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The first edition of ‘Ultrasound of the Gastrointestinal Tract’ was most enthusiastically received by the readers of “Medical Radiology—Diagnostic Imaging”. Ultrasound technology has made and continues to make steady progress, and our knowledge and expertise in this field are constantly expanding. Therefore, the series editors approached Giovanni Maconi and Gabriele Bianchi Porro and encouraged them to take over the endeavor of a second edition. We are very pleased that they agreed and that the second edition of this important book can now be presented. This is a truly comprehensive book, covering the whole spectrum of pathological conditions involving the gastrointestinal tract and addressing the established as well as novel techniques of ultrasound imaging, such as functional and 3D ultrasound, contrast agents and intraoperative ultrasound, elastography, and transperineal ultrasound.

Dedicated chapters elucidate the normal anatomy and the general methods of ultrasound examination, with the various clinical entities organized according to the prominent clinical presentations: acute abdomen, chronic inflammatory bowel diseases, infections, and neoplasm. In a separate chapter, procedures and technical developments including intravenous contrast-enhanced bowel ultrasound, oral contrast-enhanced bowel ultrasound, assessment of motor function and functional ultrasound of the gastrointestinal tract, 3D intestinal ultrasound, elastography, and other new advances in GI ultrasonography and transcutaneous gastrointestinal biopsy as well as transperineal ultrasound are described.

Distinguished scientists from all over the world contributed the book’s well-structured and concise chapters, which include the etiology, clinical presentation and the value, and different imaging modalities for the diagnosis and management of patients with diseases of the gastrointestinal tract. We are confident that this book will be a great source of information for all those involved in the care of patients with GI diseases.

Munich

Maximilian F. Reiser
Seven years ago we published the first edition of ‘Ultrasound of the Gastrointestinal Tract’. In order to update the content of the textbook, 2 years ago we agreed to write a second edition; now we are pleased to present the result of our work.

The two reasons which led us to do it were the large international success of the former edition, which sold out, and the wide appreciation of its comprehensive content and of its high-quality images, which proved to be very useful in daily practice.

New images, videos, and scientific data were inserted into the original chapters, which already provided a comprehensive overview of sonographic imaging and of its usefulness and limits in detecting acute and chronic gastrointestinal diseases, such as appendicitis, diverticulitis, obstruction, malabsorption, inflammatory and infectious bowel diseases, neoplasm, and hernias.

Completely, new chapters on techniques of investigation and on anatomy of the normal gastrointestinal tract and new topics, like rare inflammatory disorders, vasculitis, cystic fibrosis, amyloidosis and graft versus host disease, were added; finally, specific chapters were devoted to epiploic appendagitis and intestinal endometriosis.

However, every single chapter was meant to help the abdominal sonographer interpret incidental findings of the gastrointestinal tract and provide useful information for as many as possible problems in patients with abdominal complaints.

The book also considers specific technical developments and applications of gastrointestinal ultrasound such as functional and 3D ultrasound, contrast agents, operative ultrasound, sonoelastography of the gastrointestinal tract and transperineal sonography, which may become of increasing importance in the near future.

These applications may expand the use of gastrointestinal ultrasound, increasing its indications and accuracy in acute and chronic inflammatory, organic and functional disorders. In addition to that, gastrointestinal ultrasound still is a noninvasive, inexpensive, wide available and repeatable procedure, and a valid aid to select and carry out more expensive and invasive examinations.

We sincerely hope that the book will encounter the same interest and success of the previous edition and will still be a useful and insightful tool both for sonographers specialized in radiology, gastroenterology, internal medicine and surgery, and for many physicians with an interest in sonography or specifically in intestinal sonography.

The editors of this issue would like to thank the Series’ Editor, Prof. Maximilian F. Reiser, for his valuable suggestions and assistance and all the authors who have accepted to so remarkably update or rewrite their contributions. We are also grateful with Sarah Boscu McGill for the English revision of most manuscripts of the book.
A most sincere word of gratitude goes to Corinna Schaefer of Springer-Verlag for her
great, constant, patience, and untiring efforts in helping us to collect and edit the
manuscripts; her devotion deserves special recognition.

Last, but not least, a special word of thanks goes to our families for all their
encouragement and support.

We hope the readers will share our enthusiasm for the interesting and rapidly
developing matter of ultrasound and will enjoy our textbook.

Giovanni Maconi
Gabriele Bianchi Porro
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Bowel Ultrasound: Investigation Technique and Normal Findings

Giovanni Maconi, Caterina Rigazio, and Elena Ercole

Abstract

Ultrasonographic examination of the gastrointestinal tract is currently employed in many suspected acute and chronic inflammatory conditions, for purely diagnostic purposes and the follow-up of well-known gastrointestinal diseases. Improvement in ultrasonographic technology and investigation techniques of the gastrointestinal tract have overcome to a great extent all impediments and prejudices in using bowel ultrasound for the assessment of digestive diseases. Nowadays, it is possible to assess accurately the main features of the intestinal wall such as its thickness, echo pattern, vascularity, flexibility and motility, to evaluate the diameter and intraluminal content of the bowel and peri-intestinal changes, such as lymph nodes and the status of mesenteric fat. Acknowledgment of these ultrasonographic findings makes it now possible to suspect or detect various gastrointestinal diseases, and improve and speed up diagnostic process of several conditions.

1 Introduction

Nowadays, abdominal ultrasound is an integral part of the decision making process in patients with abdominal disorders. Whether ultrasound examination is performed by clinicians or radiologists, it is usually the first imaging procedure which directly follows the history and physical examination in patients with symptoms or clinical signs suggesting abdominal disease.

The main advantages of using ultrasound as the first diagnostic imaging modality in abdominal disorders may be the shortening of time needed for achieving an accurate diagnosis, avoiding unnecessary, costly or even risky procedures with a positive fall-out in terms of the saving of financial resources.
Of course, in order to obtain the maximum integration of available ultrasonographic information into the patient’s management, the clinician should have appropriate knowledge of this procedure.

Unlike parenchymatous abdominal organs, the digestive tract has for a long time been considered unsuitable for exploration by ultrasound, even though the first study showing the potential effectiveness of this technique for bowel examination dates back to the 1970s (Hauser et al. 1974; Daggett 1974; Lutz and Petzoldt 1976).

In recent years, to a great extent, technology has overcome all impediments and prejudices in using bowel ultrasound for the assessment of several digestive diseases. Thanks to its non-invasiveness, ready availability, repeatability and accuracy, ultrasonographic examination of the gastrointestinal tract is currently employed in many suspected acute and chronic inflammatory conditions, not only for purely diagnostic purposes, but also for the management and follow-up of well-known gastrointestinal diseases.

**2 Investigation Technique**

Sonographic investigation of the gastrointestinal tract is performed using conventional ultrasonographic probes. Bowel examination should begin with a convex 3.5–5 MHz probe, to have an overview of the gastrointestinal tract, in particular when the examination is part of the abdominal ultrasound. Then, for a detailed visualisation of bowel wall a 4–13 MHz high resolution linear or microconvex array should be used, because lower frequencies are useful for the examination of deep abdominal structures and higher frequencies for superficial parts.

Appropriate setting of the instrument is important for a successful examination. In particular, the focus and gain of the instrument should be adjusted to allow adequate penetration and to optimise image resolution. When available, tissue harmonic imaging (THI) should be used since it is significantly better than fundamental imaging for the depiction of the features of the wall, the luminal contents and peri-intestinal findings, such as free fluid, mesenteric lymph nodes and mesenteric fat changes (Fig. 1) (Rompel et al. 2006). If possible, specific pre-setting for each probe should be prepared, to be used in different clinical and anatomical contexts (e.g. normal and oversize patients, paediatrics, perianal disease).

For routine ambulatory examinations, it is preferable to perform the bowel ultrasound in a fasting condition. In fact, meal and feeding states may increase intraluminal gas and may hamper the evaluation of some abnormal functional features of the stomach, such as delayed gastric emptying. Also the intake of a large quantity of liquid meals and water just before bowel ultrasound should be avoided. In some instances, this may mimic partial small bowel obstruction (e.g. due to adhesions) and malabsorption (e.g. coeliac disease) hampering a correct diagnosis and the exclusion of these conditions. However, the fasting state is not mandatory (e.g. in acute abdomen, bowel ultrasound may be of value despite feeding condition).

Routine bowel evaluation of patients with chronic (or not acute) abdominal symptoms, usually should be systematically performed, e.g. starting from hypogastrium or left iliac fossa (i.e. from the sigmoid colon) and than continued to examine the colon, terminal ileum, appendix, small bowel, up to the stomach. However, other examination sequences may be valid provided the whole gut is assessed. On the
contrary, in acute setting, in particular when a well-localised abdominal pain is present, bowel examination should start from the maximum tenderness area complained of by the patient, possibly with the help of the patient, who may put the probe just over the tenderness point. However, even in the acute setting, the bowel examination should assess all parts of the gastrointestinal tract.

In the event of suboptimal visualisation of the bowel wall due to the presence of gas, graded compression of the investigated gastrointestinal segment may help to shift intraluminal gas and thereby to improve visualisation of posterior parts of the bowel, in particular for the anatomical structures in the lower quadrants of the abdomen such as appendix, terminal ileum, caecum and sigmoid colon (Bluth et al. 1979). The patients are examined in supine position but, if necessary, they may be turned on the left or right side or put in an upright position, to move the bowel and its content, to avoid the interference of gas and optimise the visualisation of the features of bowel walls.

3 Normal Bowel Wall

The main features of the bowel walls to be assessed by ultrasound include: thickness, echo pattern, vascularity, flexibility and motility. These features depend in turn on the stretching and diameter of the hollow organs, which are associated with the content and presence of peristalsis that vary site-by-site in the gut. Probe frequency and grade of pressure wield by operators are other relevant parameters that may influence the ultrasonographic aspect of the gut.

Irrespective of the segment examined, as the gastrointestinal tract is a “tube”, ultrasound generally shows a “target” sign when the bowel segment is scanned transversally and as a “track” when it is scanned longitudinally (Fig. 2).

3.1 Bowel Echo Pattern

Echo pattern and thickening are the most important features of the bowel wall, and those commonly considered to detect the diseases of the gut.

Under good conditions of visualisation, the ultrasonographic aspect of the normal bowel wall is stratified, with five layers of different echogenicity. Each layer marks the boundary between two different histological structures. Starting from inside, the first layer is the interface between the lumen (hyperechoic) and the mucosa (tenuously hypoechoic). Between the mucosa and muscularis propria (both hypoechoic) stands the submucosa (hyperechoic). The muscularis propria is limited by the last layer (hyperechoic), the serous (Fig. 3). Indeed, the wall layers and histology are not exactly matching, and the ultrasonographic image is not “the tissue” but rises from the resolution of different interfaces and reverberation artefacts (Bolondi et al. 1986; Kimmey et al. 1989; Nylund et al. 2008). However, their correspondence is used in the staging of some diseases and loss of stratification, when one or more layers are missing, is suspected or considered a sign of disease.

3.2 Bowel Thickness

The thickness of the bowel wall is regarded as the main ultrasonographic feature of the gut. Among the features of the bowel wall, this is the only quantitative parameter, and almost all studies reported only this value as the criterion to assess the presence of a gastrointestinal disease.
The measurement of wall thickness should be taken using the transducer with as high a frequency as possible, preferable 5 MHz or more or with the transducer that allows to distinguishing different layers of the wall. In fact, the measure of the thickening should be taken from the external hyperechoic layer, corresponding to the serosa, to the internal hyperechoic layer representing the interface between the mucosa and intestinal content. Only when these two interfaces are simultaneously visible in a perpendicular scan of the loop, the measurement should be considered appropriate. Since the dorsal part of the gastrointestinal tract is frequently difficult to image using transabdominal ultrasound, the measurements should be obtained from the anterior wall and repeated in that segment, both in longitudinal and transverse section, avoiding haustration and mucosal folds (e.g. in the colon; Fig. 4) and segments with spasms or contractions of the loop (e.g. in the small bowel and stomach; Fig. 5) to avoid overestimation of the thickness.

The thickness of normal gastrointestinal walls varies according to the anatomical segment, age, weight and, to some extent, to the fed/fasting state, being thicker in the sigmoid and ileum and usually increasing with age, weight and in feeding state (Nylund et al. 2012). It may also vary depending on the frequency of the transducer and the use of oral contrast agents. In fact, measurements with high frequency probes and with the use of contrast agents show thinner wall thickening (Pallotta et al. 1999; Nylund et al. 2012). However, despite normal wall thickness has been assessed as not above 2 mm, most studies and meta-analyses set the cut-off for bowel diseases (in particular for inflammatory diseases) between 3 and 4 mm (Fraquelli et al. 2005; Horsthuis et al. 2008). However, the gastric wall is usually thicker and may be up to 5–6 mm (Rapaccini et al. 1988).

### 3.3 Bowel Diameter and Intraluminal Contents

The diameter of the bowel and its content vary according to the site, the fasting/feeding state and bowel function.

Normal bowel loops usually show diameter <25 mm in the small bowel and <50 mm in the colon, even when luminal contrast agents are used. Although these values have been suggested as the cut-off for bowel intestinal obstruction, they may be valid also for other diseases and pathological conditions such as coeliac disease,
malabsorption, intestinal infectious and inflammatory diseases, pseudo-obstruction and other abnormalities of bowel peristalsis.

As far as the intraluminal content is concerned, empty gut appears in longitudinal section as a thin hyperechoic line that represents the interface between the two mucosas that face each other. Otherwise, when content is gaseous, reverberation artefacts ("ring down" artefacts or "comet tail" artefacts) can hide the bowel wall distal to the probe and only the most superficial wall can be properly studied. The gradual compression of the loop can move the gas making it possible to examine the distal wall better.

The liquid content appears anechoic, the superficial and the distal wall are both displayable and the internal profile of the mucosa as well is usually clearly appreciable (Fig. 6). For this reason, luminal contrast media for ultrasonography such as SICUS (Small Intestinal Contrast UltraSound) are used to emphasise the issues described above (see “Oral Contrast-Enhanced Bowel Ultrasound”).

Liquids mixed with a solid or gaseous component appear as corpuscular media. Its ultrasonographic image consists in spots with different sizes and echogenicity and if peristalsis is slow it is possible to distinguish levels in the content (Fig. 7).

The solid component may be appreciated with a stone-like aspect or as a dark solid mass with posterior shadowing (Fig. 8). Such content is usually observed in the colon, in particular in constipated patients, and sometimes in patients with bowel obstruction just proximally to the stenotic segment (the so called “fecal sign”).

### 3.4 Bowel Wall Vascularity

The assessment of vascularity of bowel walls and intestinal lesions is part of the sonographic evaluation of intestinal diseases. Colour or power Doppler sonography and contrast-enhanced sonography may be used to estimate the perfusion of bowel abnormalities and show neovascularisation and hyperaemia occurring in inflammatory bowel diseases and neoplastic lesions. The assessment of hyper-vascularity is therefore a useful adjunct to B-mode assessment to suggest the inflammatory or neoplastic nature of an intestinal lesion.

Also the spectral analysis of Doppler signals of arteries supplying the gastrointestinal tract (coeliac trunk, superior and inferior mesenteric arteries) and the vessels draining the intestine has been used to estimate bowel perfusion and assess the activity of inflammatory bowel disease, but data about the accuracy (e.g. sensitivity and specificity) of this method in evaluating the activity of the diseases is still
lacking. On the other hand, the only detection of corpuscular movement into the vessels can provide an estimation of the vascular bed of a tissue. On this regard, power and colour Doppler can usually assess the perfusion in vessels of 100 μm in width, with blood flow up to 1 mm/sec. Vascular perfusion in capillaries and vessels with diameter < 20 μm, can be assessed only using contrast-enhanced ultrasound (“Intravenous Contrast-enhanced Bowel Ultrasound”). These methods can be routinely employed to characterised lesions previously detected by conventional B-mode ultrasound.

### 3.5 Elasticity and Peristalsis

The assessment of bowel elasticity and peristalsis is a subjective, though important part of bowel examination. Although subjective, the estimate of compressibility of the bowel, namely the change in shape of the transverse section of the bowel under gentle compression with the probe, can be used to differentiate inflamed appendix from the bowel and, to some extent, to discriminate between a normal bowel wall from inflamed or neoplastic bowel segments and between inflammatory from fibrotic strictures in Crohn’s disease. However, the assessment of this property of the bowel remains subjective and influenced by the depth of the loop in the abdomen. Advances have been made in the sonographic assessment of stiffness of several tissues and organs, including bowel, by means of sonoelastography (“Imaging of Tissue Elasticity in Gastrointestinal Disorders”). This technique may provide quantitative and qualitative estimates of tissue stiffness. It actually represents a promising tool to characterise the gastrointestinal lesions, but its use in routine practice is not recommended so far.

The assessment and quantification of bowel peristalsis may be difficult and subjective, although useful in several intestinal diseases. Increased small bowel peristalsis has been frequently described in coeliac disease and acute mechanic bowel obstruction, while dynamic ileus is characterised by absence of peristaltic movements (see “Coeliac Disease” and “Intestinal Obstruction”). However, the precise definition of “increased peristalsis” as well as the accuracy of bowel ultrasound in the assessment of bowel movement in fasting and feeding state is still lacking.

### References


**Fig. 8** Longitudinal scan of a colonic loop with solid (long arrows) and gaseous (short arrows) content
Normal Gastrointestinal Tract

Caterina Rigazio, Elena Ercole, and Giovanni Maconi

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Abstract

Transcutaneous sonography allows the evaluation of almost all tracts of the gut. The main characteristics of the gastrointestinal tract, in particular the features of its wall, intraluminal content, and extraintestinal findings, may be assessed from the upper esophagus to the rectum, with the exception of the intrathoracic esophagus, which is not accessible to the transcutaneous ultrasound beam. This chapter describes technical approaches to intestinal ultrasound examination and main ultrasonographic findings of the normal gastrointestinal tract.

1 Introduction

Transcutaneous sonography allows the evaluation of almost all tracts of the gut, from the upper esophagus to the anus. However, parts of the gastrointestinal tract, such as the intrathoracic esophagus, are not accessible to the transcutaneous ultrasound beam and others such as gastric fundus, duodenojejunal junction, left colonic flexure, and distal sigmoid colon, are not systematically and completely evaluable, mainly due to the presence of gas or patient constitution.

Evaluation of the gastrointestinal tract should be performed taking into account the main characteristics of the bowel wall, its intraluminal content, and extraintestinal findings like lymph nodes and mesenteric fat.

Ultrasound is a dynamic and repeatable tool, which experienced sonographers usually employ using variable technical approaches to overcome the main limitations due to gas and patient constitution. Progressive bowel compression of the air-containing organ, changing the patients position, water administration, or oral luminal contrast agents can be used to assess or to improve the visualization of all parts of the gastrointestinal tract.
Fig. 1 Longitudinal (left side) and transverse (right side) scanning of cervical esophagus (arrows). T Thyroid, C Carotid artery.

Fig. 2 Ascending subcostal scanning (left side) and corresponding ultrasonographic image (right side) of the terminal esophagus (E) and gastric cardia (arrows). L liver, S fundus of the stomach.
2 Esophagus

Transcutaneous ultrasound examination of the esophagus can be performed on the cervical and sub-diaphragmatic segment only. In fact, an acoustic window for the adequate scanning of the intrathoracic segment is lacking. The best diagnostic accuracy of the whole part can be reached using endoscopic ultrasound.

Cervical esophagus is pointed out by scanning the neck on the left side of the midline with a linear probe. It is 2–3 cm deep, behind the thyroid left lobe, postero-laterally to the trachea, prior to the long muscle of the neck, and to the osseous plan designed by the transverse processes of cervical vertebrae. It has a “target” appearance in transversal scans and it is tubular looking in longitudinal scans. The lumen is generally collapsed and becomes noticeable when the salivary bolus is passing through (Fig. 1).

Terminal esophagus is sub-diaphragmatic and can be examined by scanning sagittally the epigastrium or from the left paramedian site in ascending subcostal scans: the esophagus and the esophageal gastric junction are posterior to the left hepatic lobe, anterior to the osseous plan, and to the abdominal aorta (Fig. 2).

3 Stomach

The stomach may be studied with 3.5–13 MHz convex or linear probes. The gastric wall is multilayered, and its thickness up to 7 mm, depending on its functional state (contraction or relaxation, stretching). To better visualize

Fig. 3 Transversal scans (a, c) with schematic representations (b, d) of the gastric fundus showing gastric folds appearing as “cartwheel” image
the gastric wall, the intake of a small quantity of water just before the examination can be convenient.

Fundus and gastric body can be difficult to look over because they are deep-seated and frequently filled with gas so that there is an obstacle to the passage of the ultrasound beam. Fundus and body can be imaged by scanning sagitally the epigastrium or using ascending subcostal scans from the left side, keeping the probe parallel to the axis of the costal arch. They are placed medially to the left hepatic lobe, before the tail of the pancreas and laterally to the spleen. Changing the patient position can be useful to better study the fundus and gastric body. Depending on the stretching of the organ and on its content, gastric folds can be seen as introflections of the gastric wall, scanning the organ transversally to its major axis (“carthweel” image), or as stratified structures parallel to the gastric wall using longitudinal scans (Fig. 3).

The antrum and the pyloric region can be more easily examined because they are superficial (some details can be studied with a linear probe as well). They can be detected

Fig. 4 Transversal scanning (left side) and corresponding ultrasonographic image (right side) of the gastric antrum (A) that is well demarcated by the thickened muscular layer (arrows). L liver, P pancreas, mv mesenteric vein

Fig. 5 Longitudinal scan on the long axis of stomach. On the left side it is well evident the ogival shape of the thickened muscular layer of pylorus and the duodenal bulb. On the right side the antrum
with epigastric transversal and sagittal scans below the left hepatic lobe prior to the pancreatic body and the splenoportal venous axis (Fig. 4). The pylorus can be distinguished from the antrum for its particular morphology and the greater thickness of its muscular layer (Fig. 5). Transabdominal ultrasonography may assess the anatomical variants of an operated stomach, which should be acknowledged because they can be mistaken for disorders of the small intestine or of the transverse colon. When a total gastrectomy has been performed a tubular structure, which is the terminal esophagus anastomosed to a jejunal loop, can be highlighted at the site of the stomach. In case of partial gastrectomy only the gastric stump anastomosed to jejunal loops is detectable.

4 Duodenum

The duodenum is divided into four parts each of them different for morphology, location, and relationship with the abdominal organs.

To the right of the pylorus, the duodenal bulb can be seen as a tubular structure with a thin wall and a mainly gaseous content, strongly echogenic under fasting conditions. It can be found below the left hepatic lobe, medial to the gallbladder, in front the cephalic portion of the pancreas and to the gastric antrum.

The second portion of the duodenum (descending duodenum) is antero-medial to the right kidney, lateral to the inferior vena cava and posterior to the gallbladder (Fig. 6). When the lumen is stretched by fluids, duodenal folds are recognizable as small fingerlike protrusions on the luminal site. Under the same conditions it is possible (rarely) to detect the papilla of Vater as a small (<1 cm) round structure protruding into the lumen.

The duodenal third portion has a very deep, horizontal course. It is difficult to visualize because of its seat and its lumen, normally collapsed. It can be searched with axial scans in the epi-mesogastrium before the aorto-caval plan, posteriorly to the superior mesenteric vessels.

The fourth duodenal portion (ascending) and the angle of Treitz are difficult to detect because they are located behind the stomach and frequently the gaseous content of the fundus and body is interposed. These structures can be detected with transverse scans of the epigastrium, behind the gastric antrum and before the pancreatic body and tail.

5 Small Intestine

Ultrasonography of the small intestine takes place in two stages. Usually it includes an overview scanning with the convex probe and a subsequent optimization of the details with linear or microconvex high frequency probes. The echogenicity of the wall is multilayered and the regular wall thickness, using high-resolution probes, with a slight degree of compression and in the absence of peristaltic contractions, is ≤4 mm.

Small intestine loops have increased mobility due to the peristalsis, the breathing, and the induced mobility due to the compression brought about by the probe, compared with other intestinal loops.

Mobility and compressibility of the loops are important characteristics, both in the functional study of small intestine and looking for pathological patterns. They may change in inflammatory or malignant bowel diseases and in the postsurgical adhesions syndrome.

The proper identification of the various sections of the jejunum and ileum is inaccurate for the lack of fixed landmarks but it is possible using topographic criteria and relying on the frequency of *valvulae conniventes* and of the peristaltic activity. Only the jejunum, at the Treitz level, and the terminal ileum have fixed, easily recognizable landmarks because they are located at the extremities of the mesenteric root.

The proximal jejunal loops are observed in the left hypochondrium. They have well-represented folds, frequently liquid content and active peristalsis (14 contractions per minute). Proceeding toward the terminal ileum, to the right iliac fossa, the ileal loops are detectable in the mesoipogastrium and in the lower right quadrants. The folds became rarer until they disappear and peristaltic activity slows to seven contractions per minute (Fig. 7).
The terminal ileum is easily detectable in the right iliac fossa antero-medially to the iliopsoas muscle and to the iliac vessels (Fig. 8, Video). It runs horizontally from the cecum for a short distance lowering caudally. Scanning longitudinally to its axis it is a tubular structure while in cross-sections it is a target image. It is possible to observe liquid–gas contents passing through the ileocecal valve to the colon.

6 Appendix

It is neither easy nor common in normal conditions to visualize the appendix. It may be detected using high-resolution probes and delicate maneuvering of gradual compression to move the ileal loops and the cecum in order to reduce the
artifacts due to their gaseous content. The appendix, when visible, is located in correspondence to the right iliac fossa, in front of the iliopsoas muscle, and posterior to the cecum and the terminal ileum. Since its site is susceptible to individual variability it can be useful, when looking for it, to change the patient’s decubitus (left side) and to empty the bladder. The normal appendix appears as a thin tubular structure with stratified walls. It is mobile and easily compressible, its diameter ≤6 mm (Fig. 9) (see “Acute Appendicitis and Appendiceal Mucocele”).

7 Colon

The distal sigmoid colon and the rectum are difficult to examine because of their deeper site. The colon differs from the small bowel for the characteristic haustra that determine its wavy, polycyclic shape. The echo structure of the colon wall is multilayered with a clear representation of the mucosa, submucosa, and the muscular layer. Under the
Fig. 11 Transversal (left) and longitudinal (right) scans of the rectum (arrows). It is observed behind the prostate (P) and the bladder (B).

Fig. 12 Transversal scanning (left side) and corresponding ultrasonographic image (right side) of the splenic flexure of the colon (D) that is detectable with intercostals left side scans, between the spleen (S) and the kidney (K).
same conditions given for the small intestine the normal wall thickness is \( \leq 4 \) mm. Due to the hypertrophy of the muscular layer, in the absence of concomitant alterations of parietal echo structure or of the surrounding structures, the sigma’s thickness may be normal up to 5 mm (Fig. 10).

The rectum is even thicker and it is considered normal up to 7 mm. The urinary bladder repletion can facilitate the identification of the rectum, posterior to the prostate in males and to the uterus in women (Fig. 11).

The sigma is normally located in the left iliac fossa, in front of the psoas muscle, laterally and posterior to the bladder. The frequent absence of endoluminal contents helps the exploration of both the bowel walls (distal and proximal to the probe). In case of dolicocolon, the sigma can be found in the hypogastrium and in the right iliac fossa as well. If the sigma is located in the right iliac fossa and especially if the echopattern is altered it can be difficult to distinguish it from the distal and terminal ileum. Compared to the ileum, the sigma has a more gassy content, lower peristaltic activity and hypertrophy of the muscular layer.

The descending colon can be seen along the left side, and posterior up to the splenic flexure that is detectable between the spleen and the kidney (Fig. 12). Sometimes, it can be examined with intercostal left side scans or subcostal scans in the left hypochondrium.

The transverse colon can be observed with longitudinal scans below the gastric antrum. It generally runs transverse to the upper abdominal quadrants. The transverse colon wall proximal to the probe (anterior wall) shows a typical undulating aspect, due to the hastra coli. The

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**Fig. 13** Longitudinal scan of the transverse colon \( (T) \). Hastra coli \( (arrows) \), typically filled with gas, are well represented by an *undulating line*

**Fig. 14** Longitudinal scan of the ileocecal valve \( (asterisk \ and \ arrows) \) protruding in the cecum \( (C) \) in normal condition \( (a) \) and in a Crohn’s disease patient \( (b) \). \( I \) terminal ileum
other wall, distal to the probe (posterior wall), is often hidden by the gaseous content (Fig. 13). The hepatic flexure appears below and medial to the liver, in front of the right kidney.

Similarly to the transverse colon, the ascending colon has an undulating profile and is frequently distended by feces. The ascending colon is detected along the right side, down to the right iliac fossa, where the cecum is located. When the

**Fig. 15** Shape of intestinal loops (*arrows*) and mesenteric pedicles (*p*), emphasized by free fluid into the abdomen

**Fig. 16** Ultrasonographic images with schematic representation (*right*) of mesenteric pedicles: mildly hypoechoic parallel layers separated by thin hyperechoic strips. On the *right side* of them, ileal loops can be seen as “target” like images