirect evidence of an abdominal or pelvic mass.

A specific evaluation should then be made of the bones, and abnormal areas of calcification. Evidence of previous surgery may also give clues as to current pathology.

BONES

The bone of the spine and pelvis should also be examined; a bone lesion may be evidence of metastatic disease from an already noted suspicious mass lesion and also be highly relevant in a patient already known to have a malignant primary tumour (*Figure 8*). Vertebral collapse as a result of metastatic or osteoporotic disease can be easily overlooked, and may be the cause of radicular pain mimicking pain of abdominal origin.

ABNORMAL CALCIFICATION

Abdominal aortic aneurysm

The extent and shape of a calcified aortic aneurysm can be seen on a plain abdominal film (*Figure 9*). Rarely, loss of soft tissue planes adjacent to the psoas shadows may indicate retroperitoneal haemorrhage. It should be noted that the psoas outlines may not be seen in the normal individual and therefore this is not a reliable indicator of retroperitoneal bleeding. The investigation of choice to exclude rupture in a stable patient is a contrast-enhanced CT scan of the abdomen.

Abnormal calcification can be used to make a diagnosis in the following conditions (Armstrong and Wastie, 1992):

- Gall-stones (only 10% are radio-opaque)
- Renal or ureteric stones

Figure 8. Lytic lesion within right superior pubic ramus in a patient with evidence of cystectomy. The appearances are those of transitional cell carcinoma metastasis.

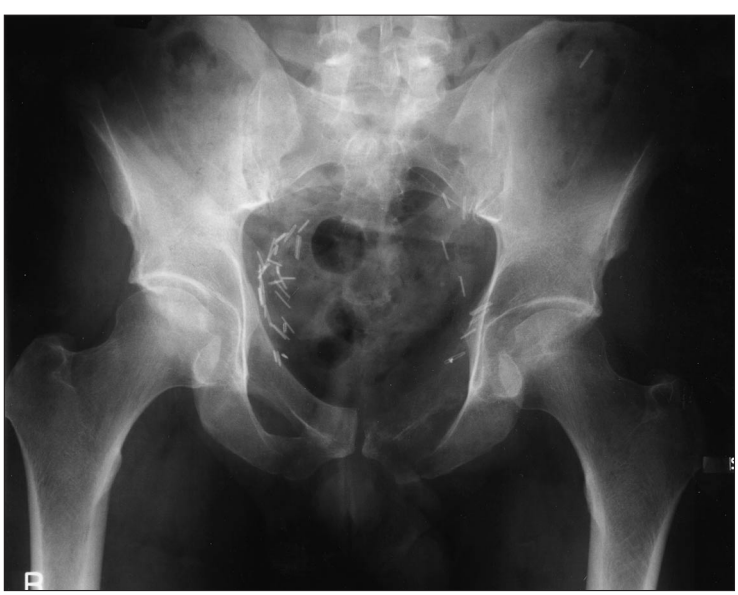
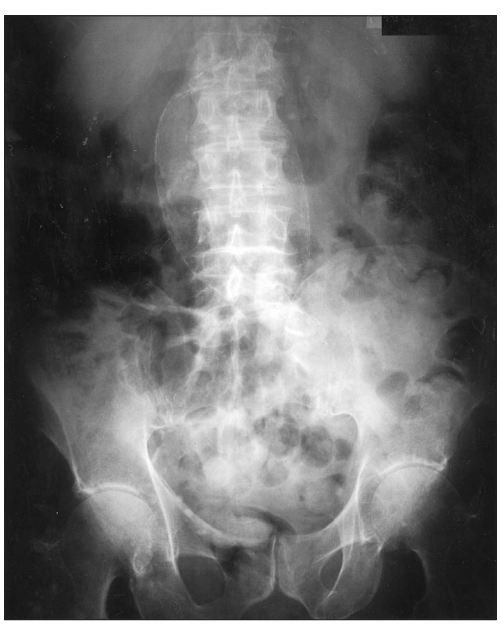


Figure 9. Calcification in the wall of an abdominal aortic aneurysm. Loss of a previously visible psoas border may be an indication of a leak.



- Chronic pancreatitis
- Appendicolith causing appendicitis (*Figure 10*)
- Liver calcification: hepatomas, old abscess, some metastases
- Uterine fibroids.

OTHER CONDITIONS

Ascites

The appearances of ascites on plain film are subtle and fluid appears as soft tissue density across the abdomen. However, significant amounts of ascites tend to accumulate in the paracolic gutters and flanks, causing gas-filled loops of bowel to float towards the central abdomen. This results in a paucity of bowel gas in the periphery. In addition, ascites within the pelvis results in loss of the normal bladder outline. Ascites is usually confirmed on ultrasound scanning of the abdomen.

Other rare causes

Included here is a case in which there is no underlying pathology but strikingly atypical appearance to the AXR, as a result of the action of the patient. This is the AXR of a patient involved in the smuggling of illicit drugs, which has been performed by the ingestion of multiple condoms containing the illicit substance. These are seen to lie as multiple lozenge-shaped opacities within the small bowel (*Figure 11*).

CONCLUSIONS

This article has aimed to present a series of AXRs showing common and some less common pathologies. It has also suggested a logical method of AXR interpretation. It must be remembered that although a large amount of information may be obtained from the AXR, clinical correlation and discussion with the radiological department is often useful in planning further radiological investigation. HM

Conflict of interest: none.

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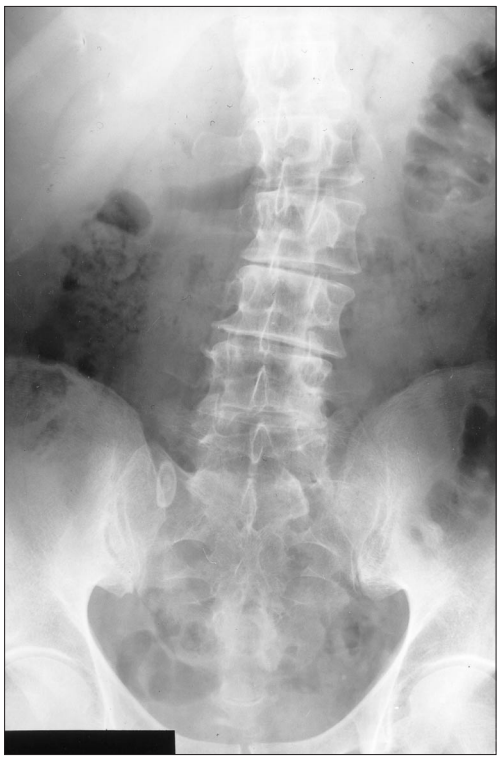

Figure 10. Calcified faecal appendicolith projected over the right sacral alar. When associated with right iliac fossa pain the diagnosis is appendicitis until proven otherwise.

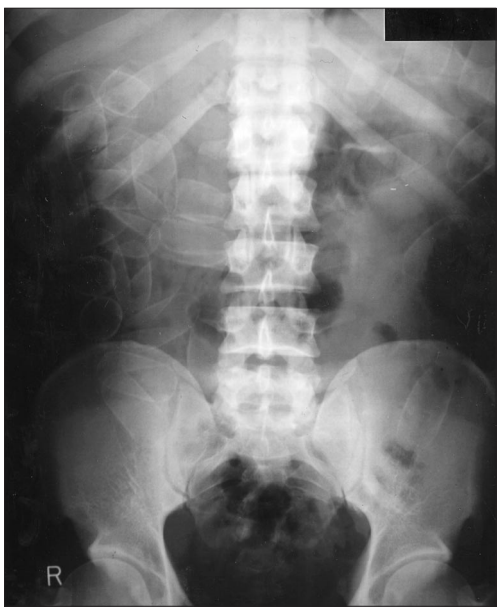

Figure 11. Plain abdominal X-ray of a patient involved in smuggling by swallowing condoms of illicit drugs. These are now seen to lie as multiple lozenge-shaped opacities within the small bowel.

KEY POINTS

- Discriminate between the small and large bowel.
- Assess the bowel diameter, and judge if dilated.
- Look for abnormal masses, or areas of calcification.
- Always remember to look for free gas; either on plain abdominal X-ray or erect chest X-ray.
- Discuss with the radiology department any need for further imaging, such as ultrasound, computed tomography or instant enema.
- Correlate appearances with clinical findings.