Gastrointestinal Ultrasound in Emergency Setting

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Contributor: Andrea Boccatonda, Damiano D’Ardes, Viola Tallarico, Susanna Vicari, Elena Bartoli, Gianpaolo Vidili, Maria Teresa Guagnano , Giulio Cocco, Francesco Cipollone, Cosima Schiavone, Esterita Accogli

Acute bowel diseases are responsible for more than one third of subjects who were referred to the emergency department for acute abdominal pain and gastrointestinal evaluation. Gastrointestinal ultrasound (GIUS) is often employed as the first imaging method, with a good diagnostic accuracy in the setting of acute abdomen, and it can be an optimal diagnostic strategy in young females due to the radiation exposure related to X-ray and computed tomography methods. The physician can examine the gastrointestinal system in the area with the greatest tenderness by ultrasound, thus obtaining more information and data on the pathology than the standard physical examination.

Keywords: ultrasound ; bowel ; emergency ; inflammation

1. Ultrasonographic Anatomy of Gastrointestinal Tract

A general approach to GIUS consists in a systematic scanning of the gastrointestinal tract [1][2][3]. First, a curvilinear low frequency probe is used to obtain a systematic overview; subsequently, a linear high-frequency probe is used for a more detailed examination of the bowel wall [1][2][3][4].

The study of both the large and small intestine usually starts in the right iliac fossa, as the cecum, the ileocecal valve and the terminal ileum are typically located in this area, over the anatomical landmarks represented by the iliopsoas muscle and the right iliac vessels [1][2][3][4].

The small bowel is the most difficult GI tract to examine; the terminal ileum is the only small bowel loop and can be identified due to its fix position in the right iliac fossa and the presence of specific anatomical landmarks. Other segments of the small bowel are difficult to examine, and ultrasound can provide a general overview of the jejunal and ileal loops through a systematic scanning approach that involves parallel lines cranially and caudally through the abdomen and by exerting enough probe pressure to display the deeper part of the abdomen [4][5].

The small bowel is characterized by the presence of valvulae conniventes, which decrease in number and height from the proximal jejunum to the distal ileum, and they are best visualized in fluid-filled bowel loops [4]. The small bowel is usually collapsed after overnight fasting. The normal maximum diameter of small bowel loops is up to 2–2.5 cm [6].

In order to study the large bowel, after the cecum has been identified, the probe is moved in the distal direction following the ascending colon, transverse colon, descending colon, sigmoid colon and the rectum. The colon is located along the peripheral areas of the abdomen, with the ascending and descending colon fixed to the retroperitoneum on the right and left, with a vertical course anterolaterally to the iliopsoas muscle. The location of the transverse and the sigmoid colon can significantly vary due to the different length of the mesocolon. The transverse colon usually has a horizontal course and can often be displayed just behind the gastric antrum, but it may also descend to the lower abdomen in cases of an elongated mesocolon. The sigmoid colon is usually seen into the pelvis, above the urinary bladder, but it can also cross the midline to the right iliac fossa or even extend up to the liver. The rectum may be seen behind the bladder by low-frequency probe [4][7].

The right colon is usually filled with stool and gas, and it allows the visualization of haustration, which gives the colon profile its typical polycyclic appearance in the longitudinal view and limits the bowel wall study to the superficial side. On the contrary, the left colon is often seen in a contracted condition, so that haustration is not usually visible and the bowel wall is better displayed [7].

The normal diameter of the colon is up to 5 cm, but the cecum could be larger in size [7]. The appendix arises from the cecum, about 2–3 cm below the ileocecal valve. Its position is highly variable, ranging between a medial course over the iliopsoas muscle and a medial or lateral elevation, or a retro-cecal course [4]. Although usually considered difficult to study, technical improvements and providers experience allow the display of a normal appendix in more than 50% of subjects [8]. When visualized with a high-frequency probe, the normal appendix appears as a tubular structure with a cul-de-sac on a longitudinal view, and as a target structure with different wall layers on a transverse view. A predominant hyperechoic appearance may result [9][10] if the lumen is filled with gas. In clinical practice, the normal appendiceal diameter measures up to 6 mm [9]. Normal appendiceal walls do not show vascularity on Doppler [11].

The bowel wall consists of five sonographic layers when examined with a high frequency transducer (above 5 MHz). The sonographic layers do not exactly correspond to the histological ones, thus representing a combination of interface echoes of the histological layers. Starting from the lumen, the first layer (hyperechoic) is the interface between the mucosa and the lumen, the second layer (hypoechoic) to the mucosa, the third layer (hyperechoic) to the submucosa, the fourth layer (hypoechoic) to the muscolaris propria and the fifth layer (hyperechic) to the interface echo between the muscolaris and the serosa [4].

According to the European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB) Recommendations and Guidelines for Gastrointestinal Ultrasound, bowel wall thickness should be measured perpendicular to the wall, from the interface between the serosa and the proper muscle to the interface between the mucosa and the lumen. A bowel wall thickness less than 2 mm could be considered as normal in a usual filling condition, for both the small and large intestine, with exceptions represented by the duodenal bulb and the rectum [4].

2. Flares and Complication of Inflammatory Bowel Diseases (IBD)

According to the EFSUMB guideline, ultrasound should be employed to evaluate inflammatory bowel diseases (IBD) at first presentation, and to examine its extent, activity and possible complications [12]. GIUS has been demonstrated to be accurate in identifying active IBD, with a sensitivity and specificity of approximately 75% to 90% and 75% to 100% in Crohn's disease (CD) and 74% to 90% and 93% to 96% in ulcerative colitis, respectively [13][14].

Compared with the alternative options, namely CT and Magnetic Resonance (MR), GIUS has the advantages of being widely available, less expensive, easily repeatable and radiation free [15].

On GIUS, the most frequent pathological findings are bowel wall thickening, changes of the bowel wall echo-pattern, hyperemia of the bowel wall, reduced elasticity and peristalsis, mesenteric fat hypertrophy, enlarged lymph nodes and the presence of abdominal free fluid [16].

The presence of a thickened bowel wall is the most important US finding in CD to detect the disease and is the most frequent index considered in scores used to evaluate IBD activity [13][17]. In the latest studies, the cut-off value most often chosen to define a pathological finding is >3 mm, with a sensitivity and specificity of 89% and 96%, respectively [18][19][20]. When a high specificity is preferred, a bowel wall thickness cut off of >4 mm should be used (sensitivity of 87% and a specificity of 98%) [20].

In the acute phase of CD, the wall thickening is caused by transmural edema: the wall layers are often well defined, and it is possible to identify a typical aspect of a "target sign" on a transverse scan. A few studies have focused on the thickening of each wall layer in CD, finding a prevalent thickening in the submucosal layer, rather than the mucosal and muscolaris layers, in active CD [21][22]. On the other hand, in cases of severe disease, a focal or extensive disruption of the bowel wall layers can be detected due to the presence of deep longitudinal ulcerations [23].

The measurement of bowel wall thickness can be completed by a semi-quantitative evaluation of its vascularity by using color or power Doppler at the level of the most thickened segments, which is correlated with disease activity [12].

In addition to parietal features, GIUS allows the visualization of CD extraintestinal features, such as mesenteric fat hypertrophy, mesenteric loco-regional lymph nodes and abdominal free fluid. Mesenteric fat hypertrophy is a frequent finding in active CD and reflects clinical and biochemical disease activity [24]. Moreover, enlarged mesenteric loco-regional lymph nodes and the presence of a small amount of abdominal free fluid are common, but non-specific, findings in acute CD.

GIUS can also detect complications of CD. Strictures are detected on US as a stretch with thickening of the wall and thinning of the lumen: there could be a dilation of the upstream tract, with a possible accumulation of liquid and/or gas. Moreover, fistulas can be observed as hypoechoic tract connecting two loops to other structures, such as the skin or bladder, and are usually characterized by vascularized walls. Abscesses could be also detected: they are represented by hypo-anechoic lesions with liquid content. Phlegmon could also be found in patients with CD, and it is characterized by hypoechoic lesions with faded edges in the absence of colliquation.

In that setting, CEUS could represent a valid tool for a more specific diagnosis. Eventually, GIUS can also detect signs of perforation, characterized by the presence of free air in the subdiaphragmatic region or intraperitoneal liquid mixed with air bubbles.

Concerning ulcerative colitis, the disease typically involves the colic walls, which appear continuously and concentrically thickened (over 4 mm) with an absence of haustrations. The most relevant complication is the toxic mega colon that appear as an abnormal dilation of the large bowel lumen (more than 6 cm) coexisting with a reduced wall thickness and dilation and liquid distension in the intestinal loops.

3. Acute Appendicitis

Acute appendicitis is one of the most frequent abdominal emergencies worldwide, with an incidence of approximately 100 per 100,000 person-years and with a lifetime prevalence of 7–8% [25][26]. The classical presentation of acute appendicitis includes right iliac fossa abdominal pain (often migratory) with localized tenderness, fever, anorexia, nausea and vomiting. However, early features of appendicitis may be subtle, and elderly and frail patients can present with nonclassical or non-specific features [27].

Despite its high incidence, the diagnostic approach to acute appendicitis is still debated: some guidelines employ scoring systems, others suggest physician clinical assessment alone, and some guidelines include standardized imaging [28][29][30]. As several studies have demonstrated a marked reduction in the negative laparotomy rate with the use of abdominal ultrasound before surgery [31][32], recent guidelines have recommend GIUS to be routinely used in every patient with suspected appendicitis [29][33][34]. Indeed, the sensitivity and specificity of GIUS performed by experienced providers are above 90%, equivalent to CT or MR, with the advantage of being widely available, noninvasive and without ionizing radiation [35][36].

The role of GIUS in cases of suspected acute appendicitis is to confirm the diagnosis or to rule it out by demonstrating a normal appendix over its entire length, and to exclude an alternative cause of abdominal pain [33]. Moreover, GIUS can differentiate between uncomplicated and complicated appendicitis, as non-chirurgic management of uncomplicated appendicitis is recommended [37].

In cases of suspected appendicitis, it is recommended to search the inflamed appendix at the point of the greatest abdominal pain, pointed out by the patient, using graded compression [38]. Alternatively, a systematic approach involving the localization of terminal ileum, cecum and the origin of the appendix, 2–3 cm below the caecum, can be used [33].

In patients with acute appendicitis, the most accurate GIUS finding is a maximum outer diameter of >6 mm, with a sensitivity and specificity of 98% [9][39]. Additional findings consistent with the diagnosis of acute appendicitis are the incompressibility of the appendix [40], maximal tenderness over the appendix [41], the presence of large fecaliths [42][43] and an increased wall vascularity in color Doppler [44]. This sign is transiently detectable, and hypervascularity disappears in complicated appendicitis due to the ischemic changes in the appendix walls: therefore, increased wall vascularity rules-in appendicitis, but absent vascularity does not exclude it [11][45].

Secondary US signs related to the inflammation of the surrounding tissues are described, such as peri-appendiceal fluid, mesenteric lymphadenopathy and hyperechoic peri-appendiceal tissue (mesenteric fat hypertrophy) [40][42][46].

In clinical practice, only the combination of different GIUS signs allows the diagnosis of acute appendicitis to be reached [40][46]. The detection of an appendix with thickened walls and hyperechoic peri-appendiceal tissue over the area of the greatest pain are the most relevant criteria in the confirmation of the diagnosis [47], while mesenteric lymphadenopathy and the color-doppler evaluation of the appendix are not specific signs and could be demonstrated in several conditions [33][40][46].

The importance of complicated appendicitis (namely gangrenous appendicitis and perforated appendicitis) in the identification of signs relies on the consequences for its management, as the confirmation of complicated appendicitis usually excludes a conservative treatment [48].

The loss of stratification of the appendix wall, and particularly the loss of the echogenic submucosal layer, is the main GIUS sign of gangrenous appendicitis, which can be associated with the lack of vascularization on color Doppler [33][49].

4. Bowel Obstruction

4.1. GIUS Signs of SBO

SBO can be diagnosed in the presence of dilated (up to 2.5–3 cm) bowel loops detected to be at least 10 cm in length [50]. The appearance of the bowel content may range between corpuscolated (more frequent in recent or sub-occlusive forms) and anechoic (more frequent in prolonged forms) [50].

Increased peristaltic “to-and-fro” movement of the bowel loops (which tends to decrease in advanced forms) is a typical finding of acute mechanical obstruction, with the visualization of collapsed loops beyond the stenotic tract [51]. The identification of the transition point, between the dilated proximal and the collapsed distal loops, allow to define the site and cause of the occlusion: the site of obstruction is the distal/terminal ileum if it is in the right iliac fossa and lower quadrants, while it is the jejunum/proximal ileum if it is in the upper quadrants and left hypochondrium. Regarding the cause of the occlusion, the loss of normal visceral sliding is suggestive of abdominal wall adhesions, while deep visceral adhesions are difficult to identify [52]. Other rarer causes of occlusion, such as intussusception, tumors, foreign bodies and external hernias, can be diagnosed due to specific sonographic appearance [51].

It is relevant to consider the alteration of the peristalsis as a criterion for the diagnosis of mechanical ileus [53], which could be reduced, ineffective or absent (paying attention to false movement due to diaphragm and not to intestinal walls). Moreover, it is relevant to point out that the diameter is not an absolute criterion to diagnose bowel obstruction during an early phase of the disease, and other signs must be considered (for example, fluid-filled and hyperkinetic bowel loops with plicar hyper-representation [54].

If the obstruction persists, it could enhance the endoluminal pressure with an increase in the liquid content between the mesenteric recesses (‘sign of the thong’) [55] and then in the abdominal cavity. The detection of free fluid is linked to bowel wall vascular changes [56][57], such as the thickening of valvulae conniventes and the disruption of wall stratification, with normal thickness at 1–3 mm, wall thickening >3 mm, thinned walls <1 mm [12][50]. When the obstruction induces a great accumulation of fluids dilating the loops, it is possible to detect the Kerckring valves, also called valvulae conniventes (“keyboard sign”) [58].

4.2. GIUS Signs of LBO

LBO is detected in ultrasound as a clear transition from a dilated (>4.5 cm) to a non-dilated part of the colon, often with liquid content in the right colon and solid stools in the left colon. Otherwise, it is often not possible to measure the diameter and to obtain a wide visualization due to the presence of gas in the obstructed colon.

5. Gastrointestinal Perforation

Gastrointestinal perforation is a rare cause of acute abdominal pain in emergency departments [59]. Peptic ulcer, diverticulitis, ischemic bowel disease, blunt or penetrating trauma, iatrogenic factors, foreign body or neoplasm are major determinants of GI perforation [60].

The sudden onset of severe abdominal pain is the main symptom, but patients can report only mild symptoms, depending on the perforation site and the amount of leakage of the intestinal contents [59].

The detection of free gas in the abdominal cavity (pneumoperitoneum) is the most relevant finding suggestive of gastrointestinal perforation [61]. Convex probes are often used, but linear probes can more clearly detect small gas bubbles and allow to differentiate intraluminal vs. extraluminal gas [62]. Some data suggest an examination protocol based on scans in the epigastrium, right and left hypochondrium, umbilical area in the supine position and right hypochondrium in the left lateral position; that protocol seems to be better than a “2-scan fast exam” based on epigastrium and right hypochondrium scans [59].

US signs of pneumoperitoneum should be searched between the liver and the abdominal wall, and they are represented by an enhancement of the peritoneal stripe and hyperechoic lines with reverberation and ringdown artifacts (“dirty shadowing”). Air artifacts (gas) movement, according to patient position (shifting phenomenon), is very suggestive of pneumoperitoneum [63]. Different maneuvers have been proposed to detect those signs; one protocol is based on shifting the patient from the supine to the left lateral position, and to show air artifacts movement [64]. When air artifacts (gas) hide the left liver lobe, the application and release of pressure by the probe displaces the artifacts, and the liver appears and disappears [64]. The scissors maneuver is based on the application and subsequent release of pressure on the abdominal wall by the caudal part of the linear probe [65]. Bowel wall thickening, bowel dilatation, free fluid (with fibrinoid septa) and changes in the mesenteric fat are additional indirect signs of perforation [62][64].

Ultrasound is characterized by a better sensitivity than abdominal X-ray (86% compared with 76%) for the diagnosis of pneumoperitoneum [66]. GIUS is characterized by a better diagnostic accuracy than upright chest and left lateral decubitus abdominal X-rays, which cannot detect perforations in 20% to 62% of cases [67][68].

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