

# Radiological signs of pneumoperitoneum: a pictorial review

*The erect chest X-ray is often the first investigation in the evaluation of free intra-peritoneal gas. This article reviews the appearances of free intra-peritoneal gas on both chest and abdominal radiographs.*

The term pneumoperitoneum refers to free air within the peritoneal cavity. Pneumoperitoneum is most commonly caused by the perforation of an abdominal viscus, but other causes must be considered. Pneumoperitoneum is often seen incidentally after abdominal surgery when it usually resolves 3–6 days postoperatively. The most common causes of pneumoperitoneum are listed in *Table 1*.

## Clinical background

Usually, a patient with a perforation of the gastrointestinal tract will present to the accident and emergency department with severe abdominal pain; classically localized at first and then becoming generalized. Malaise and vomiting may be the only accompanying symptoms. Signs found on physical examination vary from local tenderness to generalized peritonitis. Special attention needs to be paid when dealing with patients on large doses of steroids, which both predispose to erosions and

perforation of upper gastrointestinal tract and may then mask the symptoms and signs of peritonitis. Similarly, the clinical signs may be less apparent in the elderly and diabetic patients, when only vague abdominal discomfort may be present. The diagnosis of perforation then relies entirely on the X-ray, so a high index of suspicion and a good knowledge of subtle signs must be maintained (Begg, 1999).

Overall mortality and morbidity of pneumoperitoneum depends on its aetiology. In cases of perforated abdominal viscus, the prognosis is based on the degree of peritoneal contamination and the development of localized or generalized peritonitis. The most important factors that dictate mortality rates are the age of the patient, the site of perforation and the time between the onset of symptoms and the operation. It is important to make a diagnosis as soon as possible, to decrease the time between onset of symptoms and surgical intervention (Burnard and Young, 1998).

## Radiography

Computed tomography (CT) is used increasingly to evaluate cases of acute abdomen, and will demonstrate tiny amounts of free gas. However, plain radiography of the chest – the erect chest radiograph (CXR) – remains the first step in imaging a patient with clinical signs of an acute abdomen and suspicion of perforation.

## Signs of free gas on CXR

### 'Dome sign' – free air under the diaphragm

This sign is most commonly taught to medical students and young doctors as the basic sign of perforation and pneumoperitoneum (*Figures 1–3*). Pneumoperitoneum is demonstrated by the presence of bilateral dark crescents of gas under both hemidiaphragms (*Figure 1*). Visualization of the undersurface of the diaphragm is affected by the amount of air present and the orientation of the diaphragm (*Figure 2*). Gas may appear under only one hemidiaphragm, usually on the right (*Figure 3*). Classic experimental studies by Miller and Nelson (1971) showed that as little as 1 ml of air could be detected below the right hemidiaphragm on properly exposed chest films, taken with the patient in an upright position.

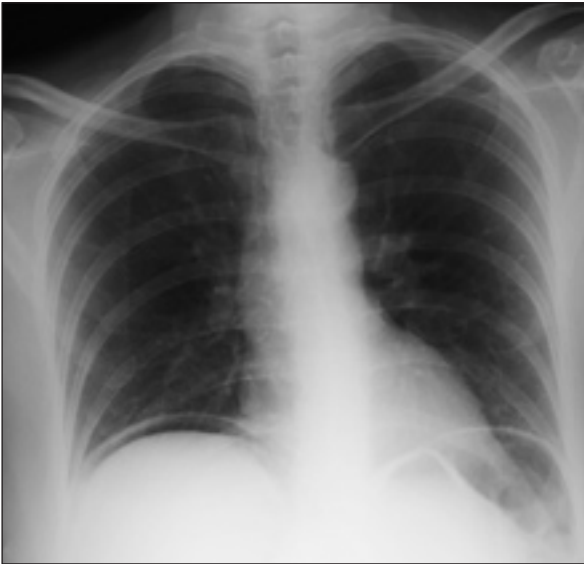
Technical features of importance in performing the erect CXR are to ensure the patient has been erect for

**Table 1. Aetiology of pneumoperitoneum**

Disruption of the wall of hollow viscus	Diseases of the gastrointestinal tract	Perforated gastric or duodenal ulcer
		Perforated appendix
		Diverticulitis
		Necrotizing enterocolitis with perforation
		Inflammatory bowel disease
		Obstruction
Intraperitoneal	Blunt or penetrating trauma	Iatrogenic perforation
		Gas-forming peritonitis
Through peritoneal surface	Through female genital tract	Rupture of abscess

**Dr Joanna Kasznia-Brown** is Specialist Registrar in the Department of Radiology, Bristol Royal Infirmary, Bristol and **Dr Chris Cook** is Consultant Radiologist in the Department of Radiology, Weston General Hospital, Uphill, Weston-Super-Mare BS23 4TQ

Correspondence to: Dr C Cook



**Figure 1. Erect chest X-ray. Dome sign – bilateral radiolucent areas under both hemidiaphragms, which represents free air in the peritoneal cavity.**

10–20 minutes before taking the X-ray. This is necessary to ensure that any free air within the abdominal cavity rises to the sub-diaphragmatic position (Sutton, 1987). In addition, if only a small amount of free air is present, it may not be visible unless the film is centred at the level of the diaphragms, with the X-ray beam passing through the hemidiaphragms perpendicularly to their highest point. Consequently, the typical CXR which is usually centred on the fourth thoracic vertebra results in an oblique view of the diaphragms and thus small amounts of free air may not be seen. Accordingly, if a CXR is being performed to exclude free gas, then this should be made clear at the time of the request.

**Figure 2. Erect chest X-ray. Massive pneumoperitoneum – a large amount of free air is seen under both hemidiaphragms (arrows) resulting in their elevation.**



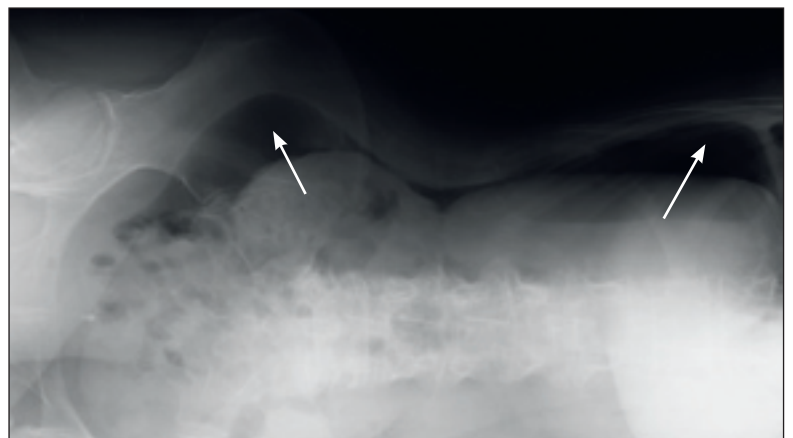
**Figure 3. Erect chest X-ray. Pneumoperitoneum – small amount of free air under only right hemidiaphragm.**

Plain radiographs taken with a patient in the decubitus position (lying on their side) may be performed in difficult cases when either the patient is unable to sit up for the examination or occasionally when the erect CXR is inconclusive (if it is not possible to determine if air below the diaphragm is actually free or within a loop of bowel). The left lateral decubitus film (with the patient lying on his/her left side) will show free air between the edge of the liver and the lateral wall of the peritoneal cavity (Figure 4). The right decubitus view is less sensitive, as gas in the stomach or colon may obscure a small amount of free air (Grainger and Allison, 2001).

### Supine abdominal X-ray

The supine abdominal radiograph (AXR) is not generally performed to evaluate potential pneumoperitoneum. Further evaluation of patients with clinical suspicion of perforation is usually by CT. However, if a plain AXR has been performed (for example in the evaluation of obstruction), the signs of pneumoperitoneum should be remembered since free gas will be seen in up to 56% of patients with pneumoperitoneum (Menuch and Siemers, 1976).

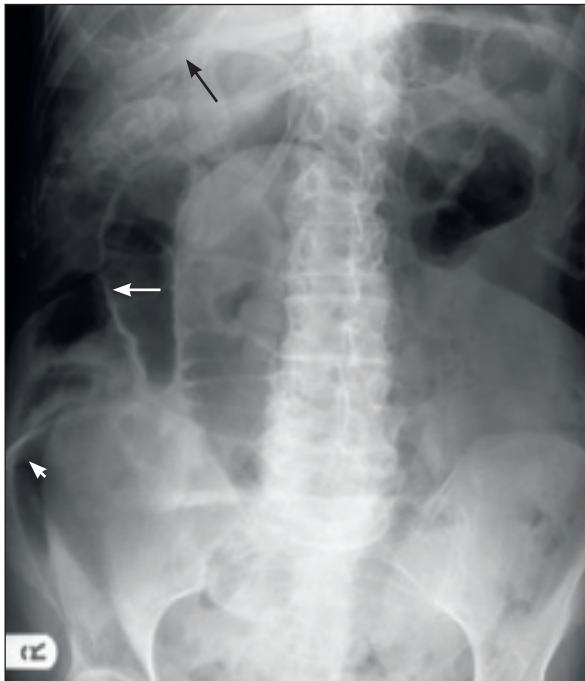
**Figure 4. Abdominal X-ray taken with a patient in the decubitus position. Free air (arrows) accumulates between the lateral wall of the peritoneal cavity and colon or free edge of liver.**



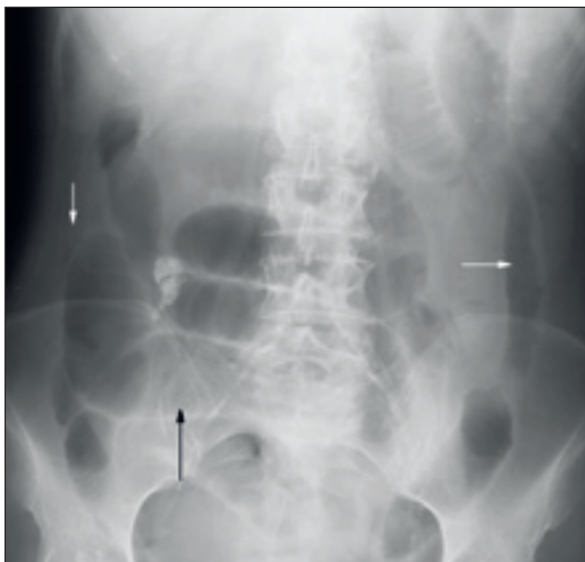
Signs of the pneumoperitoneum on the supine film may be obvious, but can be subtle and should be carefully looked for (Gore and Levine, 1994). They include:

- The double-wall or Rigler's sign
- Increased lucency in the right upper quadrant
- Outline of the normal peritoneal ligaments
- A triangle sign.

**Figure 5. Supine abdominal X-ray. Pneumoperitoneum – double wall (Rigler's) sign (white arrow), increased radiolucency in right upper quadrant (black arrow) and triangular collection of free air (white arrowhead) in the right iliac fossa between abdominal wall and caecum.**



**Figure 6. Supine abdominal X-ray. Double wall sign (Rigler's; black arrow) – gas outlining both sides of the bowel wall. Subtle radiolucent areas (white arrows) close to the abdominal wall.**



### 'The double-wall' or Rigler's sign

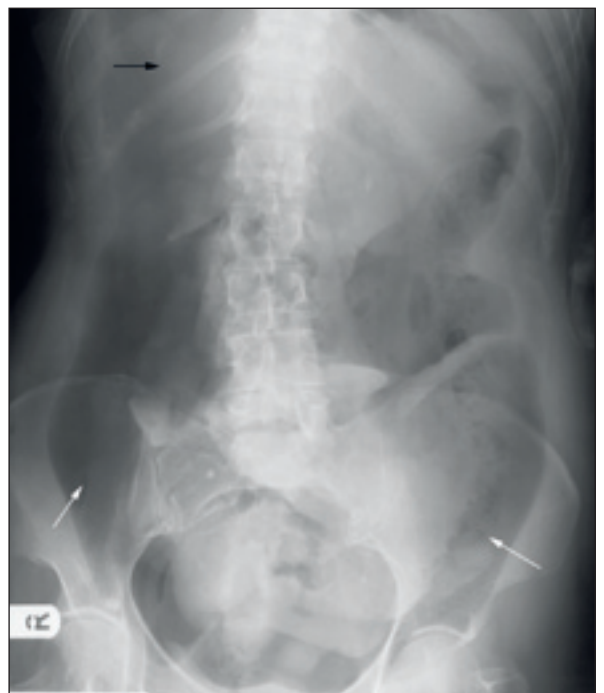
The sign was originally described by Rigler (Rigler, 1941) and it has been recognized as an important indication of pneumoperitoneum on abdominal films taken with the patient in supine position, although a moderate amount of free air must be present (Figures 5 and 6). In normal conditions, gas outlines only the luminal side of the bowel. Rigler's sign is present when free intraperitoneal gas outlines the serosa just as the intraluminal gas outlines mucosa. As a result, the bowel wall appears as a well-demarcated white line with gas on either side. Overlapping loops of dilated small bowel can mimic this sign and create false positive findings, so by preference an isolated peripheral bowel loop or the stomach should be used for evaluation.

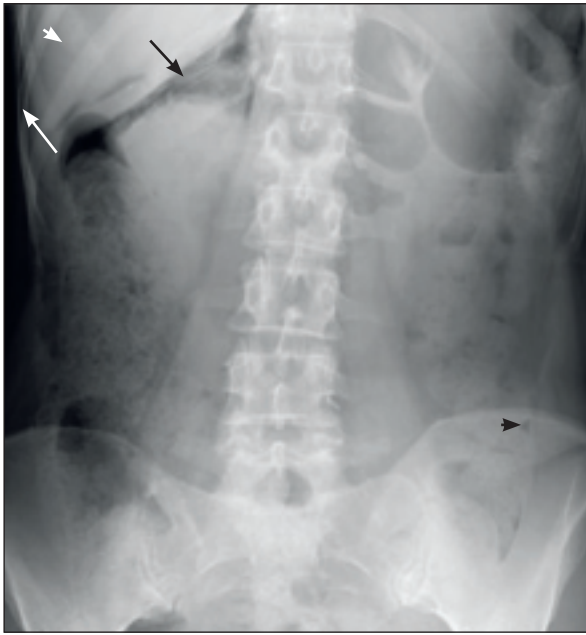
### Increased lucency in the right upper quadrant

Air accumulating superiorly in the free space between the anterior aspect of the liver and the abdominal wall may cause subtle increased lucency in the right upper quadrant (Menuch and Siemers, 1976). This collection may be a single or present in several small locules (Figures 5, 7 and 8). The following patterns are well known:

- Single large area of hyperlucency over the liver
- Oblique linear area of hyperlucency outlining the posteroinferior margin of liver
- Doge's cap sign – a triangular collection of gas in Morison's pouch (posterior hepatorenal space)

**Figure 7. Supine abdominal X-ray showing massive pneumoperitoneum. There is increased lucency in the right upper quadrant (black arrow) and in both iliac fossae (white arrows), collectively occasionally known as the football sign.**





**Figure 8.** Supine abdominal X-ray. Increased lucency in the right upper quadrant (white arrowhead) as a result of air interposed between the anterior abdominal wall and the liver (white arrow). Air collecting in Morison's pouch outlining the inferior border of the liver (black arrow). Triangle sign – free air between loops of bowel and left abdominal wall (black arrowhead).

- Saddlebag, moustache or 'cupola sign' – gas trapped below central tendon of diaphragm
- Parahepatic gas – gas bubble lateral to right edge of liver
- Air in the gallbladder fossa.

**Figure 9.** Supine abdominal X-ray. Silver's sign – visualization of the falciform ligament (black arrow).



### Outline of the normal peritoneal ligaments

With larger amounts of free air, the peritoneal ligaments may be visualized. The most common structure seen is the outline of the falciform ligament – seen as a long vertical line to the right of midline extending from ligamentum teres notch towards the umbilicus (*Figure 9*). Other structures include: lateral and medial umbilical ligaments, middle umbilical ligament and ligamentum teres (seen as a vertically orientated sharply defined slitlike or oval area of hyperlucency between the 10th and 12th rib).

### A triangle sign

This sign represents a triangular pocket of air between two loops of bowel and the abdominal wall (*Figures 5, 6, 8 and 9*). A triangular shape is unlikely to be seen if air is purely intraluminal.

### Rarer signs

The following signs have also been described but are more rarely seen:

#### Air in the lesser sac of abdominal cavity

Intraperitoneal air may enter the foramen of Winslow and become trapped in the lesser sac (*Figure 10*). This will be seen as an ill-defined lucency above the lesser curve of the stomach (Walker and Weens, 1963).

#### 'Football' sign

Originally described by Miller in infants (Miller, 1960), this sign usually indicates a large collection of gas in the peritoneal space. The free air seems to outline the entire

**Figure 10.** Supine abdominal X-ray. Free air in the lesser sac of the abdominal cavity.



oval-shaped peritoneal cavity, mimicking the shape of an American football (Figure 7).

**Scrotal air**

Scrotal air may be present in children as a result of peritoneal intrascrotal extension through the patent process vaginalis.

**Mimics of pneumoperitoneum**

Many important physiological or pathological conditions may simulate pneumoperitoneum (Chapman and Nakielny, 2003; Dahner, 2003). These may lead to misdiagnosis and thus unnecessary surgery and are listed in Table 2. The most common mimics of pneumoperitoneum are distended stomach, Chilidaiti's syndrome, lung atelectasis, and sub-diaphragmatic fat.

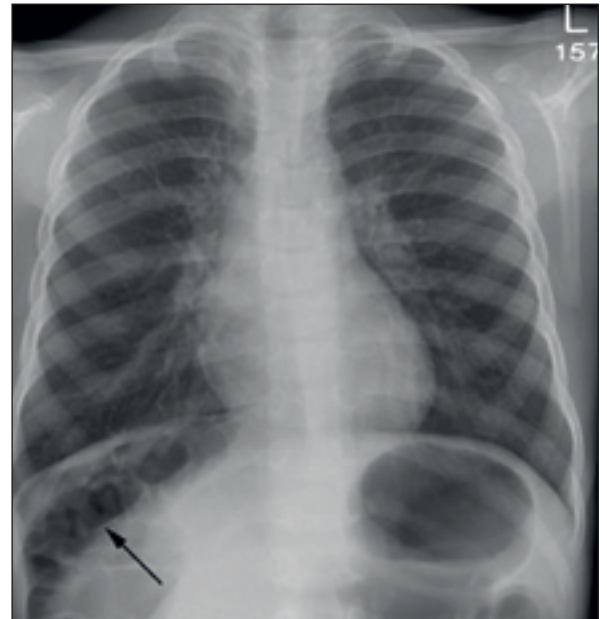
The distended gastric fundus is usually differentiated from free gas by its left upper quadrant position, pattern of rugae, and by its wall being thicker than diaphragm alone. If there is still doubt, this may be confirmed by a decubitus film.

Chilidaiti's syndrome (Figure 11) is the incidental finding of colon interposed between diaphragm and liver. Close evaluation will confirm the presence of haustral folds. Chilidaiti's syndrome is commonly seen in patients with a small liver (cirrhosis), chronic obstructive airways disease and post-laparotomy. It may also occur spontaneously without an underlying cause.

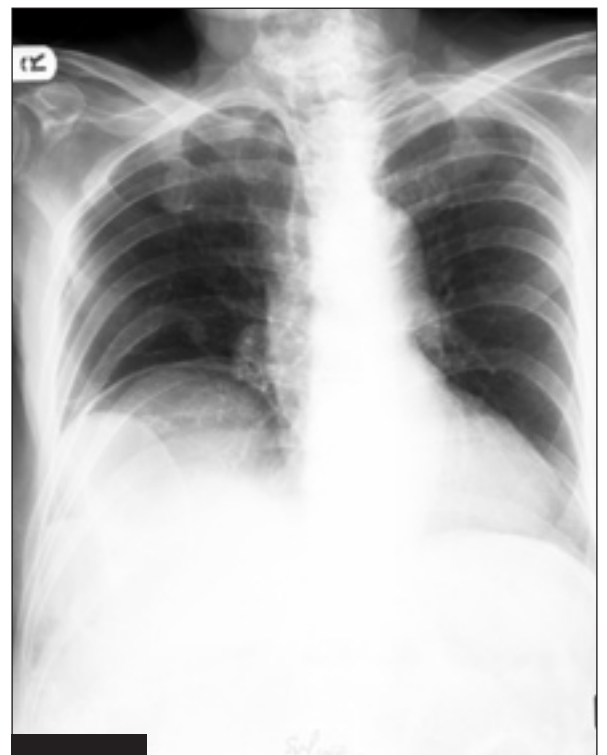
Linear atelectasis is frequently associated with infection or pulmonary embolism and is commonly seen after general anaesthetic or post-surgical intervention. It forms dense horizontal or curved bands at the lung bases, and thus the thin strip of aerated lung beneath it may mimic pneumoperitoneum (Figures 12 and 13).

Fat beneath the diaphragm, seen as a constant radiolucent stripe, can be differentiated from free gas since it is less dark in appearance. Furthermore, its size, shape and position will not change over time (if old films are available for comparison) or with patient movement (as seen on decubitus film).

**Figure 11. Erect chest X-ray. Chilidaiti's syndrome. Interposition of bowel between the liver and the diaphragm, simulating a pneumoperitoneum.**



**Figure 12. Erect chest X-ray. Consolidation in the lower zone of the right lung, with elevation and irregularity of the outline of the right hemidiaphragm mimicking free air.**



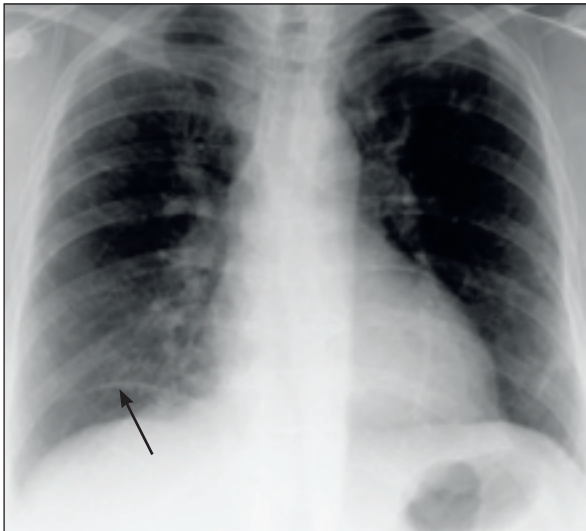
**Table 2. Process mimicking free air in the abdominal cavity**

Abdominal gas patterns	Distended stomach fundus
	'Pseudo-wall sign' – apposition of gas-distended bowel loops
	Chilidaiti's syndrome – colonic interposition between superior surface of the liver and diaphragm (Figure 11)
	Diaphragmatic hernia
	Diverticulum of oesophagus, stomach or duodenum
	Incidental gas-containing cysts within the bowel wall (pneumomatosus coli)
	Subphrenic abscess
Lung base pathology	Irregularity of the diaphragm (Figure 12)
	Basal atelectasis (Figure 13)
	Basal lung bulla
	Empyema
	Pneumothorax
Other normal anatomical structures	Subdiaphragmatic intraperitoneal fat
	Interposition of omental fat between liver and diaphragm

## Conclusions

Plain radiography remains the first line in imaging the patients with a clinical signs of an acute abdomen, including a perforated abdominal viscus. As little as 1 ml of free gas can be detected on a plain radiograph, either as an erect chest image or a left lateral decubitus abdominal image. Although modern imaging often resorts to the use of CT of the abdomen, evaluation of the AXR for signs of free gas should not be forgotten. **BJHM**

**Figure 13. Erect chest X-ray. Basal atelectasis in the right lung (arrow), no evidence of perforation.**



The authors would like to thank Dr G Stoddart for supplying Figures 2, 5, 8, 10 and 12.

Conflict of interest: none.

- Begg J (1999) *Abdominal X-ray Made Easy*. 1st edn. Churchill Livingstone, Edinburgh
- Burnard K, Young A, eds (1998) *The new Aird's Companion in Surgical Studies*. 2nd edn. Churchill Livingstone, London
- Chapman S, Nakielny R, eds (2003) *Aids to Radiological Differential Diagnosis*. 4th edn. Saunders, Edinburgh
- Dahnert W (2003) *Radiology Review Manual*. 5th edn. Lippincott, Williams & Wilkins, Baltimore, Maryland
- Gore RM, Levine MS, eds (1994) *Textbook of Gastrointestinal Radiology*. 1st edn. Saunders, Philadelphia
- Grainger R, Allison D, eds (2001) *Diagnostic Radiology. A Textbook of Medical Imaging*. 4th edn Churchill Livingstone, London
- Menuch L, Siemers PT (1976) Pneumoperitoneum – importance of right upper quadrant features. *AJR* **127**: 753–6
- Miller RE (1960) Perforated viscus in infants: a new roentgen sign. *Radiology* **74**: 67–76
- Miller RE, Nelson SW (1971) The roentgenological demonstration of tiny amounts of free intraperitoneal gas: experimental and clinical studies. *AJR* **112**: 574–85
- Rigler LG (1941) Spontaneous pneumoperitoneum: a roentgenologic sign found in supine position. *Radiology* **37**: 604–7
- Sutton D, ed. (1987) *A Textbook of Radiology and Imaging*. 4th edn Churchill Livingstone, New York
- Walker LA, Weens HS (1963) Radiological observation on the lesser peritoneal sac. *Radiology* **80**: 727–37

## KEY POINTS

- The erect chest X-ray is the examination of choice in cases of pneumoperitoneum.
- The abdominal X-ray should not usually be performed in cases of pneumoperitoneum but free gas may be seen.
- Remember the mimics of free gas as seen on the erect chest X-ray.