Abdominal Radiograph

Abhijit A. Raut[1] Prashant S. Naphade[2] Sharad Maheshwari[1]

[1]Department of Radiology, Kokilaben Dhirubhai Ambani Hospital, Mumbai, Maharashtra, India
[2]Department of Radiology, ESIC Hospital, Mumbai, Maharashtra, India

Address for correspondence Abhijit A. Raut, MD, Department of Radiology, Kokilaben Dhirubhai Ambani Hospital, Mumbai 400053, Maharashtra, India (e-mail: abhijitaraut@gmail.com).

J Gastrointestinal Abdominal Radiol ISGAR:2020;3(suppl S1):S22–S34

Abstract

Abdominal radiograph (AR) is often the initial radiological investigation performed while investigating abdominal pain even today. However, in the era of cross-sectional imaging, the role of AR in the diagnosis of acute pain abdomen is being questioned. When AR is used as a screening modality, the diagnostic yield is low. When performed in suspected cases of bowel obstruction or perforation, urinary calculi, or bowel ischemia, AR is often helpful. AR is often the first radiological investigation performed in acute abdomen. Although the role of plain radiograph is limited in the era of cross-sectional imaging, systemic approach and vigilant search for the radiological features on AR may be diagnostic and decide further line of investigation. Various gas patterns of intraluminal and free peritoneal air are helpful in localizing pathology. Different patterns of calcification seen in abdomen, ingested or inserted foreign bodies, and location of medical devices give a clue to diagnosis.

Keywords
► abdomen
► bowel obstruction
► calcification
► pneumoperitoneum
► radiograph

Introduction

Abdominal radiograph (AR) is often the initial radiological investigation performed while investigating abdominal pain even today. However, in the era of cross-sectional imaging, the role of AR in the diagnosis of acute pain abdomen is being questioned.

When AR is used as a screening modality, the diagnostic yield is low.[1] When performed in suspected cases of bowel obstruction or perforation, urinary calculi, or bowel ischemia, AR is often helpful.[2]

AR is found useful in recently operated patients to check the correct placement of the intra-abdominal catheter, drainage tube or detection of the ingested, inhaled, or introduced foreign bodies (FBs). The sensitivity of detection of the leftover metallic needle over 10 mm in length after the surgery is around 92%.[3]

An additional advantage of AR is its availability, low cost, and relatively low radiation. AR can be obtained in a short time, can be performed in uncooperative patients, and can even be performed portably. AR may be helpful assuring the treating physicians and anxious patients to start initial treatment among the patients of acute abdomen who are found to have relatively benign findings.[4] In resource-poor settings, AR can be helpful in the management of specific abdominal pathology when interpreted with an appropriate clinical background. In this review article, we describe the relevance of AR in today's scenario.

Technical Consideration

Most frequent AR is obtained in anteroposterior projection, which is acquired in a supine position slightly flexing the knees to relax the abdominal muscles. The lower edge of the cassette is positioned at the level of the pubic symphysis and the X-ray beam is centered at the iliac crest that corresponds to L4–5 intervertebral space. For average sized patient, low kilovoltage (60–75 kV) and ~ 30 mAs exposure are appropriate.

Upright posteroanterior abdominal or chest radiographs are useful in the detection of a small amount of pneumoperitoneum.

When suspected bowel obstruction patients show gasless abdomen on supine film, standing AR may show multiple air–fluid levels in the dilated small bowel loops.

DOI https://doi.org/10.1055/s-0040-1701327
ISSN 2581-9933.

Thieme Medical and Scientific Publishers Pvt. Ltd., A-12, 2nd Floor, Sector 2, Noida-201301 UP, India

Lateral decubitus AR may be helpful in extremely sick patients who cannot stand to detect free peritoneal air or dilated bowel with air–fluid levels. Left lateral decubitus AR is acquired after keeping the patient in left side down position for at least for 10 minutes. Free gas over the right lateral margin of the liver or beneath the iliac crest indicates perforated viscous.

Prone ARs are helpful when a distal colonic obstruction is suspected. In supine AR, colonic gas is seen mainly in the anterior transverse and sigmoid segments of the colon.

Portable ARs are used in extremely sick patients who cannot be transferred to the Radiology department. The portable ARs are often of poor quality. Most portable machines have fixed milliampere settings; thus, AR is taken at higher peak kilovoltage that results in reduced contrast. In addition, the sick patients are often breathless resulting in motion unsharpness artifacts.

Abdominal Radiograph Interpretation

A systemic approach to the evaluation of AR improves diagnostic accuracy.[5] Simple things such as demographic information of the patients including the name, age, and sex are crucial. Technical evaluation of the AR such as projection, markers on the film, and film quality should be assessed.

This is followed by a step-by-step assessment of AR

- Gastrointestinal tract and bowel gas pattern in stomach, small and large bowel loops
- Solid organs—evaluation of kidneys, liver, spleen, and outlines of psoas muscles
- Others—urinary bladder and gallbladder fossa
- Pathological gas
- Abnormal calcification—renal/gallbladder calculi, pancreatic or lymph node calcification
- Implanted devices, FB, catheter, drainage tube, and their position in relation to the abdominal organs
- Bones

Dilated Stomach

The stomach is located in the left upper quadrant. Sometimes thick mucosal rugal folds can be seen. The fluid-filled stomach should not be misinterpreted as soft tissue mass.

Gastric outlet obstruction on AR appears as grossly dilated stomach showing air, air–fluid level, or residual food material. It can be seen in distal antral and pyloric ulcer, growth or scarring secondary to granulomatous disease, radiation, or caustic ingestion. Diabetes, narcotic abuse, hypokalemia, uremia, porphyria, lead poisoning, and previous truncal vagotomy can cause gastroparesis (►**Fig. 1**). Acute pancreatitis, gastritis, and general anesthesia can lead to gastric dilatation. Obstruction in the duodenum can also lead to gastric outlet obstruction.

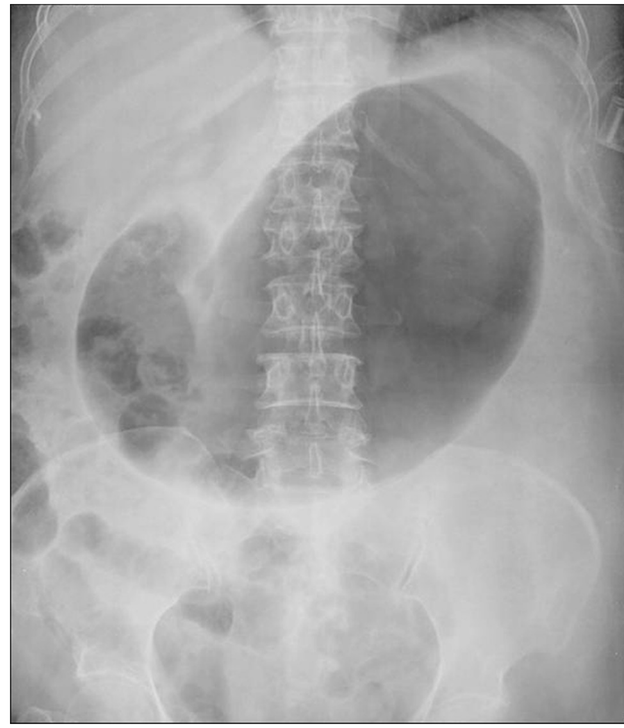

Fig. 1 Radiograph of abdomen reveals acute gastric dilatation in diabetes mellitus.

Bowel Gas Pattern

Normal adult contains less than 200 mL of bowel gas. Swallowed air, bacterial production, and diffusion from the blood contribute to bowel gas. Depending upon the location and pattern of bowel gas, the different bowel loops can be identified.

On supine film, gas is seen in the nondependent portion of bowel, which includes antrum and body of the stomach, transverse colon, and sigmoid colon and may be seen in the colon and rectum

Differentiation of small bowel gas from large bowel gas depends upon its position, bowel diameter, and mucosal folds (►**Table 1**).

Fecal matter in the bowel gives a “mottled” appearance. Gas and fecal material are frequently seen within normal caliber large bowel. The maximal caliber of the transverse colon on plain films is taken to be 5.5 cm in diameter, and the maximal cecal diameter is 9 cm.

Normal small bowel loops are normally not visible on AR. Mild fullness of small bowel loops and fluid levels can be seen in normal individuals or in patients with gastroenteritis,

Table 1 Bowel gas pattern

	Small bowel	Colon
Location	Central position	Peripheral
Diameter	<3.5 cm jejunum and <2.5 cm ileum[33]	<5 cm[33]
Mucosal folds	Circular folds—plicae circulares, 1–2 mm width	Haustral folds—2–3 mm width at 1cm interval
Contents	May contain gas	Gas and feculent material give a mottled appearance

pancreatitis, inflammatory bowel disease, and aerophagia. As against, small bowel loop obstruction shows gas-filled dilated loops more than 3 cm in diameter and no gas in colon on supine film. Air–fluid levels are seen on standing or decubitus AR.

A small amount of gas and feculent contents on AR is a normal finding. On supine films, anterior transverse and sigmoid colon usually show a larger amount of gas. The cecal diameter of 9 to 12cm indicates an impending perforation. However, diameter up to 15 to 20 cm may even be seen in individuals who recover spontaneously from Ogilvie's syndrome.[6]

Paralytic Ileus (Nonobstructive Ileus or Adynamic Ileus)

Paralytic ileus is defined as intestinal distension in the absence of mechanical obstruction due to slowing or absence of propagation of food contents. The swallowed air gets accumulated in the proximal bowel loops with resultant dilatation. Ileus can be seen secondary to various causes that include metabolic, neurologic, or infection[7] (►**Table 2**).

Dilated small and large bowel loops are seen on supine AR. On standing film, multiple air–fluid levels are seen. The dilated colon is the key point that helps to differentiate paralytic ileus from small intestinal obstruction.

Occasionally the ileus is limited to the small bowel loops. On AR, the small bowel loops are dilated with normal looking large bowel loops making this condition difficult differentiating from a small bowel obstruction (SBO).

Localized ileus or sentinel ileus is limited to a part of the abdomen in relation to the acute inflammation or infection such as acute pancreatitis or appendicitis. On a plain radiograph, focal dilatation of one or up to three small bowel loops (sentinel loops) is seen. The location of the sentinel loops limits the differential diagnosis. In appendicitis, right lower quadrant sentinel loops are seen (►**Fig. 2**). Right upper quadrant sentinel loops indicate cholecystitis, while upper or central sentinel loops indicate pancreatitis.

Small Bowel Obstruction

SBO is a mechanical interruption of small bowel loops due to various pathologic processes. The common causes include intra-abdominal adhesions, which typically occurs a week after intra-abdominal surgery. Obstructed hernias, Crohn's disease, Tuberculosis, malignancies, and volvulus are other common etiologies. Occasionally, intestinal parasites or bezoars can lead to SBO.

Table 2 Causes of paralytic ileus

Postoperative patients
Metabolic and electrolyte derangements—hypokalemia, hyponatremia, uremia,
Drugs—opiates, psychotropic agents, anticholinergic agents
Intra-abdominal inflammation
Retroperitoneal hemorrhage or inflammation
Systemic sepsis

Fig. 2 Radiograph of abdomen in a child with acute right iliac fossa pain reveals few distended small bowel loops in right iliac fossa, representing sentinel loop sign in a case of appendicitis.

In SBO, the bowel loops proximal to the obstruction are dilated due to swallowed air and accumulated secretions, while the bowel loops distal to the obstruction may be normal. Normal peristalsis pushes out the distal bowel contents within 12 to 24 hours and these loops may be collapsed.

On a plain radiograph, small bowel loops are dilated with diameter more than 3 cm, while distal bowel loops are collapsed. The air in the large colon is variable. Standing abdominal X-ray reveals multiple air–fluid levels in the dilated small bowel (►**Figs. 3** and **4**).

Classical stepladder appearance of dilated small bowel loops is seen in the advanced SBO. The grossly dilated bowel loops lie horizontally in the central abdomen. The gaseous distension may be variable and depend upon the degree of obstruction, air swallowed, emesis, and nasogastric aspiration.

Tiny air packets trapped along the nondependent surface of small bowel folds on upright or decubitus ARs resemble a string of pearls or string of beads.

The sensitivity and specificity of the plain radiograph are variable. According to Maglinte et al, the sensitivity and specificity of plain film radiography for detection of SBO are 69 and 57%, respectively, which are similar to computed tomography (CT) scan when equal numbers of low- and high-grade obstructions were included.[8]

However, an air–fluid level can be seen in mechanical obstruction or adynamic ileus or can be a normal variant. More than two air–fluid levels in distended loops are abnormal.

Acute Colonic Pseudo-obstruction

Acute colonic pseudo-obstruction also known as Ogilvie's syndrome is progressive colonic dilation caused by

Fig. 3 Radiograph of abdomen reveals multiple dilated centrally located dilated small bowel loops distended with air suggestive of small bowel obstruction.

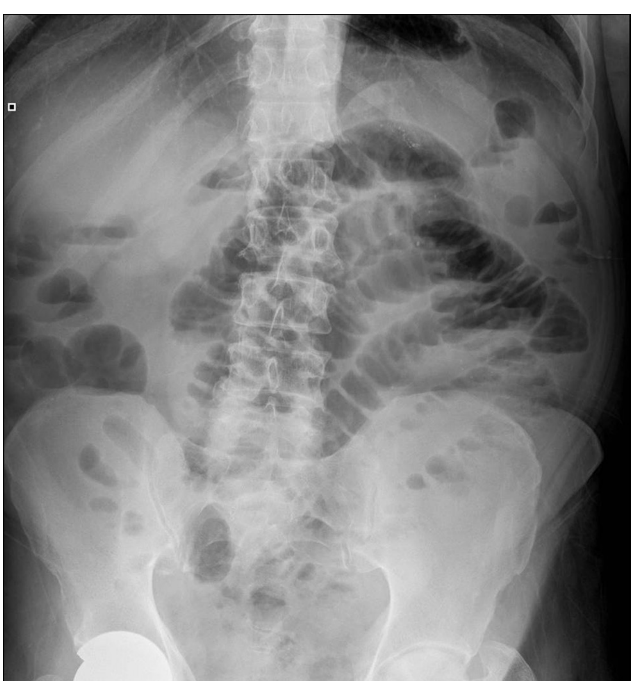

Fig. 4 Erect radiograph of abdomen reveals multiple dilated centrally located dilated small bowel loops with multiple air–fluid levels suggestive of small bowel obstruction.

interruption of sympathetic supply with unopposed parasympathetic innervation of the colon caused by various conditions such as intra-abdominal inflammation, alcoholism, cardiac disease, burns, retroperitoneal disease, trauma, and postdelivery or cesarean section.

On plain radiography, there is marked colonic distention confined to the cecum, ascending colon, and transverse colon with gradual transition near splenic flexure. However, gas may even extend up to the sigmoid colon. Absence of abrupt transition point, no obstruction lesion, and presence of rectal gas differentiate it from mechanical large bowel obstruction. Dilated cecum beyond 9 to 12 cm suggests impending perforation; however, cecal diameter up to 15 to 20 cm may be seen in Ogilvie's syndrome without any complications. Intramural gas in dilated cecum is strongly associated with bowel infarction and perforation. Colonoscopic or surgical intervention is indicated for prolonged cecal distention beyond 2 to 3 days. Diagnosis can be confirmed with water-soluble contrast enema or CT by demonstrating absence of mechanical obstruction.

Toxic Megacolon

Toxic megacolon is a fatal complication of inflammatory or infective colitis albeit it is commonly associated with ulcerative colitis. Off late *Clostridium difficile*-associated colitis has become a leading cause of toxic colitis. Other causes of toxic colitis include infections such as amebiasis, cholera, cytomegalovirus colitis and ischemic, collagenous colitis, and obstructive colorectal cancers. In ulcerative colitis, the incidence of toxic megacolon is around 10%.

The diagnosis of toxic colon is made on clinical and radiological features. These patients present with abdominal pain, distension, and signs of systemic toxicity. A grossly dilated transverse or entire colon (may even measure up to 6–15 cm) without obstructive lesion suggests the diagnosis. Nodularity of the mucosa is seen among the patients with ulcerative colitis due to inflammatory pseudopolyps.[9,10] Additional colonic air–fluid levels and loss or disturbance of colonic haustration may be seen. Colonic perforation indicates bad prognosis in toxic megacolon and shows pneumoperitoneum on AR. The dilatation of colon is not related to the duration of the illness and ~70% of the patients of colitis may present with toxic megacolon during the first episode of colitis. Increasing air in the small bowel indicates severe colitis and may develop toxic megacolon. Barium enema carries a risk of perforation and is contraindicated among these patients.[11]

Colonic Obstruction

Colonic cancer is the leading cause of colonic obstruction. Various other conditions such as diverticulitis, colonic volvulus, and adhesions may also cause colonic obstruction. Fecal impaction and FBs are other rare causes. Colonic obstruction is often seen in elderly patients and often deceptive compared with SBO. The sigmoid colon is a common site of obstruction as it is the narrowest part of the colon and it contains solid stools.

Proximal to the obstruction, the large colon becomes dilated with air up to 6 cm and cecum up to 9 cm. A paucity of air is seen in the distal colon and rectum on supine AR. Air–fluid levels may be evident on standing or decubitus film. If the ileocecal valve is incompetent, and small bowel loop dilatation is seen. A grossly dilated colon may at time perforate mainly due to progressive ischemia.

Volvulus

Volvulus occurs when the bowel loop twists around itself and along its mesentery. If the twisted bowel loop rotates more than 360°, then it causes close loop obstruction and chances of vascular compromise increase, which may result in bowel wall gangrene or perforation.

The sigmoid colon is the most common site of colonic volvulus followed by cecal and transverse colon volvulus. Patients with chronic constipation and sigmoid colonic redundancy due to a high-fiber diet, hospitalization are prone for gaseous distension of sigmoid colon and stretching of mesentery which leads to volvulus. Sigmoid volvulus may also be seen in pregnancy. Patients may present with abdominal pain, distension, and vomiting.

On a plain radiograph, the grossly distended sigmoid colon has a typical inverted U-shaped appearance. The dilated sigmoid colon without haustration extends cranially in the left upper quadrant above the transverse colon is called as the "northern exposure" sign and may elevate the left diaphragm. Here the transverse colon is considered as the equator of the abdomen. Sigmoid colon in its normal location is seen in the southern hemisphere and is inframesocolic. During volvulus, the apex of the sigmoid colon rises above the level of transverse colon, that is, to the north. Sometimes the dilated bowel may be seen in the midline or in the right upper quadrant.

The dilated sigmoid colon resembles coffee bean and is referred to as "coffee bean" sign (►**Fig. 5**). Three dense lines converging toward pelvis, two dense lines being outer walls, and central dense line being opposing inner wall are known as "three-line" or "Frimann-Dahl" sign.

For confirmation of the diagnosis, water-soluble contrast enema or CT abdomen is performed. A beak-shaped area often is seen at the level of the distal aspect of the twist in the sigmoid, beyond which there is no passage of contrast material. Additionally, an enema may occasionally reduce the obstruction. CT confirms the diagnosis and shows grossly distended sigmoid colon and demonstrates swirling of the mesentery at the site of the volvulus

Cecal Volvulus

Cecal volvulus occurs secondary to abnormal peritoneal fixation with mobile proximal colon and additional fulcrum for rotation such as adhesion or mass.

In half cases, cecum twists in the axial plane along its long axis and remains in right lower quadrant while in the other half cases, it twists and inverts with dilated cecum visible in the left upper abdomen. Another variant of cecal volvulus is cecal bascule in which cecum folds anteriorly without any twist occupying mid-abdomen.

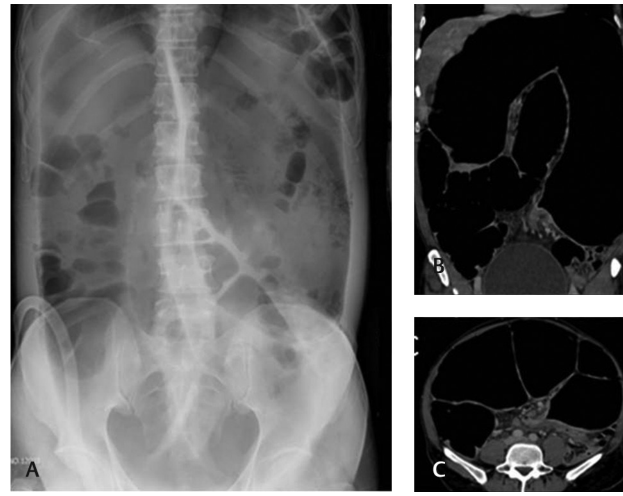

Fig. 5 Radiograph of abdomen (**A**) reveals large dilated inverted U-shaped bowel loop arising from pelvis with coffee bean shape suggesting sigmoid volvulus. Coronal (**B**) and axial (**C**) multiplanar computed tomography confirms sigmoid volvulus with swirl sign of mesentery.

Plain radiographs reveal large dilated hollow viscous in right lower to left upper abdomen depending upon the mechanism of twist. It usually shows haustration as opposed to sigmoid volvulus that is ahaustral. One air–fluid level may be present in cecal volvulus as opposed to sigmoid volvulus that shows multiple air–fluid levels. SBO is usually seen with a collapsed distal colon in cecal volvulus.

Diagnosis can be confirmed with a barium enema and CT scan. A single-contrast enema can confirm the diagnosis with collapsed distal colon up to the cecal twist with a beak-like appearance. CT scan is readily available and currently commonly used to confirm the diagnosis. Whirl sign, formed by spiraling bowel loops and mesentery associated with grossly distended cecum and proximal SBO, confirms the diagnosis.[12-14]

Acute Appendicitis

Acute appendicitis occurs secondary to obstruction of appendicular lumen with appendicular inflammation and can progress to perforation in untreated case. Plain radiographs findings are nonspecific in cases of appendicitis—appendicolith in patient with right iliac fossa pain, right iliac fossa increased soft tissue density due to localized inflammation/fluid, localized gas in right iliac fossa due local ileus, effacement of adjacent extraperitoneal fat plane, intraperitoneal or retroperitoneal gas in cases of perforation. Confirmation can be performed with ultrasound in children, thin individuals, and pregnant women. Ultrasonography shows blind ending, a peristaltic, noncompressible structure in right iliac fossa arising from cecum with diameter > 6 mm, thickened wall, and adjacent fat stranding/collection. CT scan shows dilated appendix with wall thickening, adjacent fat stranding, and collection.

Gasless Abdomen

Gasless abdomen radiograph in the neonatal age group indicates serious gastrointestinal tract abnormalities. However, several conditions, which range from benign to life-threatening conditions, may produce gasless abdomen on AR in adult.

Occasionally, healthy individuals who swallow very little air, especially during meals, may show little or no small bowel gas on AR.

Proximal to the obstruction, dilated small bowel loops are fluid-filled, which produce gasless abdomen on AR. Sometimes ischemic bowel disease may produce similar appearance on radiography. Gasless abdomen in suspected intestinal obstruction often indicates long-standing obstruction due to closed-loop obstruction, strangulation, or ischemic small bowel. It is potentially morbid condition and further evaluation with CT abdomen is helpful.

Ascites commonly produce gasless abdomen on plain radiograph. Ascites on radiograph produces various manifestations. Accumulated fluid along the liver obliterates the fat outlining of the internal edge liver, causes medial displacement of the lateral margin of liver and central location of the small bowel loops, while the ascending and descending colon are displaced medially resulting in an increase in flank stripe thickness, overall increase in abdominal density, and accumulated fluid in the pelvis produces dog-ear sign on AR.

Postsurgical patients especially total colectomy and sometimes after esophagogastrectomy, gastrectomy, and low anterior resection produce gasless abdomen on AR. Surgical clips seen on the AR may be a helpful clue indicating postoperative status.

Patients with gastroenteritis can have gasless abdomen on AR secondary to vomiting/diarrhea-related paucity of air in the bowel. Occasionally patients with large abdominal mass or gross hepatosplenomegaly occupy the abdominal cavity and produce gasless abdomen.

Pneumoperitoneum

Intra-abdominal perforation of gastrointestinal tract releases air in the peritoneal cavity with resultant pneumoperitoneum except for perforation of retroperitoneal part of duodenum and colon.

Various causes of pneumoperitoneum have been identified that include iatrogenic, spontaneous, traumatic, and miscellaneous[15] (►**Table 3**).

Patients with the pneumoperitoneum present with varying degree of pain abdomen, fever, and sepsis. The intensity of the pain depends upon type and amount of intestinal contents. AR is the initial radiological investigation and may detect pneumoperitoneum in around 55 to 85% of the patients.[16]

Miller and Nelson demonstrated that free air up to 1 mL can be detected below the diaphragm on properly exposed erect chest radiograph (►**Fig. 6**). For better yield, the patient should be kept in a left lateral decubitus position (at least 15–20 minutes prior to the chest X-ray). Standing AR is better than supine film to detect free air.[17] Left lateral decubitus AR can be performed in patients who are too sick to stand and actually more sensitive for detecting pneumoperitoneum than standing AR. Supine AR can be obtained in patients who are too sick to stand erect or lie in decubitus position.

Table 3 Pneumoperitoneum causes

Etiology	
Iatrogenic	Recent surgery, peritoneal dialysis, feeding tube placement, postendoscopy, gynecological instrumentation, and vigorous respiratory resuscitation
Spontaneous	Peptic perforation, ischemic bowel disease, bowel obstruction (benign or malignant), toxic megacolon, and inflammatory conditions such as appendicitis, tuberculosis, necrotizing enterocolitis
Traumatic	Blunt or penetrating trauma
Miscellaneous	Steroidal drugs, non-steroidal anti-inflammatory drugs, and pneumatosis coli Female genital tract–related (douching, sexual intercourse, insufflation)

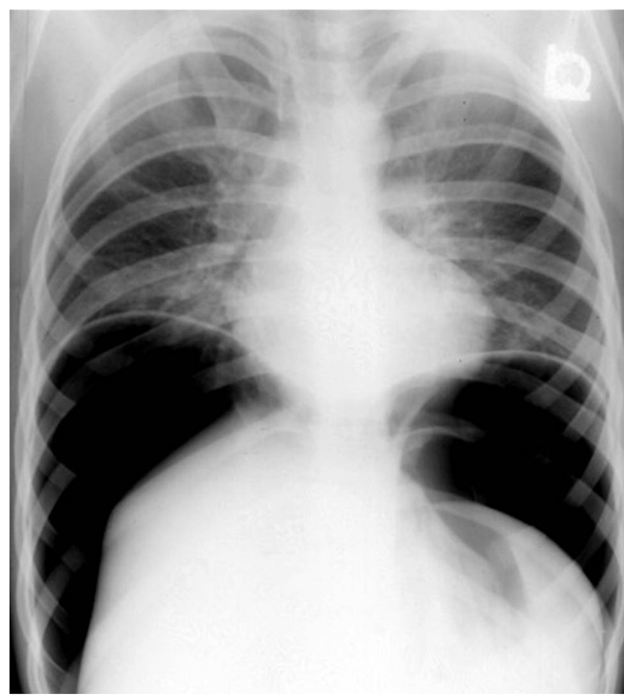

Fig. 6 Radiograph of chest and upper abdomen erect view reveals gross pneumoperitoneum under both domes of diaphragm suggestive of hollow viscous perforation.

Free peritoneal air gets accumulated in the nondependent position and may take variable shape and size. Depending upon the location of free air, Chiu et al classified radiographic findings into bowel-related signs, right-upper-quadrant signs, peritoneal ligament-related signs, and other signs.[18] Bowel-related signs include Rigler and Triangle signs (►**Figs. 7** and **8**).

Rigler sign is also known as the double-wall sign. On supine film, free intraperitoneal air in relation to the bowel is seen on either side of the bowel loop. This sign can be

Fig. 7 Portable supine radiograph of abdomen reveals pneumoperitoneum with demonstration of Rigler's sign.

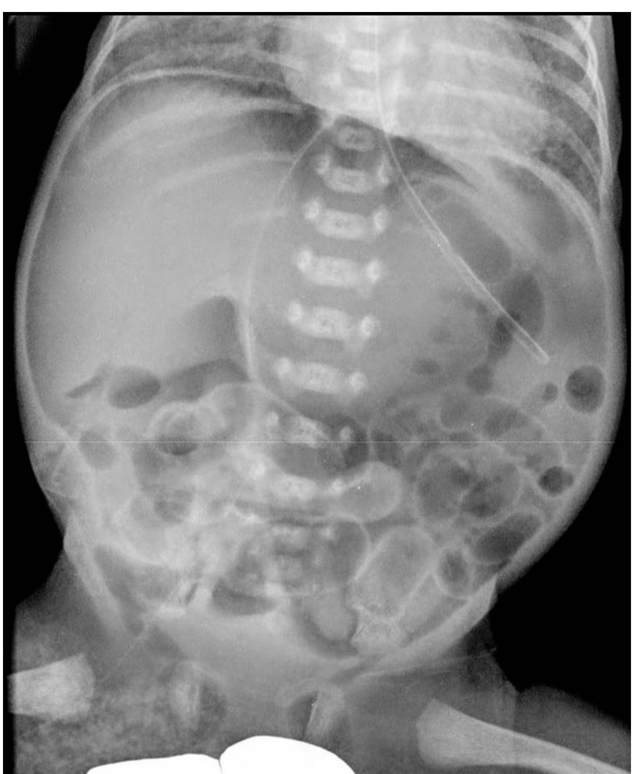

Fig. 8 Radiograph of chest abdomen of an infant reveal gross pneumoperitoneum with demonstration of football sign, falciform ligament sign, and Rigler's sign.

detected when large free peritoneal air is seen in condition such as colonic perforation. This sign can be better documented on CT scan. When free peritoneal air accumulates between three bowel loops or between two bowel loops and parietal wall, the shape resembles a triangle and this sign is called Triangle sign.[19]

Right-Upper-Quadrant Signs

When large free peritoneal air gets accumulated ventral to the liver, the liver appears more radiolucent. Free peritoneal air decreasing the brightness of the liver is called hyperlucent liver sign on the supine radiograph.[19]

Anterior superior oval sign is seen when single or multiple oval, round, or pear-shaped gas bubbles are seen over the silhouette of the liver.[19]

Fissure for ligamentum teres sign is characterized by elongated radiolucency due to free peritoneal gas accumulated within fissure for the ligamentum teres.[20] Gallbladder appears as a homogeneous opacity on supine film when a large amount of free peritoneal air gets accumulated around gallbladder. This sign is labeled as the visible gallbladder. The position of the gallbladder is a key factor. If the gallbladder is located more posteriorly, more free peritoneal air is required to delineate it.[21] Doge cap sign is due to air confined to the Morrison's pouch, that is, the posterior hepatorenal space. Air accumulated in the Morrison's space simulates the cap worn by the Doge (chief magistrate) of Venice.[22] Free peritoneal air gets accumulated in the subhepatic space and follows liver contour and resembles an oblong saucer or cigar. This free peritoneal air is labeled as hepatic edge sign.[23]

When normal diaphragmatic muscle slips protrude in moderate-to-large free peritoneal air producing distinctive elongated curvilinear shadows resemble Dolphin. This sign is labeled as Dolphin sign. On axial CT images, subdiaphragmatic pneumoperitoneum and slips of diaphragmatic muscles are well delineated.[24]

Peritoneal Ligament-Related Signs

Falciform ligament is a fold of peritoneum that attaches the liver to the ventral body wall and separates the two lobes of the liver. It extends from the umbilicus to the liver. When intraperitoneal free air accumulated in the anterior superior peritoneal cavity outlines the falciform ligament, it appears as a linear density. This is identified as falciform ligament sign.[19]

The ligamentum teres also known as the round ligament is the remnant of an obliterated left umbilical vein. When pneumoperitoneum outlines the extrahepatic ligamentum teres, it appears as linear density on the supine radiograph. This sign is well delineated on cross-sectional CT

Lower abdominal free peritoneal air may outline the lateral umbilical ligaments, which are remnant of fetal umbilical arteries and run inferolaterally from the umbilicus. Visualization of the medial umbilical ligament on supine film is called an inverted V sign and depends upon the amount of pneumoperitoneum and thickness of the ligament.[25]

Urachus is visualized in lower abdominal and pelvic pneumoperitoneum as a linear band running from umbilicus to the dome of the bladder and is termed as Urachus sign.[26]

Other Signs of Pneumoperitoneum

Football Sign

Large oval shaped radiolucency resembling American football on supine AR is indicative of massive pneumoperitoneum and diagnostic of gastrointestinal perforation. On supine films, free air accumulates in the nondependent part of the abdominal cavity anterior to the abdominal viscera. Massive pneumoperitoneum may outline the falciform ligament in the upper abdomen or median, medial, or lateral umbilical ligaments in the midline in the lower abdomen. These components indicate seams or laces of an American football.

This sign is common in infants due to the relatively smaller peritoneal cavity and late presentation. Football sign is seen commonly in gastric perforation and may be seen in necrotizing enterocolitis, bowel obstruction (i.e., malrotation with midgut volvulus, Hirschsprung disease, meconium ileus, or atresia), and sources of inflammation such as gastric or duodenal ulcers. Occasionally, it may be seen in patients on a mechanical ventilator.[27]

Cupola Sign

Free air accumulated in the median subdiaphragmatic space beneath the central tendon of the diaphragm, caudal to the heart has typical sharp upper margin and ill-defined lower margin. This free air resembles a rounded dome of the roof and is termed as Cupola sign.[18,28]

Subphrenic Radiolucency

Radiolucency that appears beneath the diaphragm, either right or left side in the supine chest radiographs, has been defined as "subphrenic radiolucency."[25]

Focal Radiolucency

Abnormal gas pattern presenting on the supine films that do not fit any of the aforementioned sign has been called "focal radiolucency."[25]

Pneumoretroperitoneum

Perforation of retroperitoneal portion of the duodenum, ascending and descending colon, and rectum results in pneumoretroperitoneum. Retroperitoneal air accumulates in a linear fashion along the margins of the kidneys, psoas muscles, and medial subdiaphragmatic region.

FBs can be ingested, inserted into a body cavity, or deposited into the body by a traumatic or iatrogenic injury. Most of the nonmedical FBs pass through the gastrointestinal tract without complications except minor mucosal injury. Complications of FBs include intestinal obstruction, secondary infection and abscess formation, perforation, or hemorrhage. We discuss various ingested and inserted FBs and medical devices seen on AR.

Ingested Foreign Bodies

Clinical and radiological presentation of ingested FBs varies and depends upon the age of the patient, kind of FB, and purpose of ingestion.

In extreme ages and mentally challenged persons, accidental ingestion of FB is more frequent while adults may ingest FB with purpose; either as an addiction, drug trafficking, or for sexual pleasure. Repeated ingestion of FB may be seen among psychiatric patients.

Albeit most of the FBs are passed off without any complication, few of the FBs may cause bowel perforation or impaction or secondary infection. Sharp and elongated FBs often get impacted at normal anatomical angulation–duodenal cap, duodenojejunal flexure, ileocecal valve, or appendix or anatomical narrowing of bowel, for example, terminal ileum, ileocecal valve, Meckel's diverticulum, or bowel stricture.

Metallic sharp objects such as needles, safety pins, or fish or chicken bones cause acute perforation. Many times, FBs may cause partial perforation or chronic inflammatory reaction with superadded infection. Often the FBs due to chronic inflammatory reaction get encrusted with bile and mineral salts and remain undiagnosed even after surgery.

Large spherical or cylindrical objects often get obstructed at the level of pylorus or anatomical or pathological narrowing of the bowel loop.

Appendicitis, appendiceal perforation, and appendicular abscess formation may develop months after FB ingestion.[29] However, many do not support this postulation, as appendicitis is a common condition and FB with appendicitis may be just an incidental finding.

Most of the metallic FBs except aluminum are radiopaque and can be readily seen on a radiograph. Enteric coated pills, animal bones, sand, gravel, and some of the poisons and medicines are radiopaque (►**Fig. 9**). Most of the fish bones, woods, thorns, and plastic items are nonradiopaque and are not seen

Fig. 9 Radiograph of abdomen reveals multiple dense tablets in bowel loops.

on radiography. Glass FBs as small as 1 to 2 mm size when get deposited in soft tissue are visible on the radiograph.

Contents of the FB if get released in the bowel may be hazardous.

Disk or button batteries used in electric gadgets often pass without complication. The chemical composition of batteries is hazardous and contains alkaline corrosive agents such as aqueous potassium hydroxide and heavy metals such as mercury and cadmium. If released in the bowel, it leads to bowel perforation and heavy metal poisoning.[30]

Drug smugglers swallow balloons containing narcotic drugs. If these balloons get ruptured in the intestine, it may cause acute drug overdose. Children and mentally challenged persons often ingest FBs in multiples and should get thoroughly examined from skull base to anus.

Most of the medications are radiolucent and not seen on a radiograph. Some of the medications chloral hydrate, the phenothiazines and many enteric-coated including pills are radiopaque.

Foreign Body Insertion

FBs may be inserted in rectum, urethra, bladder, or vagina either by children or mentally challenged individuals or for sexual pleasure. Sometimes rectal FBs may be iatrogenic and include forgotten thermometer, rectal tubes, enema tips and covers, or oral or topical medications.

Most of the rectal or urethral FBs irrespective of their size, shape, or sharpness don't cause significant trauma as often they are well lubricated by natural fluid and often due to repeated dilatation these objects are well accommodated.

Drug traffickers often swallow or insert narcotic drugs wrapped in balloon or condom in rectum, vagina, or colostomy. The appearance of these drugs is often variable on the radiograph, may be radiopaque or lucent, and often difficult to differentiate from fecal material. These packets may be visible as multiple well-circumscribed opacities of varying density in stomach, small or large bowel. Double condom sign represents trapped air in multiple layers of condom. Sometimes these packets may demonstrate a rosette configuration at one end.

Often bladder FBs get encrusted by mineral salts and debris and form bladder stones.[31] Bladder calculus, when seen in children or young individuals possibility of encrusted FBs, needs to be ruled out.

Bladder FBs are often mediolaterally placed on AR while that in the vagina and rectum they are craniocaudally oriented in children. In an adult, vaginal objects may be mediolaterally oriented.

Retained FBs in the rectum can migrate in the colon and can even reach to the hepatic flexure. Small FBs often get calcified and form fecaliths. Rectal FBs may cause perforation, bowel obstruction, or bleeding.

Medical Devices

Depending upon the location and orientation, one can identify the implanted device and its malposition.

Nasogastric (NG) tube is used either for feeding purpose or aspiration of gastric contents. The NG tube has multiple side holes and a terminal lead ball at its tip. The tip of the NG tube should be 10 cm caudal to the gastroesophageal junction and lie in the gastric antrum. If the side holes are seen in the esophagus, there is an increased risk of aspiration. If NG tube is used for aspiration purpose, then its tip and side holes should be in the dependent portion of the stomach. If the tip indents against the gastric cardia, it may induce vomiting.[4]

The tip of the nasojejunal tube used for feeding purpose should be inserted 10 to 12 cm beyond the ligament of Treitz to avoid aspiration. Large bore polyethylene or polyvinyl chloride tubes used to feed critical patients may cause mucosal injury or sometimes even bowel perforation when kept for a long time.

Gastrostomy tubes used for long-term or permanent feeding patients are of various length and appearance. The normal location of the tube is over the body of the stomach. Inflated balloon prevents tube displacement. Post gastrostomy tubes insertion imaging is not advocated unless complications such as perforation are suspected. Inflated balloon position can be checked on AR. Correctly placed tube lies in the stomach body anchored to the abdominal wall and can be seen on lateral AR. Additional cross-sectional imaging is recommended in case of tube migration. A large amount of pneumoperitoneum may be seen just after tube insertion due to minor leakage and can be self-limiting among asymptomatic patients. However, in symptomatic patients, if pneumoperitoneum is seen further imaging may be performed.

Ventriculoperitoneal (VP) shunt is a catheter inserted for drainage of the obstructed ventricle, which is tunneled subcutaneously into the peritoneal cavity. Abdominal imaging is asked when various complications such as shunt discontinuity, leak, obstruction, migration, or infection are suspected. Kink or breach in the VP shunt can be seen on AR. A plain radiograph may show abscess with air–fluid levels if there is contamination, which may be due to migration of shunt into bowel or infected shunt. Large intraperitoneal cerebrospinal fluid pseudocysts may be seen on AR causing mass effect on the abdominal viscera. Barium impregnated catheter when placed for a long period may get encrusted with calcium and may be visible on a radiograph.

When an intrauterine contraceptive device (IUCD) is not found on ultrasound pelvis, plain radiograph of the pelvis is recommended to look for the misplaced device.[32]

Normal device has varying orientation depending upon the uterine position. Device migration into the abdominal cavity may occur due to uterine perforation and may be life threatening and need urgent surgical management. Expulsion of the IUCD may be seen in the endocervical canal or vagina.[4]

Aortic stent grafts used for aortic aneurysm treatment can be easily seen on AR. Certain complications as stent expansion, migration, kinking, dislocation, and fracture can be seen in AR. Prior films may be helpful for the assessment of the position of the stent and stent migration.[4]

The ureteric stents are placed for drainage of urine across the obstruction or for the treatment of urinary stones. The stents have proximal and distal pigtail loops to prevent migration. Stents are either placed temporarily or if used for long term then need periodic replacement. Prolonged indwelling stents are at risk of encrustation in patients having lithogenic urine. Irregular calcific densities can be seen along the stent in these patients. Encrustation complicates stent removal and increases the risk of stent fracture.[4]

Retained surgical FBs are rare and pose a major medical and legal problem. The clinical presentation is highly variable and nonspecific; however, few patients may present with intestinal perforation, hemorrhage, secondary infection, peritonitis, or abscess formation. The most common site of retained surgical FBs is abdomen and pelvis. Common leftover intra-abdominal FBs include surgical sponge or needles. Abdominal towels, artery forceps, pieces of broken instruments, or irrigating sets and rubber tubes are the other uncommon retained FBs (►**Figs. 10** and **11**).

Metallic surgical FBs can be easily detected on the AR due to their distinctive appearance. Most of the surgical sponges are incorporated with radiopaque markers and can be visualized on AR (FIG). However, the sponges may get degenerated over a time period or distorted, folded or twisted and often difficult to diagnose on plain radiography alone. Associated complications as intestinal obstruction or perforation can be seen on a radiograph.

Calcification on AR is a frequent finding and seen in various morphological form and location. Calcification can be seen in vessel or conduit wall, hollow, or solid organs or neoplasms. Depending upon the morphology, location, and mobility and pattern of calcification one can limit cause of calcification and the organ affected.

Four different kind of calcification are seen depending upon contour, border, sharpness, marginal continuity, and internal architecture. These include concretions, conduit wall calcification, cystic calcification, and solid mass calcification.

Concretions—Concretions or precipitates often get deposited in the vessel or hollow viscus and show central lucent nidus and peripheral faint or brightly radiopaque density depending upon calcium concentration. They are variable in shape and have contiguous uninterrupted margins. Gallbladder calculi are faceted, while the same composition biliary calculi are rounded (►**Fig. 12**). Similarly, ureteric calculi and

Fig. 10 Radiograph of abdomen in a recent postoperative patient reveals curvilinear hyperdensity in pelvis secondary to radiopaque marker in retained sponge—gossypiboma.

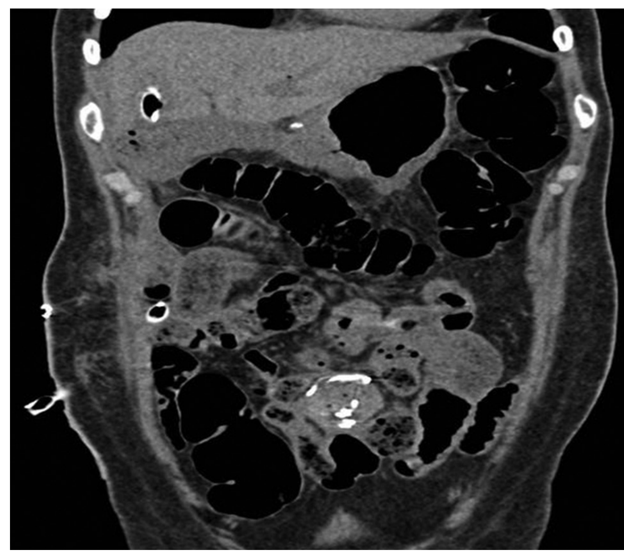

Fig. 11 Coronal multiplanar computed tomography confirms gossypiboma in above-mentioned radiograph.

Fig. 12 Erect radiograph of abdomen reveals multiple rounded gall stones with small bowel obstruction likely secondary to adhesions.

pancreatic calcification have irregular edges, while bladder calculi show smooth outer surface.

Concretions show variable density pattern. Urinary calculi are homogenously dense, phleboliths show central area of lucency, while gallstones, bladder concretions, and appendicoliths have concentric laminations.

Rarely concretions are seen out of expected anatomical locations that include phleboliths in hemangioma, gall stone impacted in the distal ileum following cholecystoenteric fistula, or intraperitoneal appendicoliths following ruptured appendicitis.

Conduit wall calcification—blood vessels, ureter, urethra, vas deferens, pancreatic ducts, and bile ducts are common conduits seen in abdominal cavity. Conduit calcification is circumferential and appear ring like density when seen end on. Conduit wall calcification can be seen as linear opacities when the arteries are oriented parallel to the X-ray beam. It is often discontinuous along the course of vessels; for example, abdominal aorta and its branches often show heavily atherosclerotic calcified plaque on AR. Aortic bifurcation and intrarenal atherosclerotic calcification has marginal branching pattern. Isolated calcific plaque may simulate calculus when seen in relation to renal pelvis vessels.

Cyst Wall Calcification

Calcium deposition can occur in the wall of fluid-filled masses such as true epithelial cysts, pseudocysts, and aneurysms. On AR, it appears as curvilinear smooth calcification with an ovoid configuration and is often discontinuous. There may be mass effect on the adjacent organs or the cyst may get distorted by the adjacent viscera or vessels.

Cyst like calcification may be seen in vascular aneurysms, hydatid cysts, perinephric hematoma, adrenal cysts, renal carcinomas, and porcelain gallbladder. Sometimes these may resemble eggshell. Cyst wall calcification in lower abdomen can be seen in mesenteric cysts, calcified appendicular mucoceles, and calcified benign tumors of the ovary.

Solid Mass Calcification

Solid mass calcification has wide range of radiographic appearance and seen anywhere in the abdomen. These are often irregular with dense center and incomplete margin. These calcifications can be amorphous, curvilinear, flocculent, or speckled. Calcified lymph nodes are the most common solid mass like calcification seen in Indian subcontinent. They are seen along the long axis of mesentery oriented from left upper quadrant to right lower quadrant. Calcified fibroids are the most common lower abdominal calcific masses in women. They are often flocculent radio densities with radiolucencies within of variable size (►**Fig. 13**).

Calcific adenomas, hamartomas, hemangioma, renal carcinomas, tuberculous, and chronic pyogenic abscesses of the kidney, liver, spleen, and calcified pancreatic masses (benign or malignant cystadenomas) occasionally can be seen on AR (►**Fig. 14**).

Fig. 13 Radiograph of pelvis reveals rounded pelvic masses with popcorn calcification suggestive of calcified fibroids.

Fig. 14 Radiograph of abdomen reveals large coarse calcified liver hemangioma.

Location

Conventionally the AR is divided in upper and lower quadrants, which are further divided in right and left quadrants. Location and pattern of calcification can be helpful for limiting differential diagnosis (►**Table 4**).

Mobility

Mobility of calcification may provide additional clue for diagnosis. Change in location of calcific density may be associated with gravity, respiration, peristaltic activity, and growth of masses. AR when taken in different position may show change in position of calculi in gallbladder and grossly hydronephrotic kidney. Depending upon the distensiblity of bladder ovarian teratoma may show change in position. Ureteric calculi often change position when examined over different time.

Table 4 Location of calcifications

Location	Organ and related pathology
Right upper quadrant	• Gallbladder—calculi, Porcelain gallbladder • Liver—calcific cysts, granuloma • Renal—calculi, calcific abscess • Adrenal—hematoma, tumor • Vascular calcification • Pancreas—chronic calcific pancreatitis (►**Fig. 15**), tumors
Left upper quadrant	• Spleen—granuloma, calcific cyst, abscess • Kidney—calculi, cysts • Adrenal—hematoma, tumor • Pancreas—chronic calcific pancreatitis, tumors • Vascular—calcifications
Right lower quadrant	• Ureter—ureteric calculi • Bowel—appendicolith, calcific diverticulum • Lymph node
Left lower quadrant	• Ureteric calculi • Bowel—calcific diverticulum • Lymph node
Pelvis	• Urinary bladder, lower ureteric calculi, phleboliths • Uterus—fibroids • Ovary—calcific ovarian masses • Lymph node

Fig. 15 Radiograph of abdomen reveals pancreatic calcifications and thumbprinting.

Conclusion

AR is often the first radiological investigation performed in acute abdomen. Although the role of plain radiograph is limited in the era of cross-sectional imaging, systemic approach and vigilant search for the radiological features on AR may be diagnostic and decide further line of investigation. Various gas patterns of intraluminal and free peritoneal air are helpful in localizing pathology. Different patterns of calcification seen in abdomen, ingested or inserted FBs, and location of medical devices give a clue to diagnosis.

Funding
None.

Conflict of Interest
None declared.

Acknowledgments
The authors are thankful to Dr. Ravi Ramkantan, Head of Department, Kokilaben Dhirubhai Ambani Hospital, and KEM Hospital, Mumbai, for providing guidance and the figures.

References

1 Mirvis SE, Young JW, Keramati B, McCrea ES, Tarr R. Plain film evaluation of patients with abdominal pain: are three radiographs necessary? AJR Am J Roentgenol 1986;147(3):501–503
2 Ahn SH, Mayo-Smith WW, Murphy BL, Reinert SE, Cronan JJ. Acute nontraumatic abdominal pain in adult patients: abdominal radiography compared with CT evaluation. Radiology 2002;225(1):159–164
3 Ponrartana S, Coakley FV, Yeh BM, et al. Accuracy of plain abdominal radiographs in the detection of retained surgical needles in the peritoneal cavity. Ann Surg 2008;247(1):8–12
4 Loo JT, Duddalwar V, Chen FK, Tejura T, Lekht I, Gulati M. Abdominal radiograph pearls and pitfalls for the emergency department radiologist: a pictorial review. Abdom Radiol (NY) 2017;42(4):987–1019
5 James B, Kelly B. The abdominal radiograph. Ulster Med J 2013;82(3):179–187
6 Nanni C, Garbini A, Luchett P, et al. Ogilvie's syndrome (acute colonic pseudo-obstruction): review of the literature and report of four additional cases. Dis Colon Rectum 1982; 25:157–166
7 Townsend CM Jr, Beauchamp RD, Evers BM, Mattox KL, Sabiston Textbook of Surgery International Edition. Elsevier Health Sciences; 2015
8 Maglinte DD, Reyes BL, Harmon BH, et al. Reliability and role of plain film radiography and CT in the diagnosis of small-bowel obstruction. AJR Am J Roentgenol 1996;167(6):1451–1455
9 Autenrieth DM, Baumgart DC. Toxic megacolon. Inflamm Bowel Dis 2012;18(3):584–591
10 Halpert RD. Toxic dilatation of the colon. Radiol Clin North Am 1987;25(1):147–155
11 Wolf BS, Marshak RH. "Toxic" segmental dilatation of the colon during the course of fulminating ulcerative colitis: roentgen findings. Am J Roentgenol Radium Ther Nucl Med 1959;82:985–995
12 Rosenblat JM, Rozenblit AM, Wolf EL, DuBrow RA, Den EI, Levsky JM. Findings of cecal volvulus at CT. Radiology 2010;256(1):169–175
13 Peterson CM, Anderson JS, Hara AK, Carenza JW, Menias CO. Volvulus of the gastrointestinal tract: appearances at multimodality imaging. Radiographics 2009;29(5):1281–1293

14 Moore CJ, Corl FM, Fishman EK. CT of cecal volvulus: unraveling the image. AJR Am J Roentgenol 2001;177(1):95–98
15 Ly JQ. The Rigler sign. Radiology 2003;228(3):706–707
16 Roh JJ, Thompson JS, Harned RK, Hodgson PE. Value of pneumoperitoneum in the diagnosis of visceral perforation. Am J Surg 1983;146(6):830–833
17 Woodring JH, Heiser MJ. Detection of pneumoperitoneum on chest radiographs: comparison of upright lateral and posteroanterior projections. AJR Am J Roentgenol 1995;165(1):45–47
18 Chiu Y-H, Chen J-D, Tiu CM, et al Reappraisal of radiographic signs of pneumoperitoneum at emergency department. Am J Emerg Med 2009;27(3):320–327
19 Cho KC, Baker SR. Extraluminal air. Diagnosis and significance. Radiol Clin North Am 1994;32(5):829–844
20 Cho KC, Baker SR. Air in the fissure for the ligamentum teres: new sign of intraperitoneal air on plain radiographs. Radiology 1991;178(2):489–492
21 Radin R, Van Allan RJ, Rosen RS. The visible gallbladder: a plain film sign of pneumoperitoneum. AJR Am J Roentgenol 1996;167(1):69–70
22 Brill PW, Olson SR, Winchester P. Neonatal necrotizing enterocolitis: air in Morison pouch. Radiology 1990;174(2):469–471
23 Menuck L, Siemers PT. Pneumoperitoneum: importance of right upper quadrant features. AJR Am J Roentgenol 1976;127(5):753–756
24 Cho KC, Baker SR. Depiction of diaphragmatic muscle slips on supine plain radiographs: a sign of pneumoperitoneum. Radiology 1997;203(2):431–433
25 Pinto A, Miele V, Schillirò ML, et al. Spectrum of Signs of Pneumoperitoneum. Semin Ultrasound CT MR 2016;37(1):3–9
26 Jelaso DV, Schultz EH Jr, The urachus–an aid to the diagnosis of pneumoperitoneum. Radiology 1969;92(2):295–298
27 Rampton JW. The football sign. Radiology 2004;231(1):81–82
28 Mindelzun RE, McCort JJ. The cupola sign of pneumoperitoneum in the supine patient. Gastrointest Radiol 1986;11(3):283–285
29 Balch CM, Silver D. Foreign bodies in the appendix. Report of eight cases and review of the literature. Arch Surg 1971;102(1):14–20
30 Studley JGN, Linehan IP, Ogilvie AL, Dowling BL. Swallowed button batteries: is there a consensus on management? Gut 1990;31(8):867–870
31 Lebowitz RL, Vargas B. Stones in the urinary bladder in children and young adults. AJR Am J Roentgenol 1987;148(3):491–495
32 Peri N, Graham D, Levine D. Imaging of intrauterine contraceptive devices. J Ultrasound Med 2007;26(10):1389–1401
33 James M. Messmer and Marc S. Levine; Gas and Soft Tissue Abnormalities; Textbook of Gastrointestinal Radiology (4th edition), 12, 178–196. Philadelphia, PA: Elsevier/Saunders; 2015

