6 Gastrointestinal Tract

The GI tract is a vital organ. Its ultrasound analysis has been rarely listed in abdominal ultrasound reports, since the bowel is often considered a hindrance to the analysis of deeper structures (Fig. 6.1). Yet the GI tract is the location of life-threatening conditions at nearly each segment. Using careful analysis, at least one small part of the 7 m of the abdominal bowel can be analyzed.

Our 5-MHz microconvex probe is perfect for this investigation.

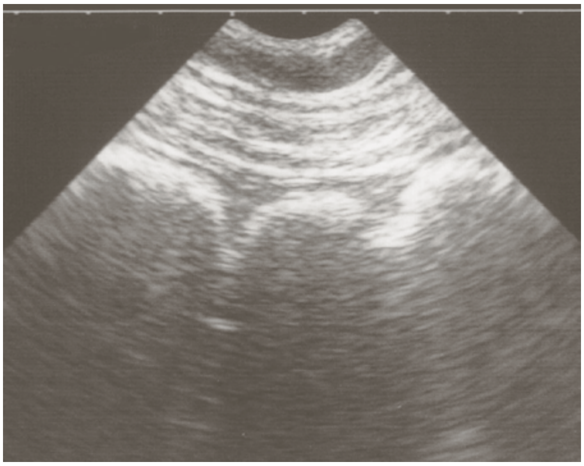

Fig. 6.1 U-lines. The probe is applied on an abdomen full of gas. No deep structure can be identified, since digestive gas stops the progression of the ultrasound beam. Note, however, that the artifacts can be described as inverted U shape – consequently labeled U lines – suggesting colic loops

Normal Ultrasound Patterns

The features of pneumoperitoneum in Chap. 5 have shown that free gas and intradigestive gas have distinctive patterns. We will consider, as usual in critical ultrasound, the static signs (gas artifacts, wall features), then the dynamic sign, of major relevance.

Normal GI Tract: Static Signs

In the absence of a gas barrier, the bowel can be analyzed. Its wall thickness, practically unchanged from the stomach to the colon, ranges from 2 to 4 mm [1].

In the presence of a gas barrier, the GI tract can still be analyzed. The generated artifacts are in fact providers of information. We tried to give a standardized language for describing them in the section about pneumoperitoneum in Chap. 5 page 38. The U-lines are an example of air artifacts (Fig. 6.1). Vertical narrow well-defined comet-tail artifacts reminiscent of the lung B-lines (see Fig. 17.2 page 153) are may be a feature due to jejunal villi.

Normal GI Tract: A Basic Dynamic Sign, Peristalsis

The GI tract peristalsis is a major sign, and will be described in detail. The GI tract is a vital organ. Any vital organ has permanent dynamics (lungs, heart, vessels). Ultrasound has the critical advantage of real-time imaging, enabling assessment of this dynamic (Fig. 6.2).

Peristalsis gives permanent crawling dynamics, with regular contractions [2]. The presence of peristalsis can be objectified in a few seconds. This is the usual pattern in the normal subject. Prolonged observation (at least 1 min) seems necessary to affirm abolition of peristalsis.

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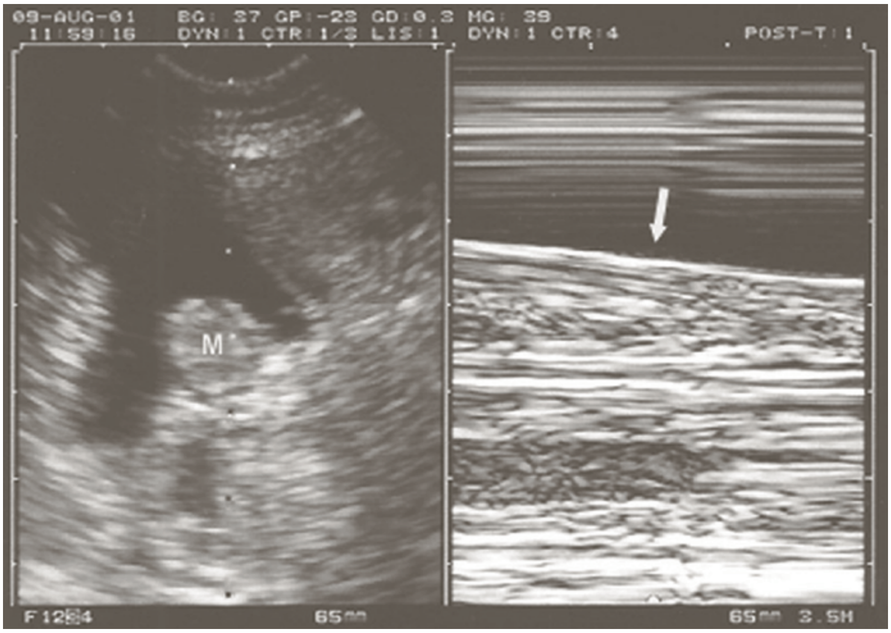

Fig. 6.2 GI tract peristalsis. *Left*: Real-time observation of a bowel loop (*M*) within peritoneal effusion. *Right*: M-mode. These oblique lines (*arrow*) demonstrate a normal peristalsis. This simple image also invalidates the dogma that peritoneal fluid in itself creates abolition of peristalsis

The peristalsis can be seen from the stomach (antrum at least) to the ileon, and does not seem, in our experience, visible at the colic area.

Observations clearly showed that a number of situations are *not* able to abolish bowel peristalsis:

- Mechanical ventilation with high-dose morphinomimetic sedation and even curare administration.
- Peritoneal fluid like massive ascites: this is clearly established by our observations.
- A recent laparotomy, even with a procedure touching the bowel, such as colectomy. We have observed peristalsis of the small bowel clearly present 24 h after colectomy.

Even when the bowel is full of gas, the peristalsis can again be seen, through characteristic dynamics of the gas contents (the "crawling gas sign").

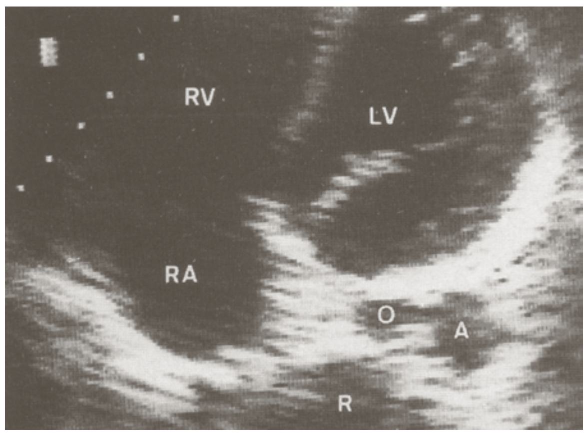

Fig. 6.3 Thoracic esophagus. Transverse, pseudo-apical scan of the heart. The esophagus (*O*) is surrounded by the rachis (*R*), the right auricle (*RA*), the left ventricle (*LV*) and the descending aorta (*A*)

Esophagus

The cervical esophagus descends behind the trachea, but is slightly visible to the left (see Fig. 24.11 page 251).

The upper thoracic esophagus is rarely visible using an external approach. Below the carina, if there is a sufficient heart acoustic window, the esophagus is recognized as a tubular flattened structure that passes in the angle between the heart and descending aorta (Fig. 6.3).

In the critically ill patient, the gastric tube and above all its frank acoustic shadow make a landmark that facilitates the location of the esophagus. The esophageal balloon of a Blakemore tube can be visualized posterior to the left auricle (Fig. 6.4).

The esophagus penetrates the abdominal cavity just anterior to the aorta. The frank acoustic shadow of a gastric tube is a practical landmark (Fig. 6.5).

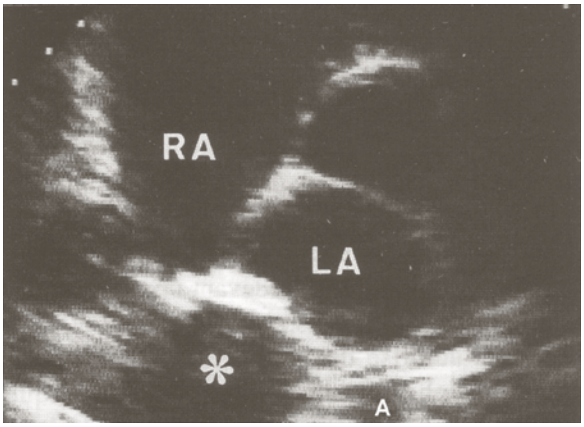

Fig. 6.4 Blakemore probe. The inflated esophageal balloon (*asterisk*) drives away the posterior wall of the left auricle (*LA*)

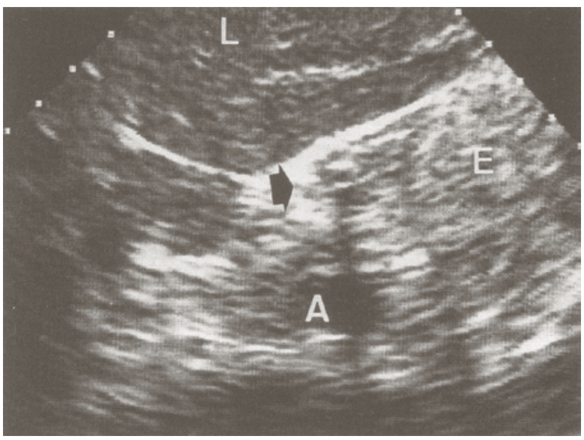

Fig. 6.5 Abdominal esophagus. It is seen (*arrow*) anterior to the aorta (*A*), behind the left hepatic lobe (*L*) and continuing up to the stomach (*E*). The frank posterior shadow arising from the gastric tube (*arrow*) is an efficient landmark. Transversal epigastric scan

Stomach

The vertical portion, or fundus, passes between the liver and spleen (Fig. 6.6). It is better visualized by a lateral, transsplenic approach, visible in the concavity of the spleen, than by an anterior approach (Fig. 6.7).

The horizontal portion, or antrum, should be investigated by the epigastric approach. The antrum (analyzed by a longitudinal scan) is round or ovoid, its size is a function of its content that can be empty or filled (Fig. 6.8).

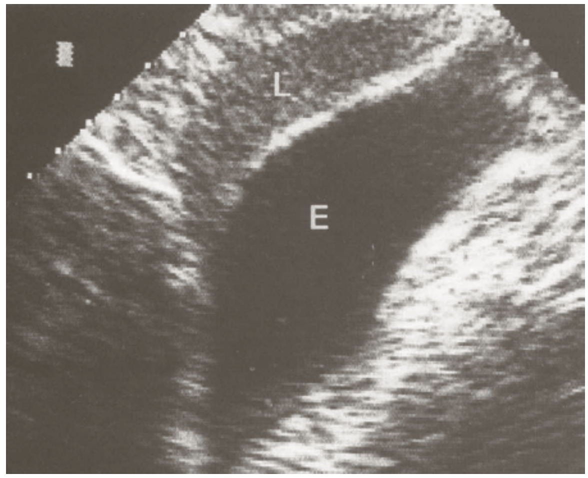

Fig. 6.6 Vertical portion of the stomach (*E*), outlined by an anechoic fluid content. Longitudinal scan. *L* hypertrophied left hepatic lobe

Fig. 6.7 How we search for the vertical portion of the stomach through the spleen. Note in this image from left to right a part of the lung (with a lung artifact), an hypertrophic steatosic liver (clear echostructure), the spleen, and the stomach (here in distension). Longitudinal scan of the left phrenic point

Duodenum

The duodenum is probably not a segment for the beginner. The duodenal bulb follows the pyloric stricture. The second duodenum descends vertically and surrounds the pancreas head. Duodenal fluid sequestrations should not be confused with pathological images (the gallbladder, which is at the contact of D2, the vena cava, aorta, etc.). The third duodenum is visible between the aorta and the superior mesenteric artery.

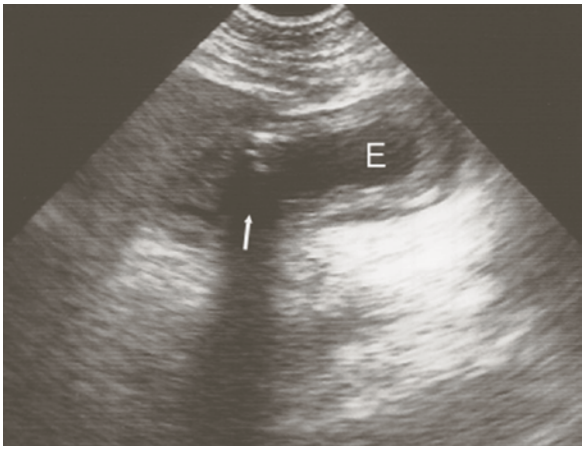

Fig. 6.8 Nasogastric tube. It is immediately detected using the frank acoustic shadow *(arrow)* more than the tube itself. Horizontal portion of the stomach (*E*), just under the liver. Note how precisely the wall thickness can be measured and an anechoic fluid content described. Epigastric longitudinal scan

Small Bowel

It is almost always possible to visualize at least some loops of the small bowel. The jejunum is recognized by the endoluminal villi (Fig. 6.9). The ileum has a tubular, regular pattern (see Fig. 5.6 page 35). Observation shows that acute life-threatening disorders of the bowel affect the whole of the bowel. Consequently, ultrasound analysis of an even small portion can be rich in information. Many relevant items can be extracted:

1. Peristalsis (see upper).
2. Cross-sectional area. The normal caliper of the small bowel is approximately 12–13 mm.
3. Contents can have either a homogeneous echoic (see Fig. 5.6 page 35) or hypoechoic pattern (Fig. 6.9). The clinical relevance of this distinction is being investigated.
4. Wall thickness ranges from 2 to 4 mm [1]. Fine analysis of the wall is greatly facilitated when there is liquid contrast from both sides, i.e., peritoneal effusion associated with fluid content, two conditions often present in acute disorders (Fig. 6.9).

Colon

The colon is a tubular structure with visible haustra (Figs. 6.10 and 6.11), without identifiable peristalsis. Roughly, the ascending and descending colon are vertical structures located in the flanks, the transverse colon is horizontal at the epigastric level and distinct from the stomach.

Rectum

We still have not found indications for critical ultrasound at this area.

Fig. 6.9 Dilated jejunal loop. The wall, perfectly outlined between peritoneal effusion and fluid content, is thin. The fluid is here hypoechoic. The caliper of this loop is 30 mm. Jejunal villi can be recognized (the fishbone sign). Small intestine occlusion. Transverse scan of the pelvic area

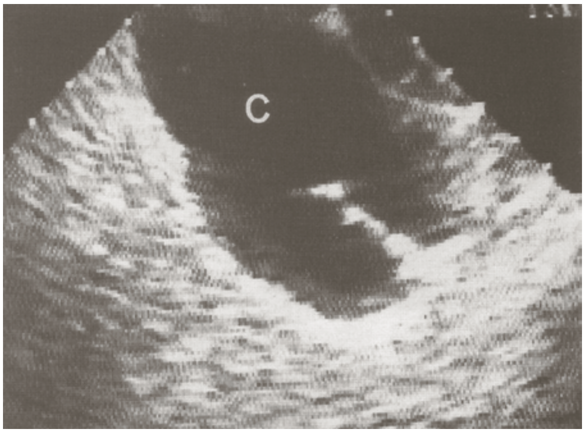

Fig. 6.10 The cecum (*C*) in a longitudinal scan. Fluid sequestration makes it easy to identify. If such huge amounts of fluid are seen in the whole bowel of a shocked patient, the diagnosis of hypovolemia as the cause or a major participation in the shock can be reasonably envisaged

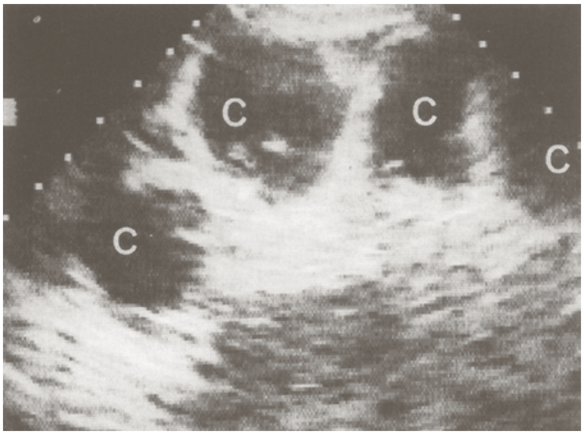

Fig. 6.11 Descending colon and its haustra. Round, anechoic images, piled up along the left flank in a longitudinal scan (*C*). Slight Carmen maneuvers of the probe show that all these images communicate. This patient had hypovolemic status

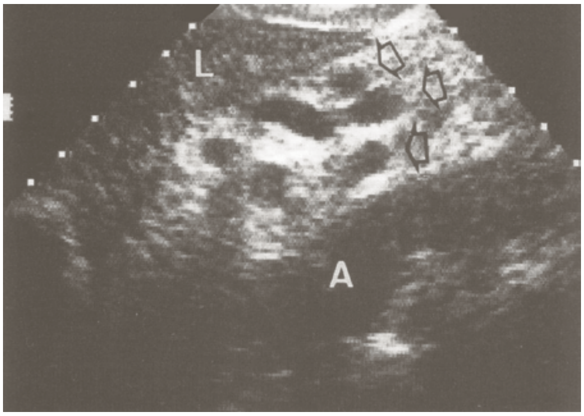

Fig. 6.12 Esophageal varices. In this longitudinal scan, several tubular anechoic images are visible below the liver. The Carmen maneuver shows that they communicate with each other along the lesser omentum (*arrows*). These are stomachic coronary varices (*L* liver, *A* aorta)

Pathologic Findings

Esophagus

Before dealing with the rare esophageal emergencies, one application is useful in extreme emergencies: recognition of esophageal intubation when the clinical diagnosis is difficult (see Fig. 24.11 page 251).

Esophageal rupture is an emergency whose low frequency usually makes the conditions for a late diagnosis, typically yielding a poor prognosis. Ultrasound can alter this usual vicious circle. A routine ultrasound examination performed facing any thoracic or abdominal drama will promptly show one of these elements: pneumothorax, cervical subcutaneous emphysema (see Fig. 18.14 page 176), pleural effusion, which appears as complex (due to a mingling of gas and alimentary particles), and frank pus withdrawn from liberal ultrasound-guided thoracentesis.

As regards hemorrhage, ultrasound does not replace fibroscopy. However, esophageal varices are accessible to ultrasound: they give sinuous tubular anechoic structures along the lesser omentum, a hyperechoic area located inside the smaller curvature of the stomach (Fig. 6.12). With GI tract hemorrhage, detection of esophageal varices makes an argument for portal hypertension as the cause of bleeding – demanding suitable therapy. Ultrasound can provide other signs of portal hypertension (see Chap. 7).

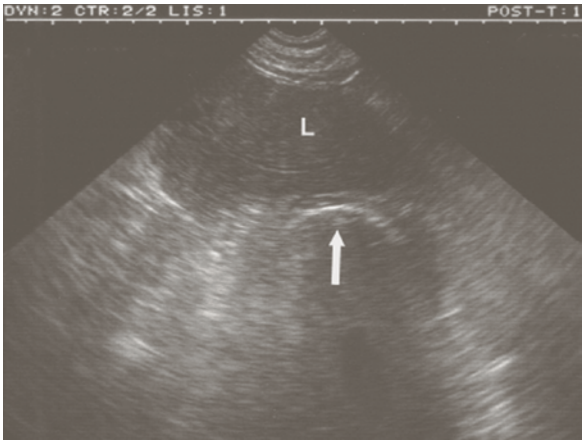

Fig. 6.13 Blakemore probe, gastric balloon. This arciform structure that may mimic an "U line" stops the echoes (*arrow*). On echoscopy, one can see it stumble upward when traction is exerted on the tube, since it outlines the gross tuberosity, the very aim of the procedure. Epigastric transversal scan. *L* liver

A Blakemore–Linton tube can be inserted using ultrasound guidance. The intragastric position of the tube, before filling, can be detected by visualizing the acoustic shadow, which is frank, tubular, and unique. The gastric balloon can then be inflated. It makes a large, round image, convex outside, highly echoic, with a frank acoustic shadow. The tube is then pulled to the head until resistance is encountered. The gastric balloon becomes visible at the top of the fundus (Fig. 6.13). The esophageal balloon can then be inflated. It creates a mark behind the left auricle

(Fig. 6.4). Monitoring thus with ultrasound is quick and reliable if the operator is trained and the patient has favorable echogenicity.

Stomach and Duodenum

Ultrasound analysis of the stomach can provide a great deal of information. Preoperative checking for vacuity or repletion requires only a few seconds in good conditions, allowing to avoid the traditional 6-h fasting. One can also search for a residue during enteral feeding. Acute gastric dilatation can be seen in patients with acute abdominal disorder, and is also a rare (but easy to detect) cause of acute dyspnea, which gastric aspiration can relieve.

Gastric liquid retention gives a massive collection with multiple echoic particles, like in weightlessness, and sometimes an air–fluid level (Fig. 6.14). This pattern can be unsettling for young operators, and should not lead to diagnoses such as splenic abscess. Similarly, if the stomach is ectopic, i.e., intra-thoracic, such an image should be recognized as *not pleural* (see page 135). Gastric stasis can be associated with bulbar ulcer [3].

The correct positioning of a feeding tube within the gastric lumen can be assessed, alternatively with the mandatory radiograph. Its tubular structure and above all its frank acoustic shadow allow easy recognition (Fig. 6.8). This application is contributive when the end of the tube is at the antrum level, far less when it remains in the fundus area.

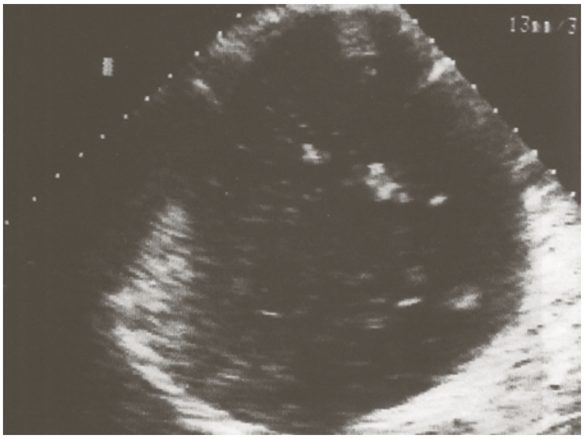

Fig. 6.14 Acute gastric dilatation. Major fluid stasis. The content is heterogeneous with hyperechoic alimentary particles. Epigastric transversal scan. Patient in acute dyspnea – relieved by the gastric draining - a rare cause of acute dyspnea

Ultrasound can document gastric or duodenal ulcer. Without replacing fibroscopy, it is a reasonable initial approach. The ulcer is rarely detected, showing a thickened, irregular wall. A duodenal ulcer can be associated with gastric stasis [3]. In the case of fluid collection outside the duodenum with gas bubbles, or pneumoperitoneum (see Chap. 5), the diagnosis of complicated ulcer (with leakage) is probable [4].

The stomach can be used as an acoustic window for exploring deeper structures such as the pancreas. The stomach should be filled with water, using the gastric tube that is usually present. A slight right decubitus will trap the air bubbles in the vertical portion of the stomach [5]. Last, a full stomach can be precisely located in the still hypothetical aim of performing bedside gastrostomy under sonographic guidance.

In caustic intoxications, ultrasound can detect diffuse edema along the GI tract, with a thickened and hypoechoic wall. Search for a left pleural effusion (a sign of esophageal rupture) or peritoneal effusion is part of the initial examination and the follow-up of the patient.

Ultrasound's contribution in the diagnosis of GI tract hemorrhage is detailed in Chap. 29.

Small and Large Bowel: Introduction

Ultrasound plays a priority role, even compared with plain radiographs, colonoscopy, or even CT. In the critically ill, two major changes are accessible:

1. Abolished peristalsis

See description above. Observations have shown a high correlation between abolished peristalsis and the existence of an abdominal drama such as mesenteric infarction or GI tract perforation. The presence of peristalsis is as a rule a reassuring finding. In a series of 20 patients considered for emergency surgery, seven of them actually surgical cases, the sensitivity of an abolished peristalsis for the diagnosis of an abdominal disorder requiring prompt surgery was 100%, the specificity 77% [6]. Consequently, in a suspicion of acute abdomen, the detection of the presence of peristalsis is a strong argument for ruling out a GI tract disorder requiring surgery.

Fig. 6.15 Thickened bowel. Three loops are visible in cross-section. Note the substantial wall thickening, accurately measured between a peritoneal effusion and anechoic fluid digestive content

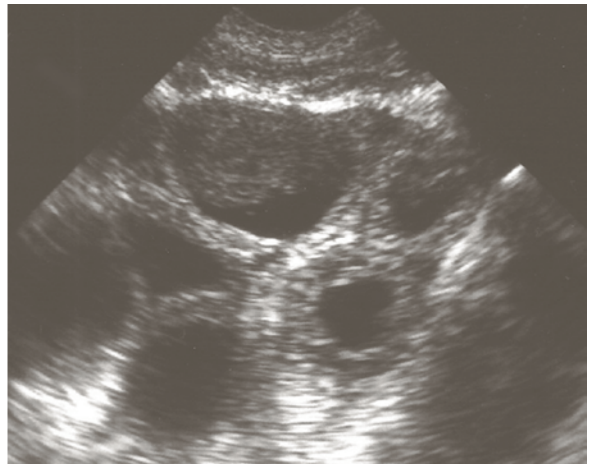

Fig. 6.16 Mesenteric infarction. Thickening of the wall (observable through the entire small bowel), and above all complete absence of peristalsis. Akinesia of this vital organ is striking in real-time. Note the fluid content of the bowel loops. Pelvic scan

Let us recall that a recent laparotomy or sedation with morphine or curare is not an explanation for bowel standstill.

2. Wall thickening (Fig. 6.15)

Parietal thickening occurs in many severe situations. The observation seems to indicate that even in the case of focal disorder, a large portion of the GI tract is involved, helping in making a rapid diagnosis even if scanning limited areas.

Small Bowel: Acute Ischemic Disorders

We have grouped different disorders, such as mesenteric ischemia, mesenteric infarction, and mesenteric necrosis, into this single section. Classically, it is due to arterial occlusion, venous occlusion, or, may be more often in the ICU, low outflow. The difficult diagnosis, which usually results in delayed treatment and a poor prognosis, is widely acknowledged [7]. Plain radiography can show pathologic gas (portal gas, pneumatosis intestinalis). Tonometry has been tried. Duplex sonography may be interesting in occlusive causes, although not replacing arteriography. Additionally, laparoscopy has been proposed, but cannot show basic patterns such as mucosal thickening, not apparent from outside. Colonoscopy is useful for colonic locations. CT, apart from classical drawbacks (cost, transportation, etc., see page 182 of Chap 19), can yield troublesome false-negative results.

In this context, ultrasound deserves a top-ranking place. Our observations usually show a complete and diffuse abolition of peristalsis. Sensitivity of this single sign is 87%, specificity 75% considering nonselected controls, and 88% considering controls with clinical suspicion [6]. A small percentage of ICU patients (12%) without GI tract impairment show abolition of peristalsis, for reasons not mastered at this moment for lack of gold standard. A thickening of the wall (which is moderate, 5–7 mm) is found in only half of our cases (Fig. 6.16). Peritoneal effusion is present in half of the cases. Portal gas is rare but quasispecific (see Figs. 7.2 and 7.3 page 54).

The literature describes dilated loops, abolition of peristalsis, very thin wall (1 or 2 mm) in the arterial causes, and thickened and hypoechoic wall in the venous causes [8, 9]. In late cases, parietal microbubbles and flattening of the jejunal villi, peritoneal effusion, portal gas or even hepatic abscesses and portal or mesenteric venous thrombosis have been described [10, 11].

The superior mesenteric vein is accessible in the absence of gas (Fig. 6.17). Since it passes anterior to the rachis, a compression can be made in order to assess its patency, and without the help of the Doppler technique (see Chap. 12).

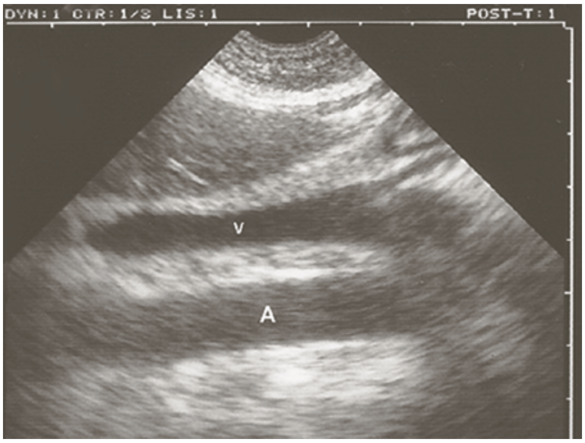

Fig. 6.17 The superior mesenteric vein. It is usually visible (*V*). Young users often confound it with the inferior vena cava, but it passes anterior (not lateral) to the abdominal aorta (*A*). The good quality of the image makes it possible to study the venous content, here anechoic. A compression maneuver completely collapses the lumen. Longitudinal view

Fig. 6.18 Colic ischemia. Cross-section of the descending colon. The lumen is virtual, but the wall can be accurately measured, here to 7 mm

Doppler could find a place if finding signs of impaired perfusion [12,13]. We wait to collect enough cases in order to see whether Doppler is redundant with our other findings.

Large Bowel: Acute Ischemic Disorders

In the case of colic ischemia and necrosis, our observations often show thickened colic wall (Fig. 6.18). Small bowel peristalsis appears nearly always abolished, a beneficial finding for an early diagnosis.

Pseudomembraneous Colitis

Studying the ultrasound features of this complication of antibiotics may theoretically select the requirements for colonoscopy. The ultrasound pattern, insufficiently described in the literature [14], shows marked thickening of the colic wall, collapse of the lumen and frequent hemorrhagic ascites. Our rare observations also showed irregular debris floating within abundant intraluminal fluid, a pattern evoking parietal dissection.

Mucitis

Few observations in oncologic patients show thickened intestinal wall and abolished peristalsis.

Bowel Dilatation

The diagnosis of intestinal obstacle was classically made using plain radiographs, which raises problems in the supine patient. For some more X-rays, CT has replaced plain radiographs. Yet ultrasound is a rapid alternative, showing these two signs:

1. Dilatation of the bowel [15]

A dilated jejunum has a characteristic pattern (Fig. 6.9). More subtlety is required to distinguish between dilated ileum and normal colon. The best clue: the colon is a frame surrounding the small bowel. Disseminated loops of the same caliper are an excellent sign of small bowel.

2. An air–fluid level

Two maneuvers are possible.

1. Using the swirl sign. In a supine patient, when the probe is applied vertically on the abdomen, a gas pattern is first observed. A slight pressure (not to harm) is then applied on the abdomen with the probe and free hand (see Fig. 11.9 page 86). When this pressure is shifting the gas collection, a fluid pattern immediately appears on the screen. At this moment, small movements made at the side of the bed will create swirls. These swirls generate a characteristic ultrasound pattern: sudden (fleeting) succession of gas phases with fluid phases (Fig. 6.19). This suggestive pattern does not require long explanation.
2. This maneuver (unnamed): the probe is held transversally on the anterior wall of abdomen (therefore

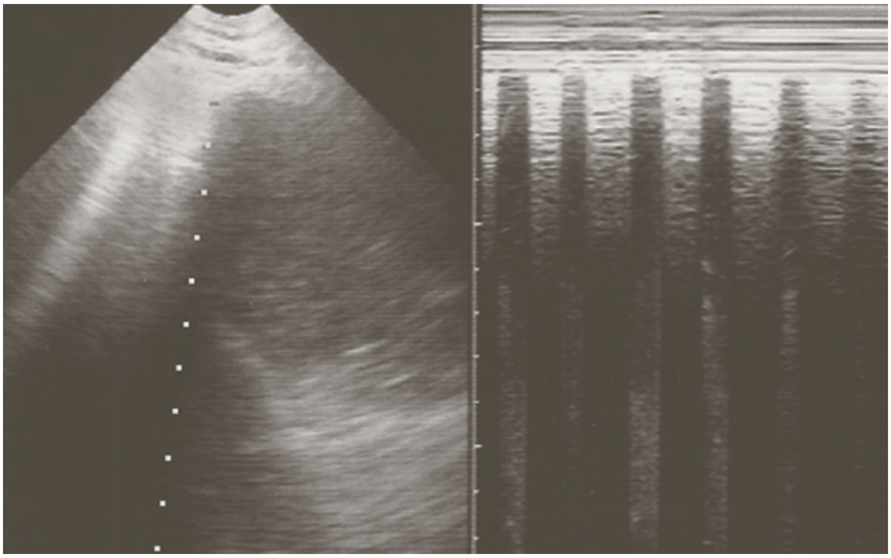

Fig. 6.19 Occlusion with air–fluid level. Demonstration of the swirl sign using the M-mode. *Left:* Real-time: air barrier at the left, fluid mass at the *right* of the screen. *Right:* Time-motion: the air–fluid level has been gently shaken and the swirl created is the source of these sudden changes due to air or fluid transmissions

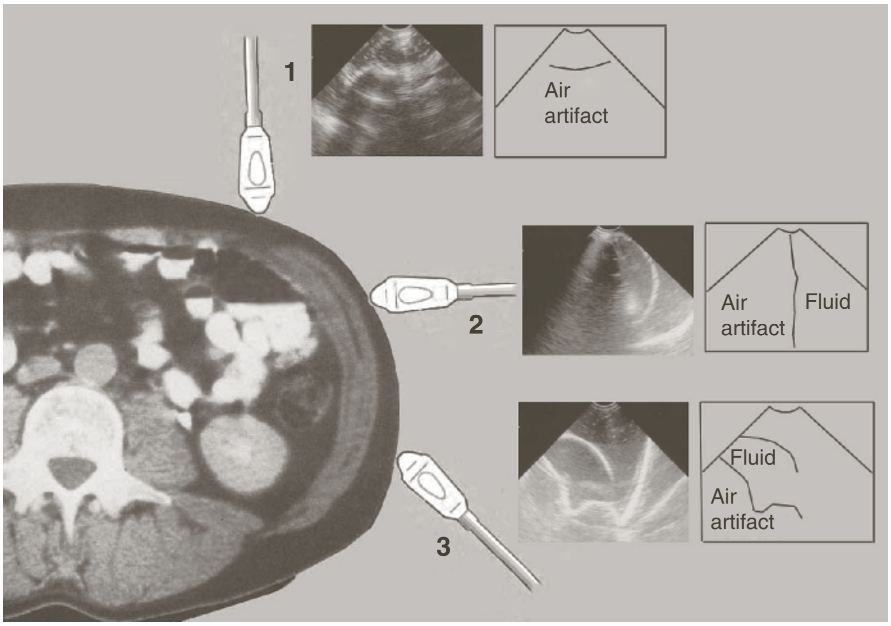

Fig. 6.20 Occlusion with air–fluid level. The probe *1* is vertical. The gas stops ultrasound displaying a horizontal line. The probe *2* is inserted at the horizontal level of the gas–fluid level. *To the right* of the image, fluid is observed; *to the left*, the image is hard to analyze, since air artifacts are tangential. The probe *3* reaches the gas–fluid level from behind. Probe *3* displays fluid, then an air artifact (the right beams reach this line earlier, hence the oblique line displayed). The air–fluid interface has a permanent dynamic characteristic of an air–fluid level, making a variant of the swirl sign

pointing to the ground), then shifted to the left side of the abdomen, in such a way that the probe is now parallel to the ground. The top of the screen is oriented to the anterior part of the abdomen, the bottom of the screen to its posterior part. Therefore, the gas is at the left of the image (with acoustic barrier), the fluid at the right, and the gas–fluid level is at the middle. Now, if the probe gets slightly a little posterior, the beam will reach first the fluid content, then be stopped by the gas content. Therefore, the gas–fluid line will be depicted on the screen, with a shimmering dynamic of this line (Fig. 6.20).

Once the diagnosis is done, real-time ultrasound can specify details that radiography and often CT do not: especially bowel dynamics. Complete absence of wall motion is seen in the paralytic ileus. To-and-fro movements of fluids due to ineffective contractions of the bowel can be seen in cases where there is an obstruction.

Peritoneal effusion is possible – and its analysis (tap) can be instructive.

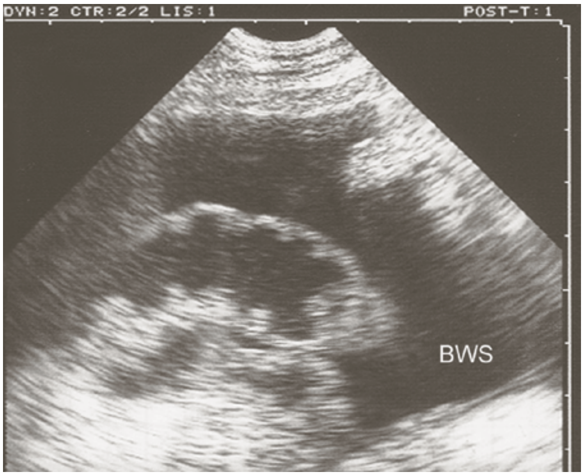

Fig. 6.21 Melena. This portion of the small bowel, outlined by ascites (*BWS* – for bat wing sign), is hypoechoic, indicating fluid. As was the case in this patient, this pattern can be the first sign of a GI tract hemorrhage, preceding any other sign

Fluid Digestive Sequestration

In a patient with shock, ultrasound detection of fluid sequestration within the intestines (Figs. 6.6, 6.10, and 6.14) immediately assumes a hypovolemic mechanism caused by digestive disorders (this sign will be associated with other ultrasound signs of hypovolemia). Scanning the abdomen makes it possible to roughly evaluate the sequestrated volume of fluid, which can reach several liters.

In a patient with clinically occult hemorrhagic shock, ultrasound can identify not yet exteriorized melena, which will appear as a fluid in the bowel (Fig. 6.21). This pattern is not specific, but ultrasound can be considered the first test able to detect GI tract hemorrhage, before the appearance of any clinical or biological anomaly.

Miscellaneous

Appendicitis and many semi emergencies are not in the scope of this book. Complicated appendicitis with shock usually yields moderate peritoneal effusion, which can be punctured. Intussusception yields suggestive signs on occasion [16]. Among some signs of midgut volvulus, the superior mesenteric artery can be seen right to the vein (the "whirlpool sign").

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