

## **Abdominal extra-luminal gas - Is it always gastrointestinal perforation?**

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## Learning objectives

- Recognize the presence of extra-luminal gas and its radiological findings to determine its etiologic meaning;
- Identify causes of extra-luminal gas in the abdomen that require emergent approach by looking for image signs of underlying pathologic process.

## Background

Pneumoperitoneum refers simply to air within the peritoneal cavity. A pneumoperitoneum frequently indicates a perforated abdominal viscus which requires emergent surgical management making an early diagnosis essential. The careful interpretation of CT findings as well as the location of free gas can be diagnostic leads. Frequently, extraluminal gas bubbles are found in close vicinity of the perforation site.

We should not assume a narrow diagnostic hypothesis since treatment options, conservative or emergent, depend on the underlying pathology. The presence of extra-luminal air in the abdomen can have a multiplicity of differential diagnosis such as infection of the peritoneal cavity by gas producing organisms, ischemia, neoplasia, trauma and thoracic causes. Benign causes such as recent instrumentation should also be considered. Intraperitoneal free air is considered normal only during the first week after abdominal surgical procedures, after this time period has elapsed, it should be considered a pathological finding.

## Findings and procedure details

The peritoneal and extraperitoneal spaces show no gas under normal circumstances. Damage to the GI tract, such as commonly caused by inflammation, malignancy or trauma, can cause leakage or gas from the aforementioned tract to the surrounding peritoneal or extraperitoneal spaces. In the supine patient, this gas will rise lying against the anterior abdominal wall.

According to the location, the extra-luminal gas can be classified as pneumoperitoneum, pneumoretroperitoneum, intestinal pneumatosis and intra-hepatic gas including aeroportia and pneumobilia or even intraparenchymatous gas in solid organs.

The intraperitoneal segments of the GI tract compose the stomach, part of the duodenum, small bowel, appendix, transverse and sigmoid colon.

The retroperitoneal segments of the GI tract are the oesophagus, second, third, or fourth portion part of the duodenum, ascending and descending colon and rectum and the retrocaecal appendix.

A supine abdominal radiograph and upright chest radiograph may demonstrate free gas, the latter being one of the gold standards for demonstrating subdiaphragmatic air. Several findings are characteristic of pneumoperitoneum including ( [Fig. 1](#) on page 8 and [Fig. 2](#) on page 8 ):

- Double wall sign (**Rigler's sign**) which shows air outlining both sides of the bowel wall;
- **Falciform ligament sign** is created by free air in a supine patient outlining the falciform ligament;
- The **football sign**, when large amounts of gas shape the peritoneal cavity.
- Free air beneath the diaphragm (**Cupola sign**)
- **Continuous diaphragm sign**, when a large pneumoperitoneum exists and the left hemidiaphragm and right hemidiaphragm contrasted by the free gas and the entire diaphragm is visualized.

However, the conventional radiological study has low sensitivity and specificity and cannot determine the site of perforation and normal radiographs do not exclude the diagnosis.

US can detect a minimal amount of free gas because of its ability to produce distinctive bright echoes and ring down artifact.

CT has the advantage of being highly sensible in detecting extra-luminal gas and at the same time allows the evaluation of the entire abdominal cavity that can help to acknowledge the underlying pathologic process, because treatment varies dramatically depending on the source. When suspecting a perforation, the CT study should use multiplanar reconstructions and the window should be adequate (lung window) to improve gas bubbles identification. One should carefully search for a perforation site looking for defects in the bowel wall and secondary signs like abnormal bowel wall thickening or mesenteric stranding. The location of the gas can be a diagnostic clue of the perforation site, for instance, if specifically found in the gastroduodenal ligament it can indicate a gastric or duodenal perforation.

## CAUSES OF EXTRALUMINAL GAS

There are many factors that can cause extraluminal air, be it causes which require emergent treatment or on the contrary, self-limited causes that can be approached with conservative treatment. Some frequent causes of pneumoperitoneum will be approached.

### **Perforated gastric or duodenal ulcer**

Perforation of a peptic ulcer is the most common cause of pneumoperitoneum or pneumoretroperitoneum ( [Fig. 3](#) on page 9 and [Fig. 4](#) on page 10 ). In most of the cases the ulcer self-seals with omentum. The finding of a few bubbles of gas adjacent to the stomach or the gastroduodenal ligament can point to a peptic ulcer perforation.

From a medical image standpoint, on a CT one will find air or liquid close to the duodenum and a gap in the duodenal wall which can be associated with thickened parietal duodenum, abnormal wall enhancement, abscess and adjacent fat densification. There are clues in the distribution of the gas bubbles that can allow one to infer a possible rupture point:

- Gas in right anterior pararenal space points to perforated anterior wall of the stomach and duodenal bulb.
- Air in the lesser sac points to perforated posterior wall of the stomach;

Gas can migrate from the perforation along the hepatoduodenal ligament into the fissure for the ligamentum venosum and be found adjacent to the portal vein.

### **Perforated diverticulitis**

Perforated diverticulitis is a common cause of acute abdomen, frequently presenting in the sigmoid colon. Perforated sigmoid diverticulitis originates free gas, first tracking in to the adjacent sigmoid mesentery and later the rest of the peritoneal cavity ( [Fig. 5](#) on page 11, [Fig. 6](#) on page 12 and [Fig. 7](#) on page 13).

### **Perforated appendix**

Occasionally in the presence of appendicitis there can occur perforation of the organ causing free gas which can spread to the rest of the peritoneal cavity. A retrocaecal placement of this organ can cause retroperitoneal gas.

### **Emphysematous cholecystitis**

Abdominal and pelvic emphysematous infections can be life-threatening conditions that require aggressive medical or even surgical management.

Emphysematous cholecystitis is caused by gas-forming organisms that infect the gallbladder wall. Gas can be found in both the gallbladder wall and lumen and the development of the abscess can lead to bile duct involvement. Emphysematous cholecystitis shows a higher prevalence of acalculous disease and gallbladder perforation when compared with all cases of acute cholecystitis.

Ultrasound examination can show highly echogenic reflectors with low-level posterior shadowing as well as reverberation artifact ("dirty shadowing") with luminal or gallbladder wall origin ( [Fig. 8](#) on page 14 ). The most sensitive and specific imaging method for identifying gas within the gallbladder wall or lumen is the CT ( [Fig. 9](#) on page 15 ).

### **Emphysematous pancreatitis**

Severe acute pancreatitis can rarely lead to emphysematous pancreatitis caused by necrotizing infection of the pancreas. The presence of gas-forming bacteria leads to the formation of gas within or around the pancreas ( [Fig. 10](#) on page 16 ).

Ct is the best way to detect the existence of parenchymal gas as well as characterizing its location and distribution; it also allows the assessment of the possible consequences such as abscess formation and parenchymal necrosis. This condition has poor prognosis making early surgical debridement or percutaneous drainage necessary.

### **Fistulization in the GI tract**

Often, either spontaneously or following surgical procedures, fistulizing tract with the GI tract requiring surgical treatment can occur. Biliary ileus is a rare cause of intestinal obstruction in which a bilio-enteric communication causes the passage of a biliary calculus to the GI tract, through a fistula and usually to the duodenum. The image findings of this entity are named Rigler triad: consisting of the presence of air in the biliary tract (pneumobilia), small intestinal dilation and the presence of calculus in the intestinal lumen (usually in the terminal ileum) ( [Fig. 11](#) on page 17 ).

Sometimes, leakage or fistulizing tracts arise after intraabdominal surgical procedures ( [Fig. 12](#) on page 18 ). It is of paramount importance to identify the fistulizing tract in the CT as well as signs of complications to perform a correct therapeutic approach.

### **Pneumatosis intestinalis**

Pneumatosis intestinalis can be either a primary or secondary disorder that refers to gas within the bowel wall. Primary pneumatosis intestinalis occurs less frequently than secondary and manifests as cystic gas on the colon on plain film and CT occurring when no other abnormality is apparent. Secondary pneumatosis intestinalis is much more frequent and arises in the setting of pulmonary or bowel disease showing up as a linear gas collection throughout the bowel wall. Pneumatosis intestinalis can be an incidental finding for instance in a COPD patient, however, in an acutely ill patient with mesenteric ischemia, the presence of an ischemic bowel is highly suspect. When an intestinal ischemia is present, besides pneumatosis intestinalis, gas can also be seen in the small mesenteric veins, superior mesenteric vein or portal vein ( [Fig. 13](#) on page 19 ).

### **Intrahepatic gas**

In the liver, gas can be inside the biliary tree, portal vein or intrahepatic ligaments as well as the hepatic parenchyma.

Pyogenic liver abscesses are most frequently caused by biliary tract disease. The highest sensitivity test to detect liver abscesses is the CT, the presence of gas favors the imaging diagnosis of abscess. The manifestations of gas within a liver abscess can be as multiple small foci of gas, large quantities of gas or air-fluid levels.

Bowel ischemia is the most frequent cause of portal venous gas. In a CT, the accumulation of gas in the intrahepatic portal veins causes low-attenuation areas which carries the gas by centrifugal blood to the hepatic periphery, extending to within 2cm of the liver capsule. Unlike pneumobilia, when portal vein gas collects, its collections are smaller and find themselves in the liver periphery ( [Fig. 13](#) on page 19 ).

The presence of gas in the biliary tree (pneumobilia) is most commonly a consequence of surgery like choledochoenterostomy or sphincterotomy of the sphincter of Oddi. There are other causes such as trauma, infection by gas producing organisms (i.e. emphysematous cholecystitis), fistulas connecting the biliary system and the intestinal tract (i.e. gallstones ileus) or malignant involvement of the ampulla of Vater. Pneumobilia is more frequent in the left lobe with a branching pattern with a more central placement than portal venous gas ( [Fig. 11](#) on page 17 ). When using US, the presence of air in the bile ducts is responsible for bright reflections with shadowing and ring-down artifacts. When positioning the patient, the gas has a tendency to displace.

A gastro duodenal perforation can cause free gas that will pass along the hepatoduodenal ligament to the fissure for the ligamentum venosum, manifesting as discrete locules instead of a branching pattern ( [Fig. 14](#) on page 20 ).

However, in more recent years, distinct clinical conditions and interventions have been known to cause hepatic gas at imaging. Surgery, hepatic artery embolization, percutaneous tumor ablation, liver biopsy and the use of oxidized regenerated cellulose (surgical sponge used to achieve intraoperative hemostasis), the latter, which can contain gas is identified with CT up to 8 weeks after placement depending on the type, site and amount used. This haemostatic sponge may mimic a post-operative abscess and it is important to recognize it in imaging studies since it can lead to unnecessary intervention. Features that herald the presence of a haemostatic sponge rather than an abscess on CT are gas bubbles of uniform size and linear configuration and an area with soft tissue density without peripheral enhancement or gas-fluid levels. One must acknowledge that the presence of haemostatic materials can also co-exist with abscesses in the same site ( [Fig. 15](#) on page 21 and [Fig. 16](#) on page 22 ).

### **Portomesenteric venous gas**

Mesenteric ischemia is the most serious and frequent cause of portomesenteric vein gas in adults. The bowel wall ischemic damage ranges from mucosal erosions or ulcerations to transmural necrosis. Because of this damage it is believed that gas in the portal veins arises from luminal gas that perforates the bowel wall. The small mesenteric, superior and inferior mesenteric veins carry gas from the intestinal lumen to the portal vein and into the liver. Changes in bowel wall thickening, edema and pneumatosis are also found in mesenteric ischemia ( [Fig. 13](#) on page 19, [Fig. 17](#) on page 23 and [Fig. 18](#) on page 24 ).

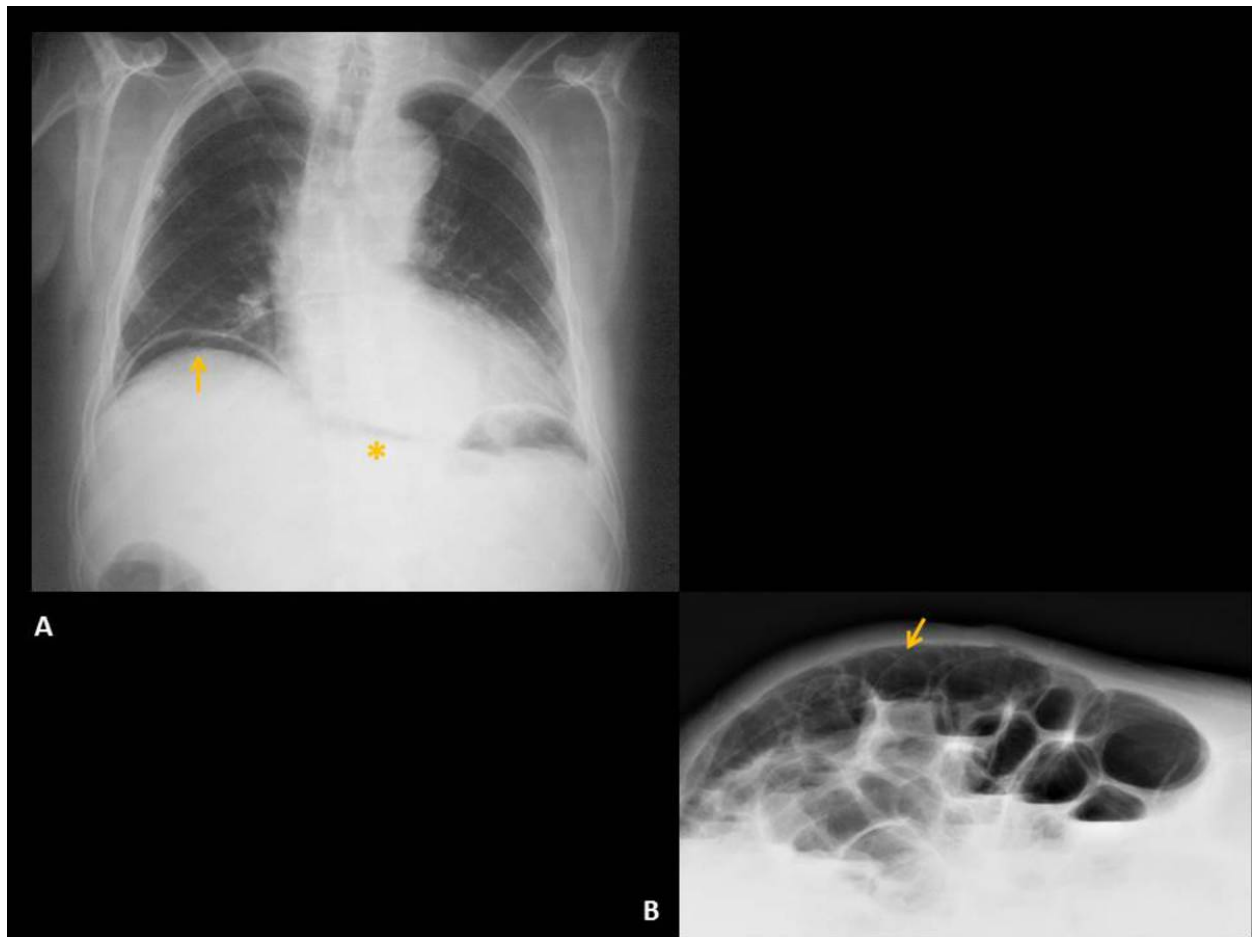
There are other disease processes responsible for portomesenteric vein gas. The increased use of invasive techniques has led to the appearance of an increased number of iatrogenically caused portomesenteric vein gas as a consequence of interventional procedures and transplantation for instance. The referred cases have a favorable prognosis without the need for surgery. This data taken into account suggests that the finding of portomesenteric vein gas on a CT should be carefully evaluated assessing the clinical context in which it occurs before making a decision regarding diagnosis and therapy. Surgery should be considered only if the underlying cause of the disease demands it.

### **Thoracic causes**

Several conditions of thoracic origin can cause extraluminal gas via direct air dissection into the peritoneal/retroperitoneal space. Most frequently the thoracic causes are mechanical ventilation, pneumomediastinum, pneumothorax, pre-existing pulmonary

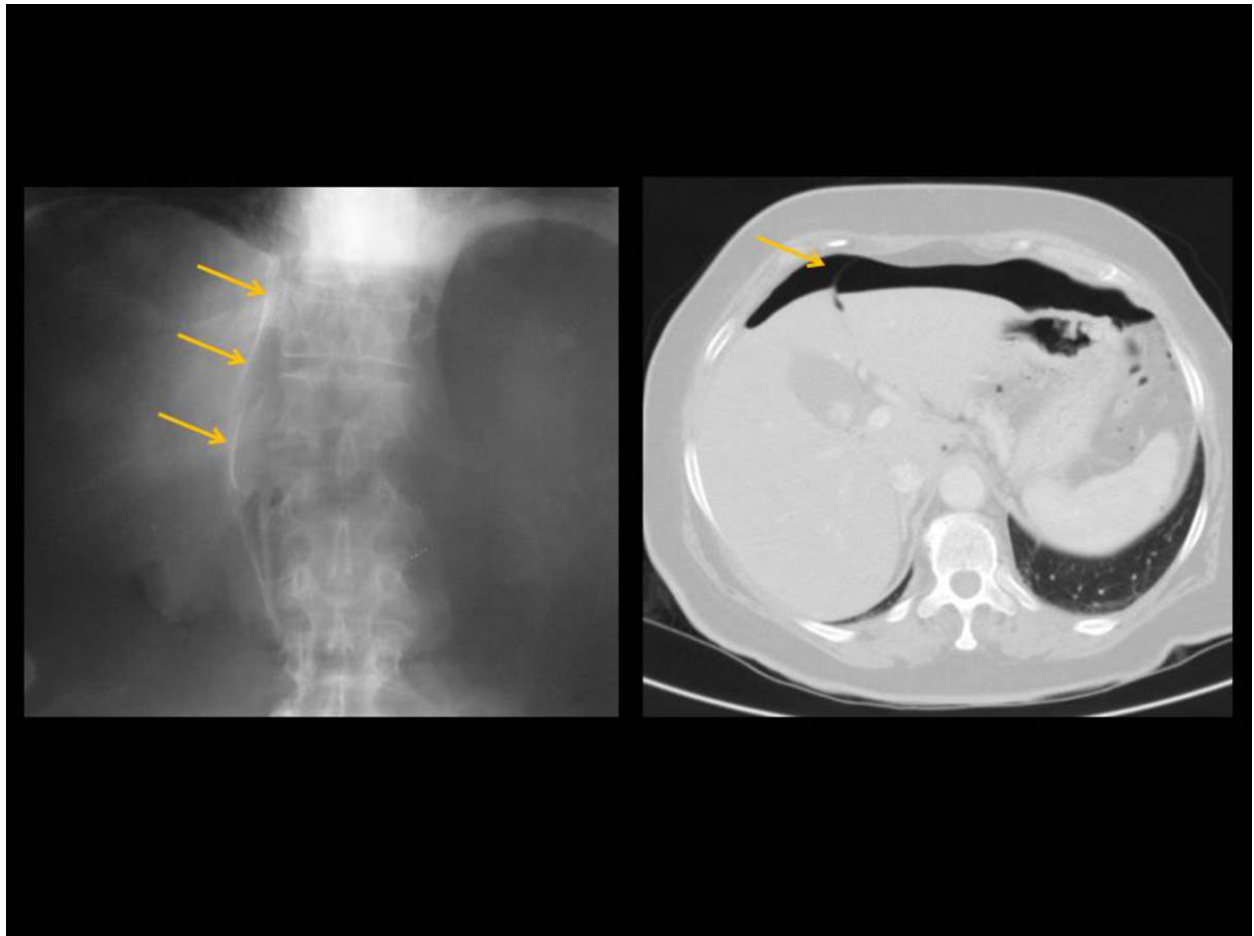
disease (Asthma, COPD) and esophageal perforation ( [Fig. 19](#) on page 25 and [Fig. 20](#) on page 26 ).

**Images for this section:**

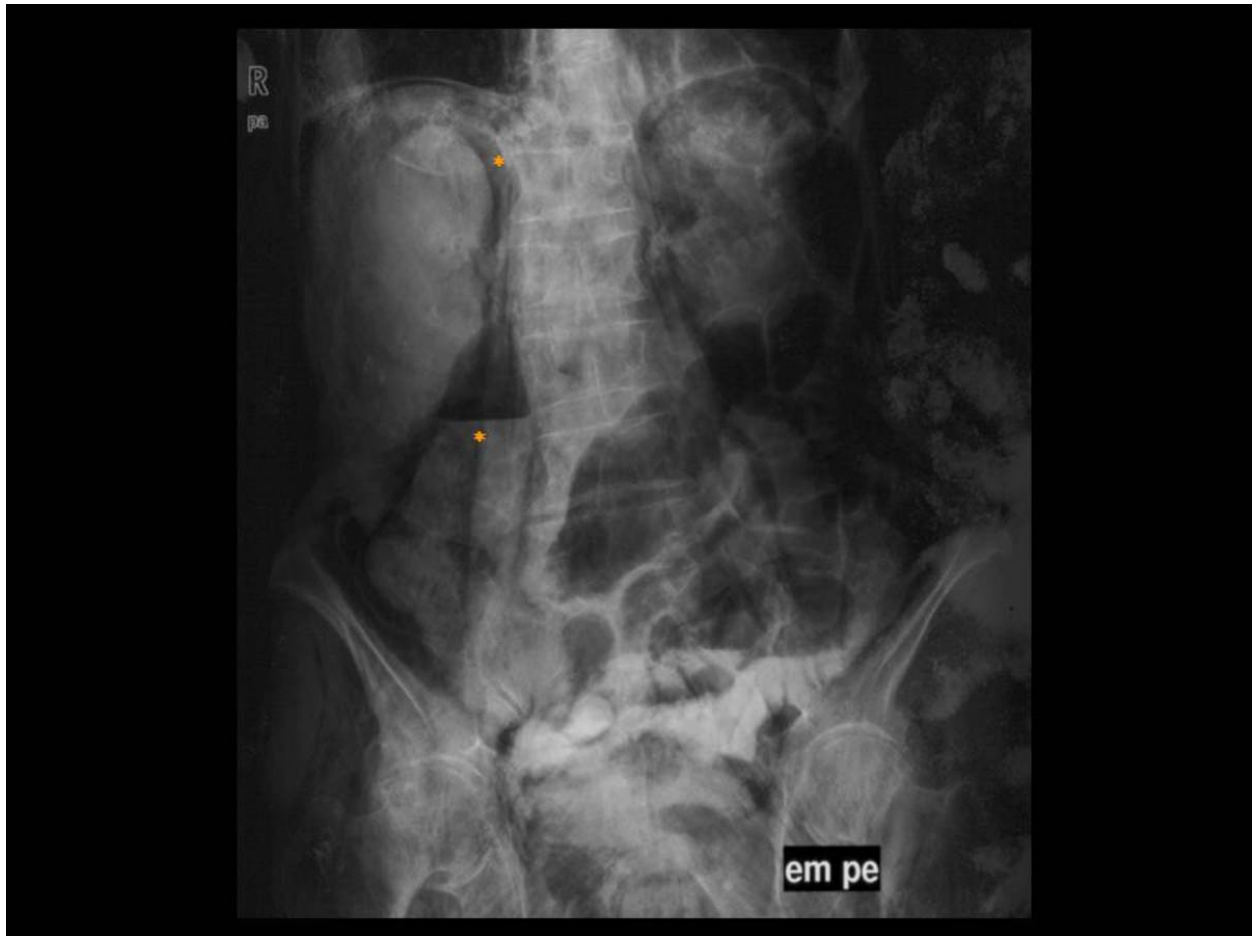


**Fig. 1:** Pneumoperitoneum. (A) Chest X-ray shows a small amount of gas beneath the diaphragm (arrows). The continuous diaphragm sign is also seen (\*). (B) Plain abdominal radiograph reveals extraluminal gas - Rigler's sign (gas on both sides of the bowel wall).

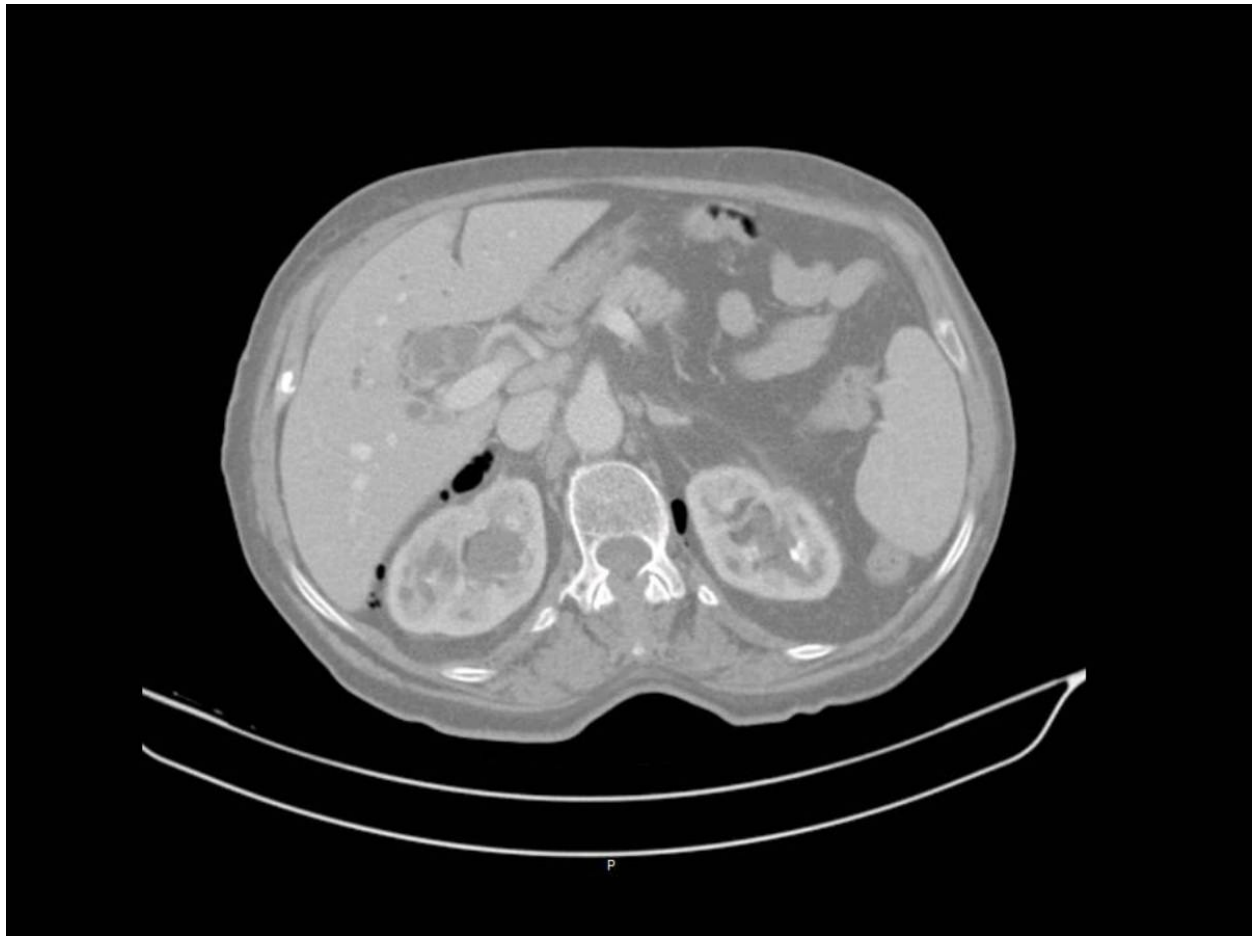




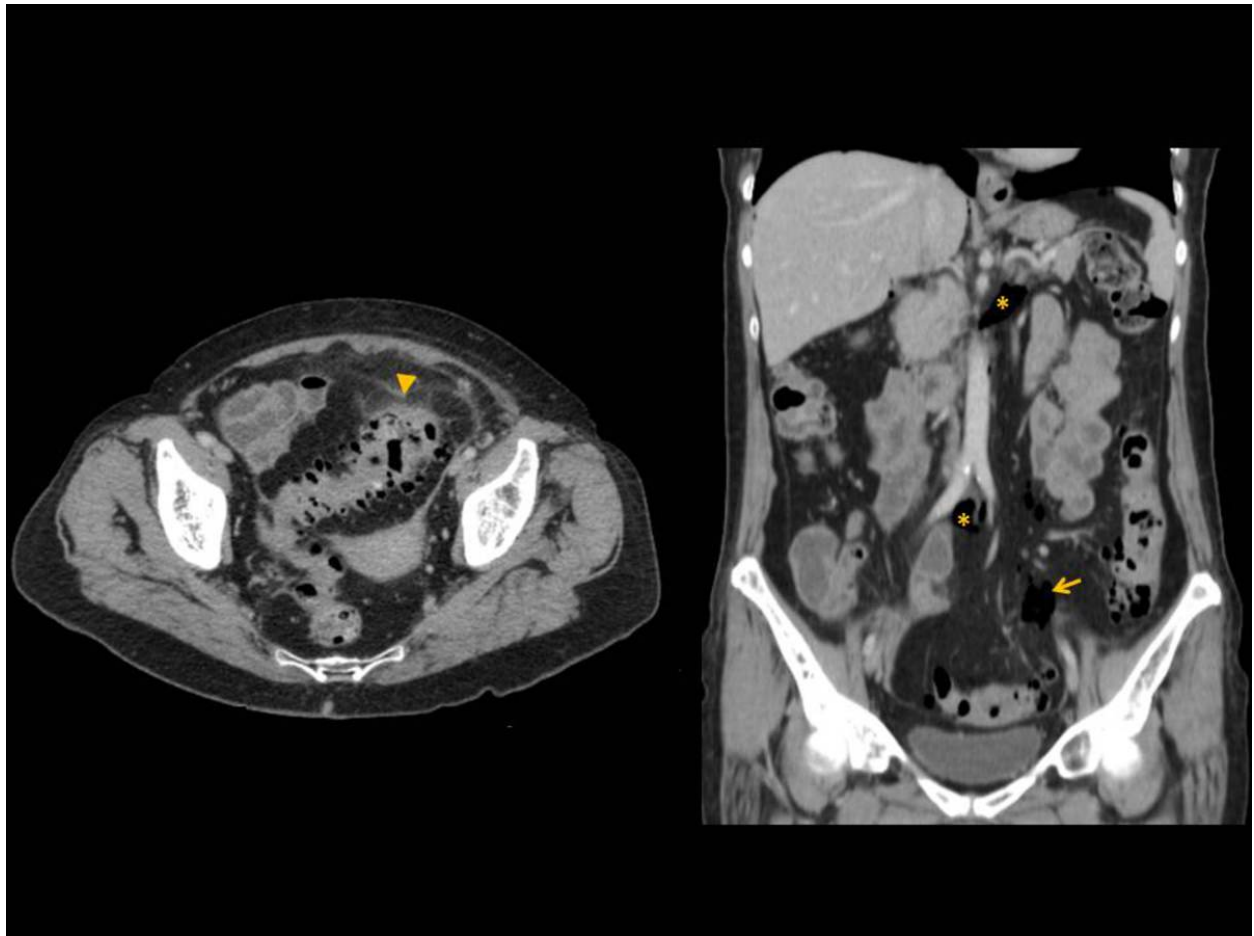
**Fig. 2:** Falciform ligament sign. In the supine position, the gas assumes an anterior placement best appreciated by the falciform ligament sign, which consists of free air outlining the falciform ligament, demonstrated on the plain radiographs and on CT scan.



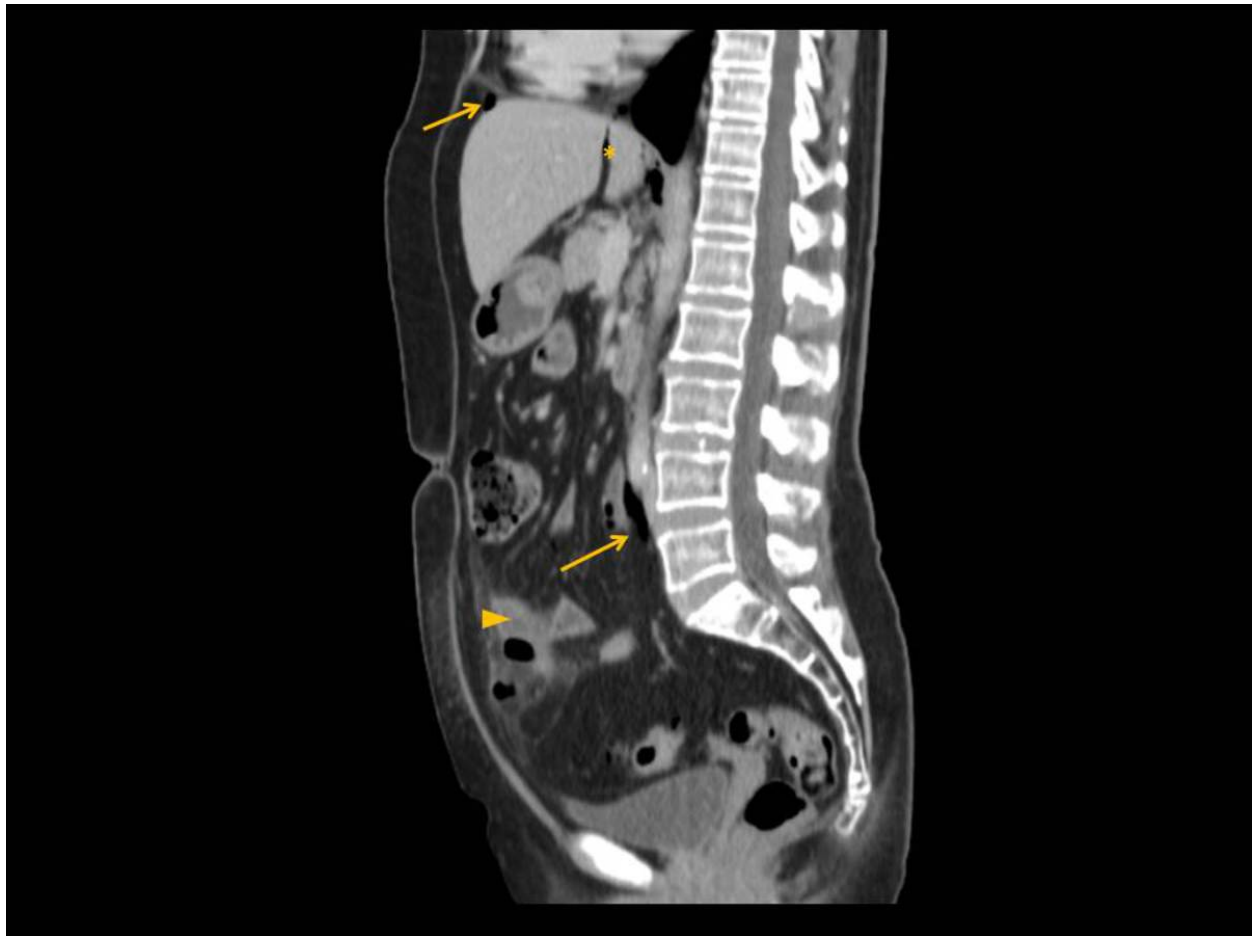
**Fig. 3:** Abdominal radiograph shows pneumoretroperitoneum (\*) after duodenal rupture.



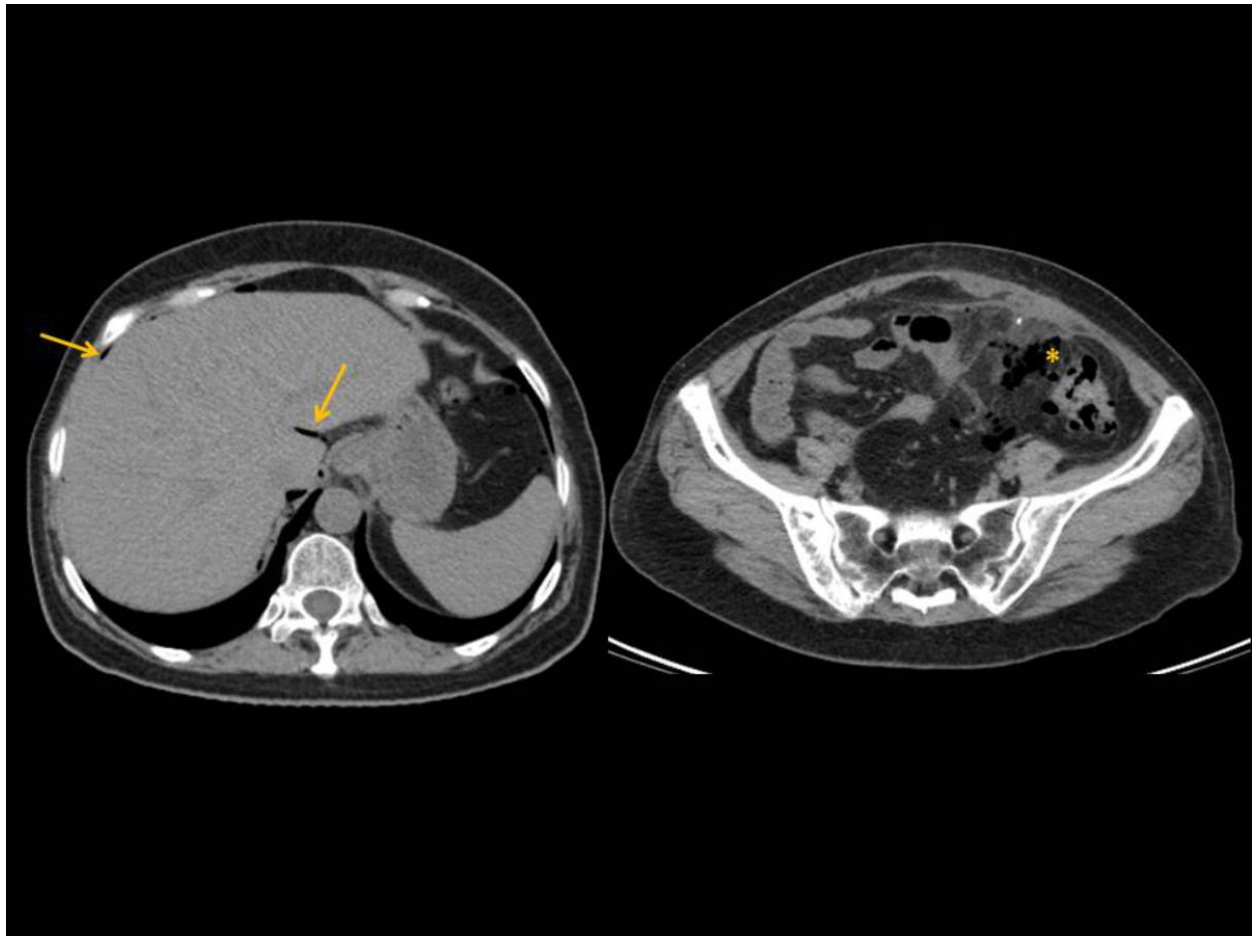
**Fig. 4:** Duodenal perforation after endoscopic retrograde cholangiopancreatography. CT scan shows retroperitoneal air bubbles, as in the right and left perirenal spaces.



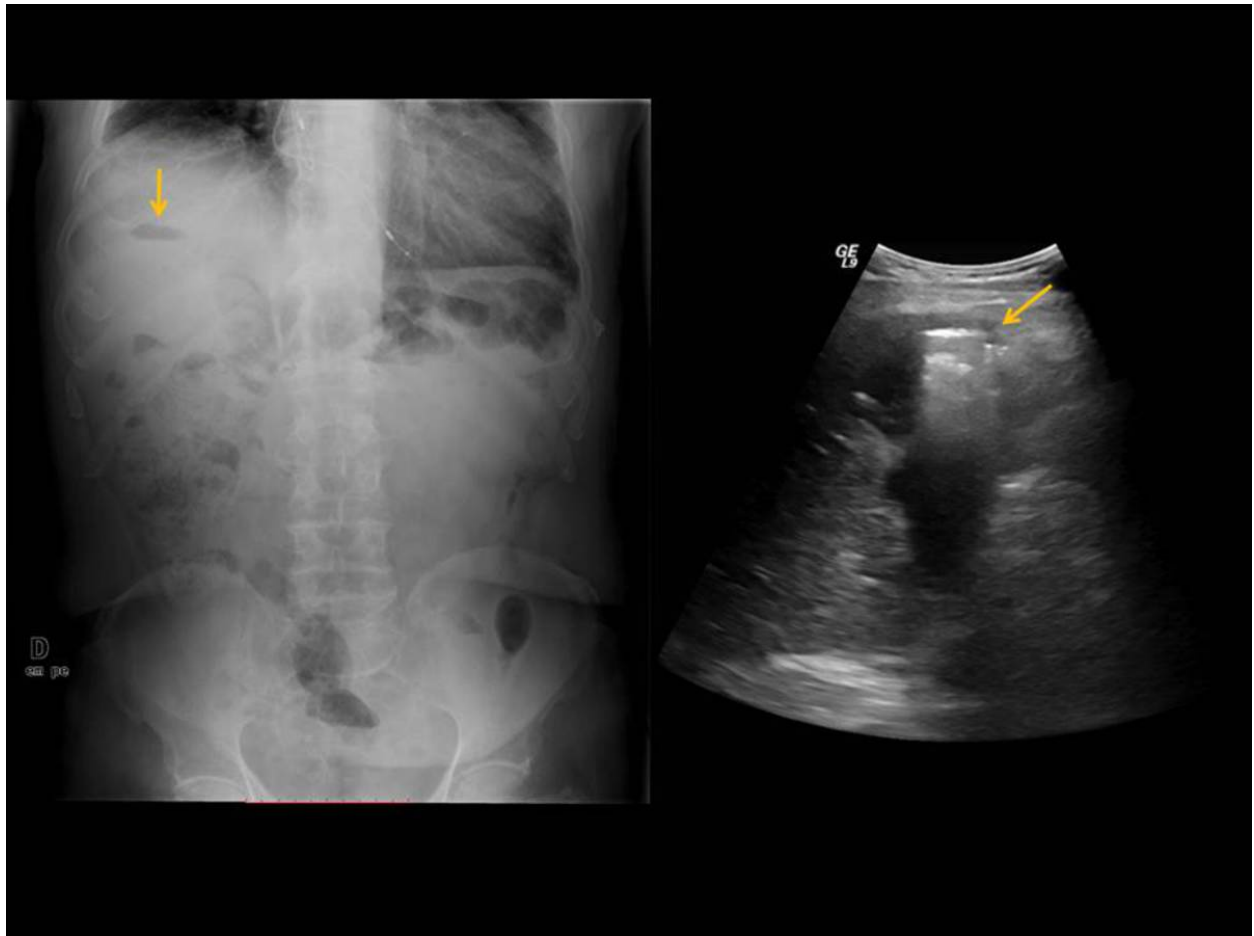
**Fig. 5:** Axial and coronal CT images shows perforated sigmoid diverticulitis, with free intraperitoneal gas tracking along the sigmoid mesentery (arrows) and then the rest of the peritoneal cavity (\*). The presence of mesenteric stranding (arrowhead) adjacent to the sigmoid diverticula points to the rupture local.



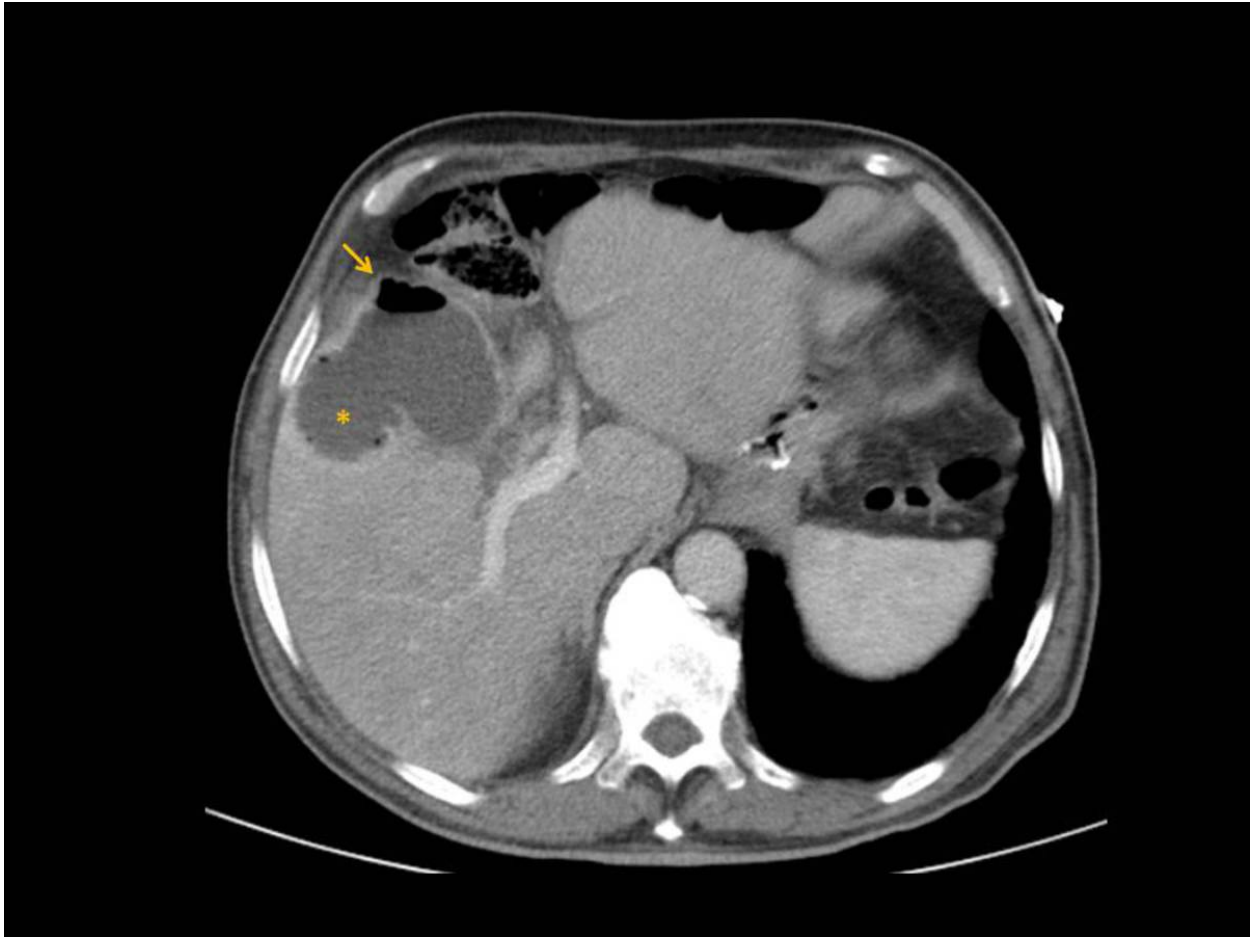
**Fig. 6:** Sagittal CT images from same patient as Fig. 5. Note the free intraperitoneal gas along the mesentery to the fissure of the ligamentum venosum (\*) and the mesenteric stranding (arrowhead) seen in diverticulitis.



**Fig. 7:** Another example of perforated sigmoid diverticulitis. Note the mesenteric stranding and free gas bubbles adjacent to the rupture local (\*), as well as free gas surrounding the liver (arrows).



**Fig. 8:** Emphysematous cholecystitis. Upright abdominal radiograph (A) obtained in a 78-year-old diabetic man demonstrates an air-fluid level in the right hypochondrium (arrow). US (B) shows a distended gallbladder, with thickened and irregular walls, with evident bright echoes and "dirty" acoustic shadowing.

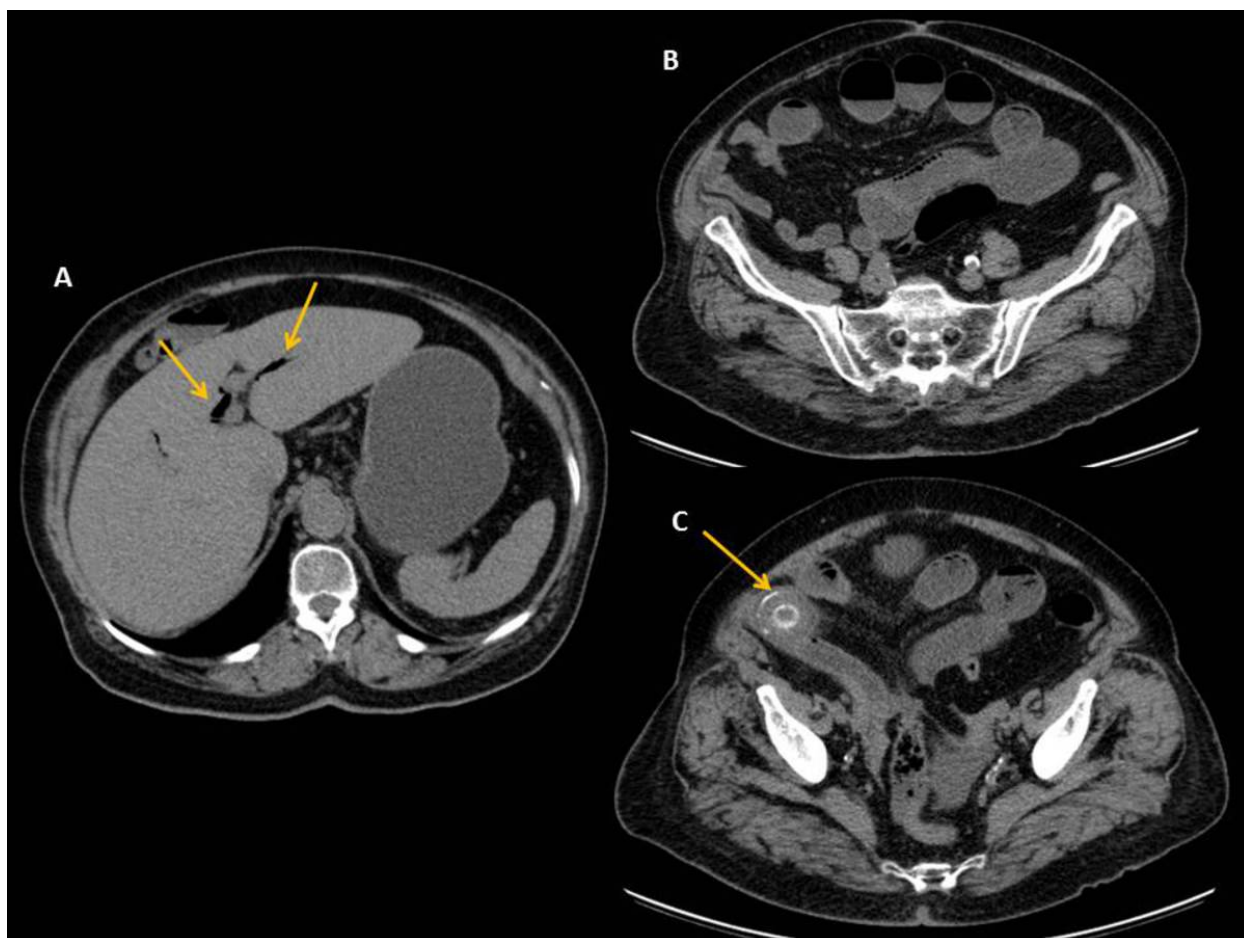


**Fig. 9:** Emphysematous cholecystitis. Contrast-enhanced CT scan through the upper abdomen shows intramural and intraluminal gas in the gallbladder (arrow) showing associated perivesicular collection also with gas bubbles (\*), favoring abscess collections.

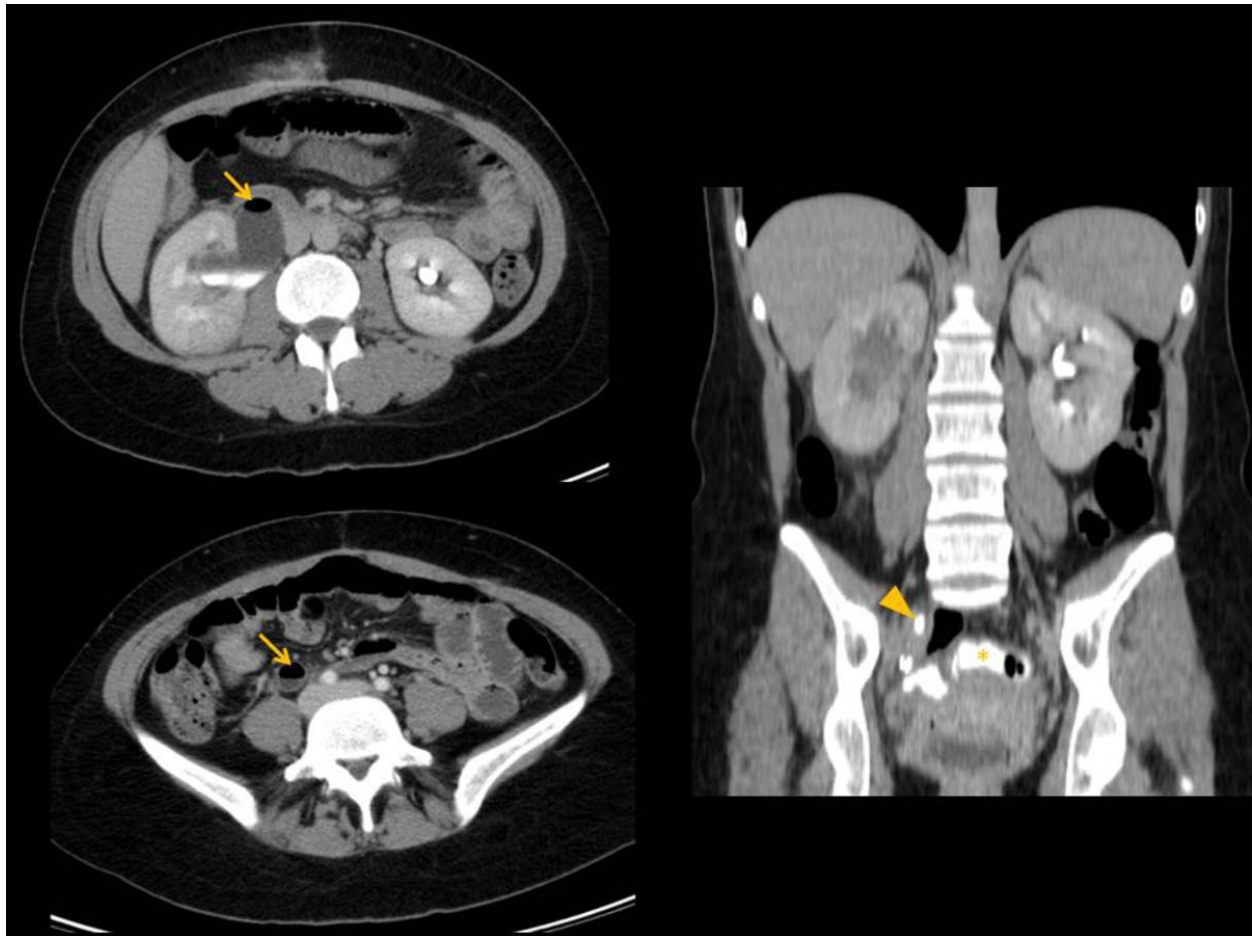




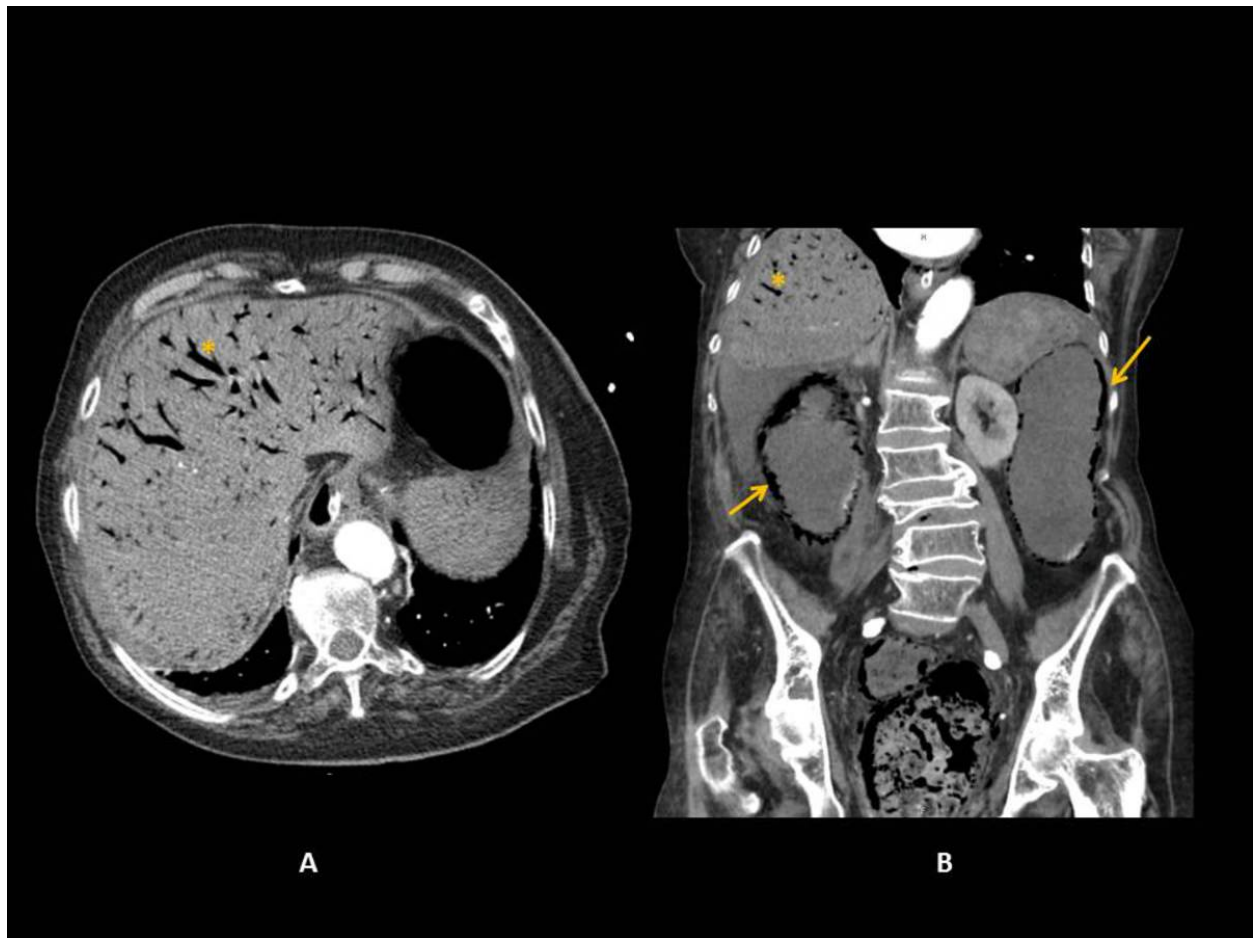
**Fig. 10:** Emphysematous pancreatitis. CT scan of the abdomen demonstrates gas surrounding the body and tail of the pancreas. There are inflammatory changes involving the surrounding fat of the pancreas.



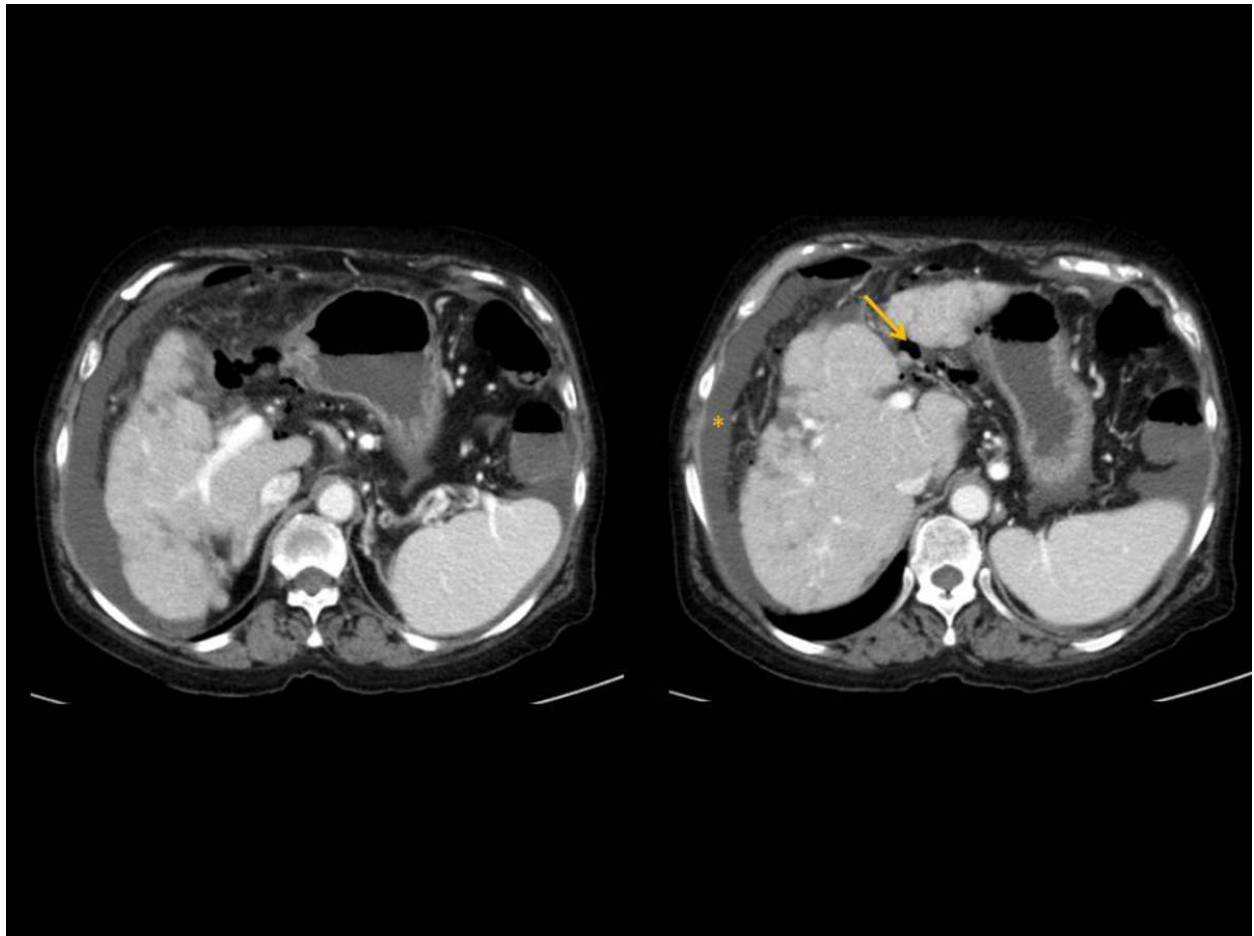
**Fig. 11:** Gallstone ileus. CT scans show tubular areas of low attenuation in the biliary tree (arrows), corresponding to pneumobilia (A). Note the central location of the air, which does not extend to within 2 cm of the liver capsule. (B) Distended small intestine is observed with air-fluid levels (\*). (C) A gallstone is observed at the terminal ileum (arrowhead) due to a cholecystoduodenal fistula. The presence of pneumobilia, dilated small intestine and the presence of a luminal calculus in the intestine characterize the Rigler triad.



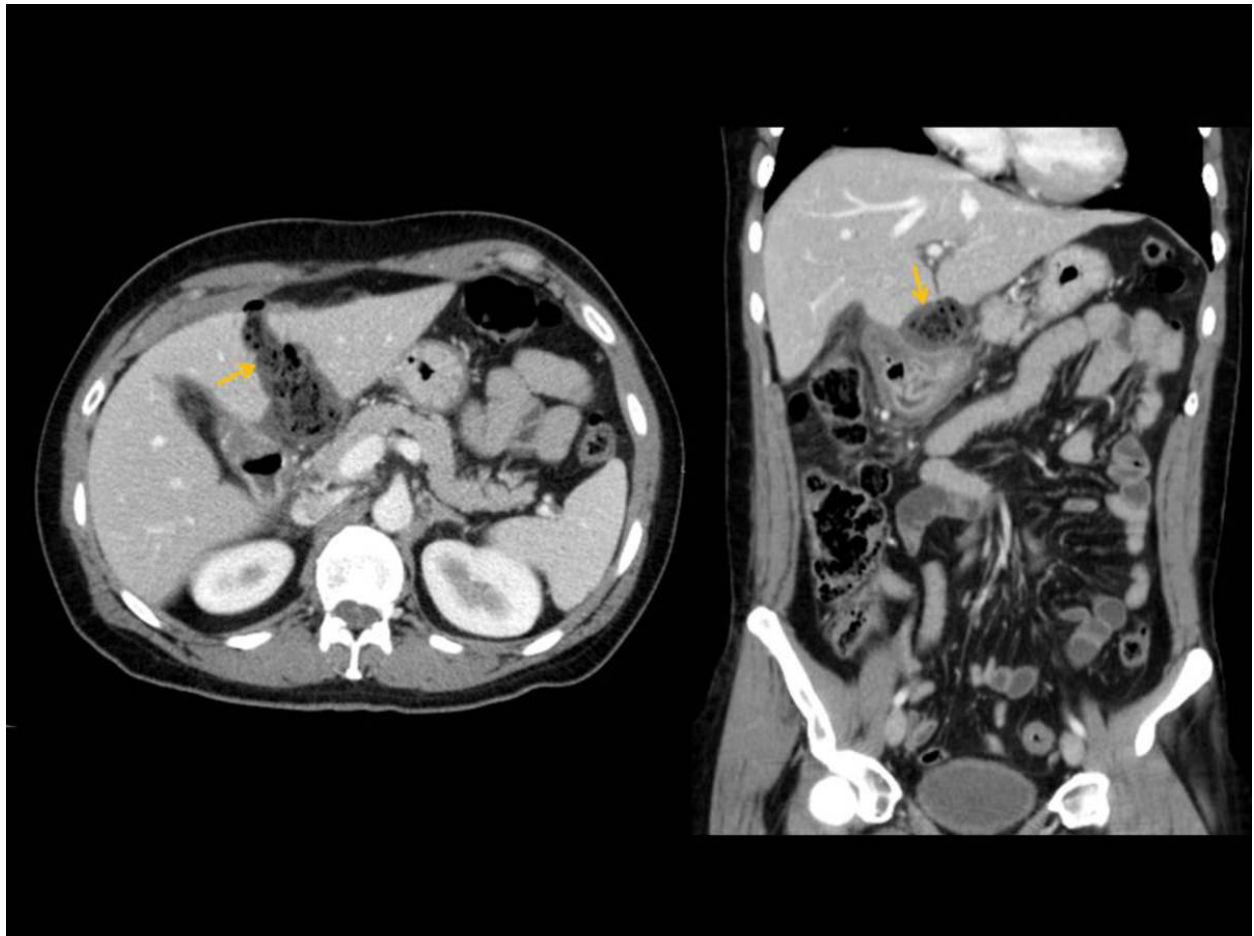
**Fig. 12:** Patient with complicated ovarian cyst removal by laparoscopy. Contrast-enhanced CT scan obtained at the level of the kidneys shows ureterohydronephrosis and air within the right ureter (arrows). The most distal portion of the ureter (arrowhead) communicates via thin fistulous tract with the sigmoid, causing the appearance of iodine contrast in the sigmoid (\*) - iatrogenic ureterosigmoid fistula.



**Fig. 13:** Mesenteric ischemia. Axial CT image shows branched areas of decreased attenuation, findings that are consistent with gas in the intrahepatic portal veins (\*) extending to liver periphery (A). Aeroportia is also visible in coronal CT reconstruction (B), as well as extensive pneumatosis intestinalis (linear gas collections throughout the bowel wall).

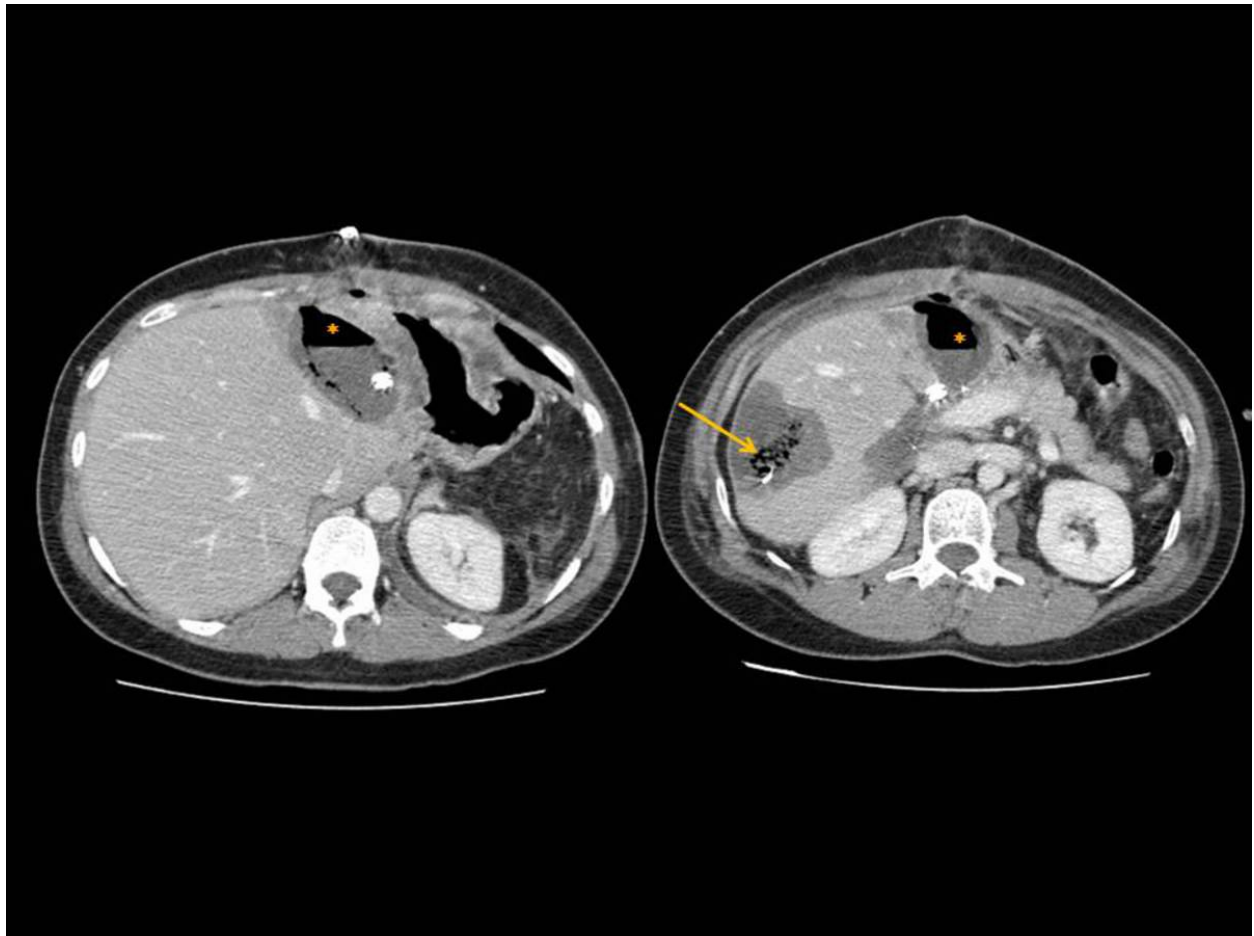


**Fig. 14:** Axial CT images demonstrate a few locules of gas (arrow) seen in the hepatoduodenal ligament and the fissure for ligamentum venosum, which indicates a gastro/duodenal perforation. Note also the presence of peritoneal fluid (\*) and stigmata of chronic hepatopathy. The patient went to surgery which confirmed a perforated duodenal ulcer.

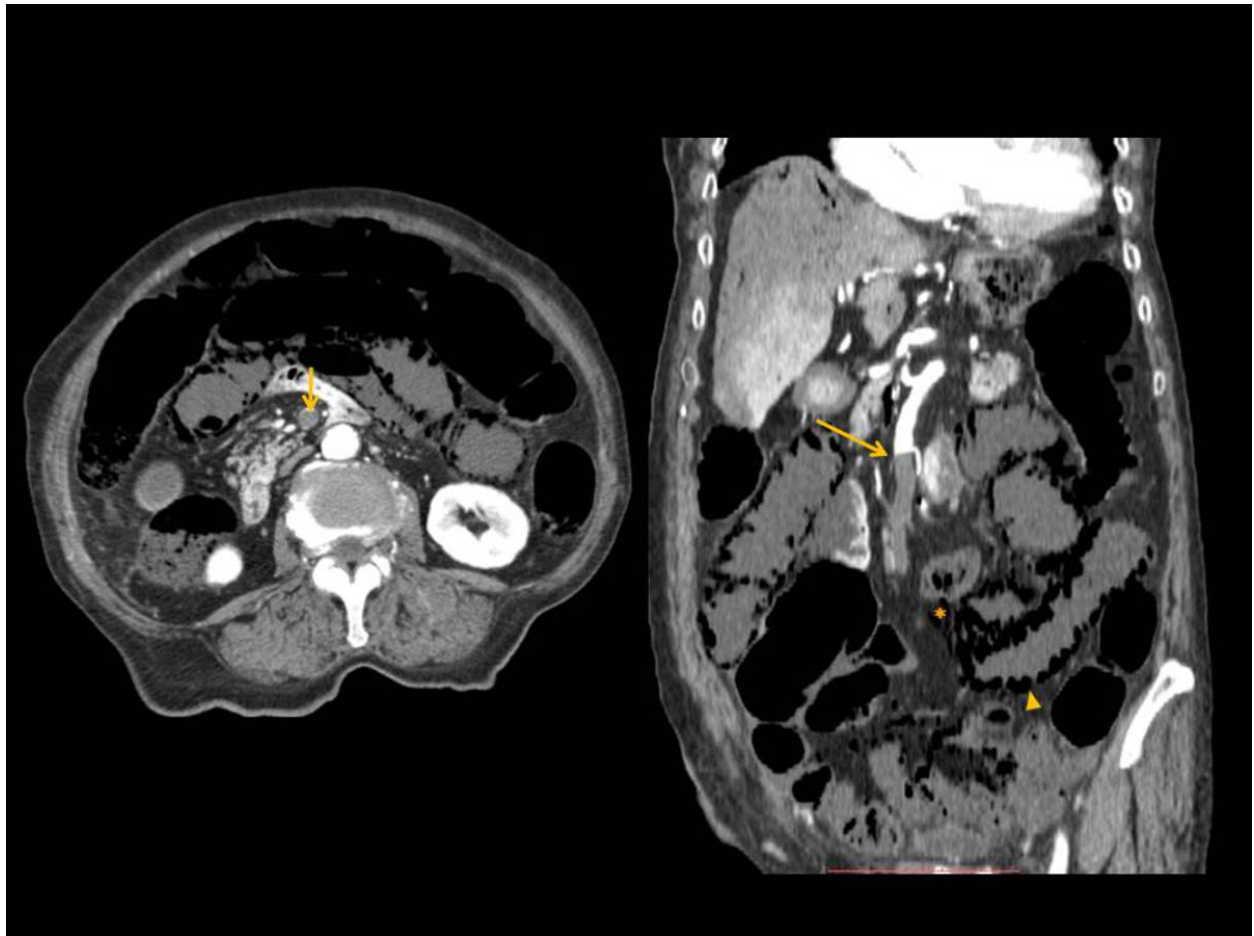


**Fig. 15:** Patient underwent laparoscopic cholecystectomy three days prior to these images. During the procedure, hepatic laceration occurred in the right lobe, adjacent to the falciform ligament, haemostatic control intraoperatively was achieved with surgicel® (haemostatic sponge).



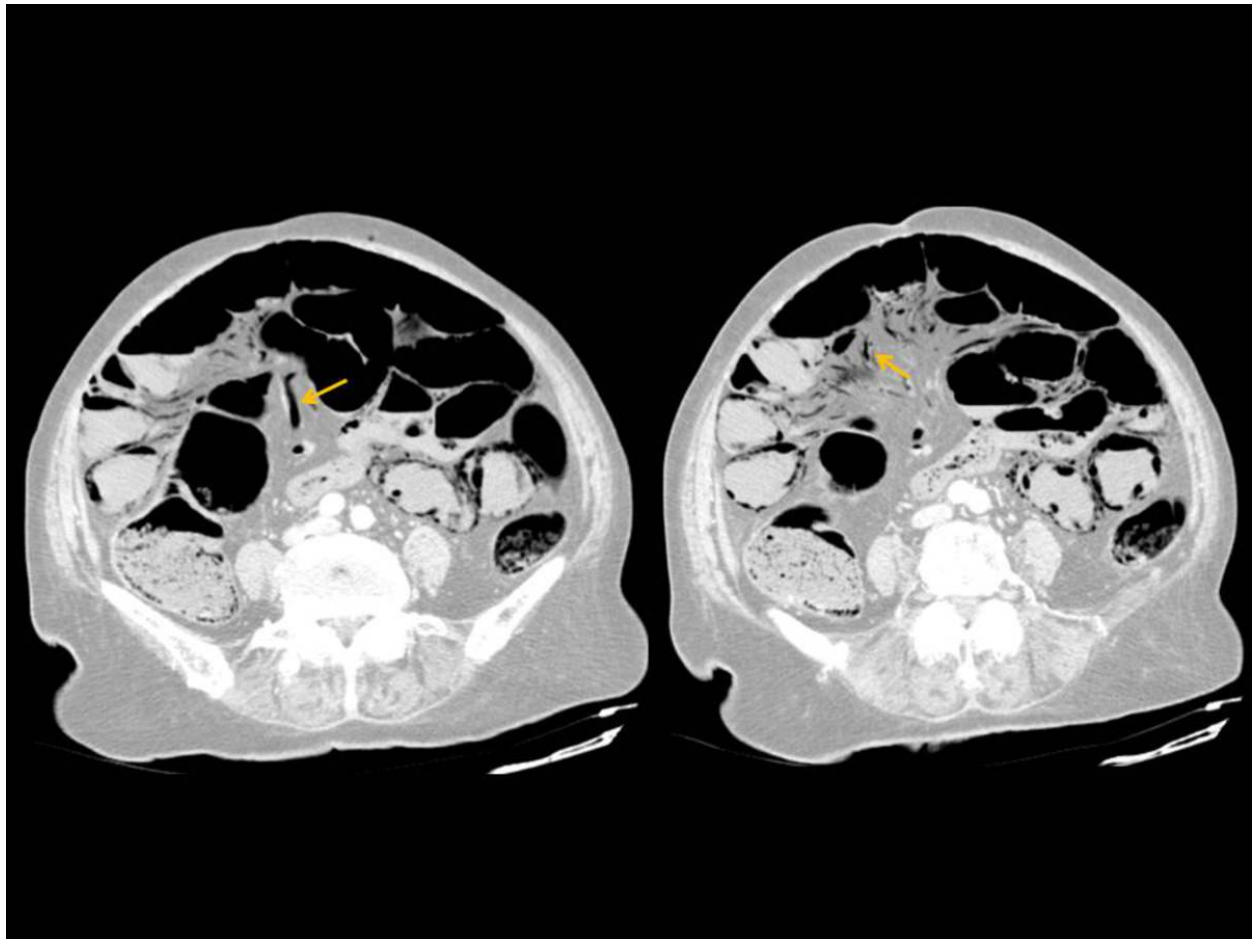


**Fig. 16:** CT scan shows two hypodense areas with gas bubbles in the liver, both represent haemostatic material. However, one should consider the possibility of the more anterior area (\*) representing a material overinfection, since there is an air-fluid level.



**Fig. 17:** Mesenteric ischemia. Contrast-enhanced CT scan demonstrates a thrombus in the superior mesenteric artery (arrow). Gas is seen along the mesentery (\*), in the portal veins and massive pneumatosis intestinalis (arrowhead). Note the absence of enhancement of the bowel wall and hypoperfusion signs in the hepatic parenchyma.

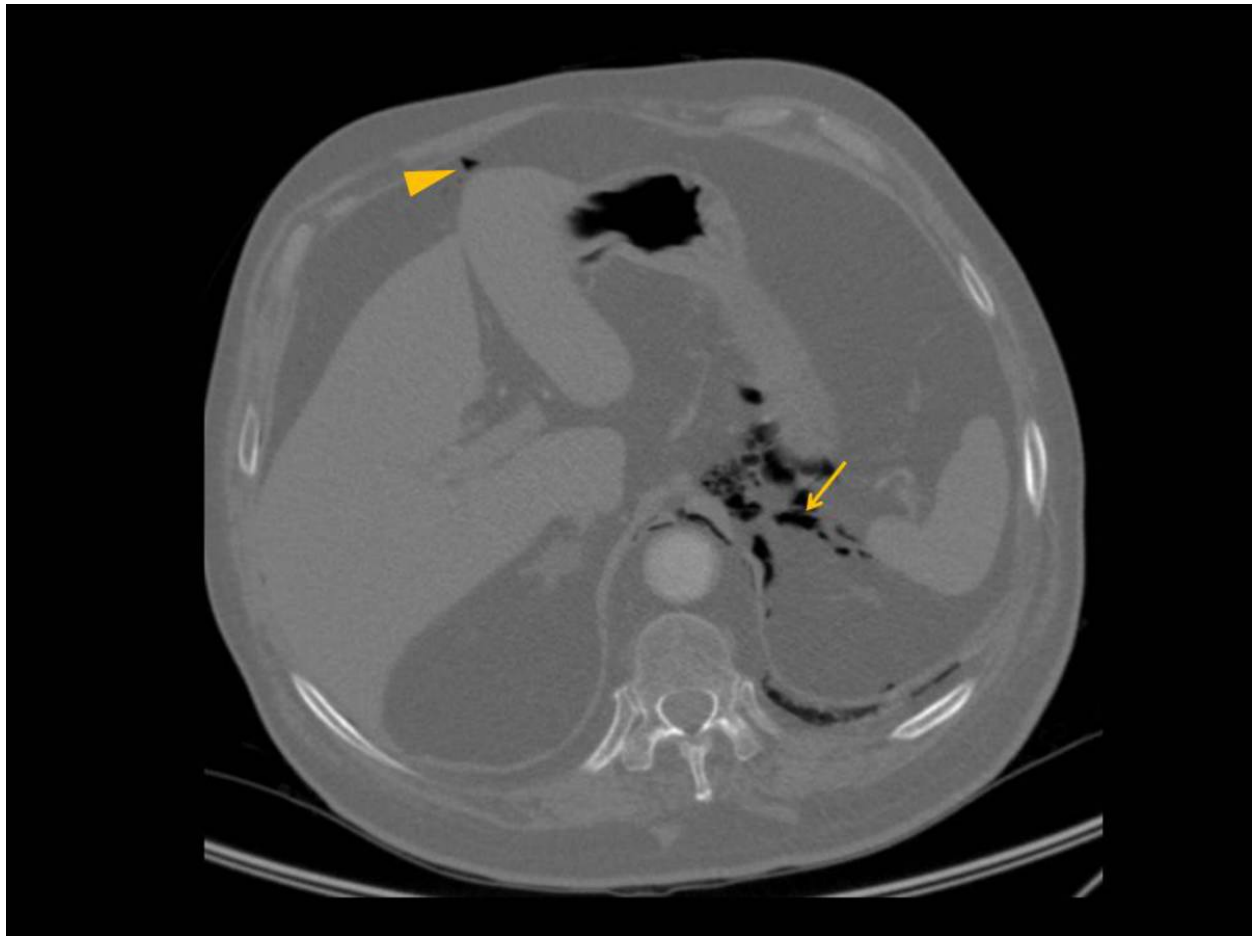




**Fig. 18:** Mesenteric ischemia (same case as figure 17). Gas is seen in the superior mesenteric vein and mesenteric veins (arrows) which appears as tubular or branched areas of decreased attenuation in the mesenteric border of the bowel. Pneumatosis intestinalis is also observed.



**Fig. 19:** Coronal CT image shows subcutaneous emphysema (arrowhead), pneumomediastinum (\*) and pneumoperitoneum/pneumoretroperitoneum (arrow) by direct air dissection after traumatic thoracic injury.



**Fig. 20:** Axial CT image of the same case seen in figure 19. Note free gas in the peritoneal space (arrowhead) and in the retroperitoneum (arrow).

## Conclusion

Several pathologies can be diagnosed analyzing the usual imagiologic signs of extraluminal gas. The site of these gas bubbles and its migration along the peritoneal connections can point to the perforation site.

Free gas isn't always due to hollow viscera rupture and the radiologist must be familiarized with several entities responsible for extraluminal gas and distinguish them between the benign and the life-threatening conditions, giving the proper importance to the findings according to the clinical presentation.

## Personal information

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