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Gastrointestinal Ultrasound (GIUS) in Intestinal Emergencies – An EFSUMB Position Paper

Gastrointestinaler Ultraschall (GIUS) bei intestinalen Notfällen – Ein EFSUMB-Positionspapier

Authors

Alois Hollerweger[1], Giovanni Maconi[2], Tomas Ripolles[3], Kim Nylund[4], Antony Higginson[5], Carla Serra[6], Christoph F. Dietrich[7], Klaus Dirks[8], Odd Helge Gilja[9]

Affiliations

1. Department of Radiology, Hospital Barmherzige Brüder, Salzburg, Austria
2. Gastroenterology Unit, Department of Biomedical and Clinical Sciences, "L.Sacco" University Hospital, Milan, Italy
3. Department of Radiology, Hospital Universitario Doctor Peset, Valencia, Spain
4. Gastroenterology, Haukeland University Hospital, Bergen, Norway
5. Department of Radiology, Queen-Alexandra-Hospital, Portsmouth Hospitals NHS Trust, Portsmouth, United Kingdom of Great Britain and Northern Ireland
6. Internal Medicine and Gastroenterology, S. Orsola University Hospital, Bologna, Italy
7. Department of General Internal Medicine Kliniken Hirslanden Beau-Site, Salem und Permanence, Bern, Switzerland
8. Gastroenterology and Internal Medicine, Rems-Murr-Klinikum Winnenden, Germany
9. Haukeland University Hospital, National Centre for Ultrasound in Gastroenterology, Bergen, Norway

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Correspondence

Dr. Alois Hollerweger
Department of Radiology, Hospital Barmherzige Brüder, Kajetanerplatz 1, 5010 Salzburg, Austria
Tel.: ++43/6 62/80 88
alois.hollerweger@bbsalz.at

ABSTRACT

An interdisciplinary group of European experts summarizes the value of gastrointestinal ultrasound (GIUS) in the management of three time-critical causes of acute abdomen: bowel obstruction, gastrointestinal perforation and acute ischemic bowel disease. Based on an extensive literature review, statements for a targeted diagnostic strategy in these intestinal emergencies are presented. GIUS is best established in case of small bowel obstruction. Metanalyses and prospective studies showed a sensitivity and specificity comparable to that of computed tomography (CT) and superior to plain X-ray. GIUS may save time and radiation exposure and has the advantage of displaying bowel function directly. Gastrointestinal perforation is more challenging for less experienced investigators. Although GIUS in experienced hands has a relatively high sensitivity to establish a correct diagnosis, CT is the most sensitive method in this situation. The spectrum of intestinal ischemia ranges from self-limited ischemic colitis to fatal intestinal infarction. In acute arterial mesenteric ischemia, GIUS may provide information, but prompt CT angiography is the gold standard. On the other end of the spectrum, ischemic colitis shows typical ultrasound features that allow correct diagnosis. GIUS here has a diagnostic performance similar to CT and helps to differentiate mild from severe ischemic colitis.

ZUSAMMENFASSUNG

Eine interdisziplinäre Arbeitsgruppe von europäischen Experten gibt einen Überblick über den Wert des gastrointestinalen Ultraschalls (GIUS) bei der Abklärung von 3 zeitkritischen Ursachen eines akuten Abdomens: Ileus, Perforation und akute Darmischämie. Basierend auf einer ausgiebigen Literaturrecherche werden Aussagen für eine zielgerichtete diagnostische Abklärung bei diesen intestinalen Notfällen präsentiert. GIUS ist eine gut etablierte Methode bei der Frage nach einem mechanischen Dünndarmverschluss. Metaanalyen und prospektive Studien haben eine mit der Computertomografie (CT) vergleichbare, gegenüber der Röntgen-Abdomen-Nativaufnahme aber bessere Sensitivität und Spezifität gezeigt. GIUS kann Zeit und Strahlungsdosis sparen und hat den Vorteil einer direkten Beurteilung der peristaltischen Aktivität. Gastrointestinale Perforationen sind eine Herausforderung

für weniger erfahrene Untersucher. Obwohl GIUS in der Hand des erfahrenen Untersuchers bei dieser Diagnose eine relative hohe Sensitivität erreicht, ist die CT die sensitivste Methode. Das Spektrum der Darmischämie reicht von der selbstlimitierenden ischämischen Kolitis bis zur fatalen Darminfarzierung. Bei der akuten arteriellen Mesenterialischämie kann GIUS zwar Hinweise geben, die rasche CT-Angiografie ist aber der Goldstandard. Am anderen Ende des Spektrums ermöglichen typische Ultraschallzeichen die korrekte Diagnose der ischämischen Kolitis. GIUS ist hier vergleichbar mit der CT und hilft milde von schweren Formen zu unterscheiden.

Introduction

Acute abdomen is a condition that demands urgent diagnostic evaluation and treatment. Today, gastrointestinal ultrasound (GIUS) and/or computed tomography (CT) scans are widely used to determine the cause of acute abdominal pain, so that targeted surgical intervention is possible in most cases and unnecessary surgery can be avoided [1].

Acute intestinal diseases account for more than one third of patients who present with acute abdominal pain [2, 3]. GIUS is frequently used as the initial imaging tool for diagnostic evaluation of these patients [4–7]. Two of the most frequent acute intestinal conditions, appendicitis and diverticulitis, have already been covered by the taskforce group (TFG) with EFSUMB recommendations in gastrointestinal diseases [8]. This paper deals with the other most important intestinal emergencies, namely bowel obstruction, gastrointestinal perforation and acute ischemic bowel disease.

The sonographic features of other rare acute intestinal conditions such as focal fat necrosis (omental infarction and epiploic appendicitis), angioneurotic edema, Meckel's diverticulitis, intussusception, and intestinal graft versus host disease have been discussed elsewhere by the same TFG [9]. Specific pediatric acute intestinal conditions are not within the scope of this paper.

Statements about imaging signs and use of imaging methods were created and voting on the statements was performed by 16 members of the TFG in an online survey. The agreement/disagreement level was scored on a five-point Likert scale as follows: A+: agree; A–: rather agree; I: indecisive; D–: rather disagree; D+: disagree.

Bowel obstruction

General remarks and clinical presentation

Bowel obstruction is a common challenge in emergency departments. In particular, small bowel obstruction (SBO), which is 4–5 fold more common than large bowel obstruction (LBO), accounts for approximately 2 % of all visits and up to 16 % of hospital admissions of patients with acute abdominal pain [10, 11]. LBO is mostly due to colonic malignancies. The most frequent cause of SBO is adhesions from previous surgery, in particular if complicated by peritonitis. These account for up to 80 % of cases, while Crohn's disease, tumors, hernias and volvulus are far less common [12, 13]. Only a subgroup (about 30–60 %) of patients with SBO will undergo surgery [14–18]. The mortality rate is increased if there is delay in diagnosis and if there are associated co-morbidities such as diabetes or cardiovascular, lung and neurological diseases [19].

In patients with a history and physical examination suspicious for SBO, blood tests and imaging are usually required to confirm the diagnosis and guide management [20].

The clinical presentation of patients is variable and no single clinical symptom is diagnostic. Abdominal pain, nausea, vomiting, absence of passage of flatus and/or feces and abdominal distension are the most common symptoms of SBO [21]. The clinical signs also vary significantly depending on the cause. For example, acute presentation is seen in cases of bowel incarceration or strangulation and prolonged symptoms in cases of malignant strictures. The location of obstruction may result in different presentation with primarily vomiting in proximal SBO vs. distension and abdominal cramps in distal SBO [22]. Nevertheless, it is often difficult to distinguish simple obstruction from strangulation [21, 22].

Abdominal pain associated with SBO is often described as crampy and intermittent. Changes in the character of the pain (e. g. from intermittent pain to constant pain) may indicate the development of serious complications, such as bowel wall necrosis or perforation. On physical examination, abdominal distention is present in about 60 % of patients with less distention when the gastric outlet, the duodenum or proximal small bowel is obstructed. Hyperactive bowel sounds occur early and hypoactive bowel sounds later in the disease process. Fever, tachycardia, peritoneal signs, leukocytosis, and metabolic acidosis suggest complicated disease such as vascular impairment or perforation [21].

In this context imaging procedures like GIUS should help to address the following:

1. Confirmation or exclusion of bowel obstruction,
2. Whether small bowel dilatation/ileus is mechanical or functional,
3. Identification of the site of obstruction,
4. Identification of the cause of the obstruction,
5. Recognition of the risk of associated critical intestinal ischemia and the need for emergency surgery,
6. The appropriateness of conservative management for patients not requiring immediate surgery [22, 23].

Examination technique and sonographic signs of bowel obstruction

A 3-step examination technique is suggested:

1. Epigastrium: to assess the stomach
2. Left mid-abdomen: to assess the jejunum and descending colon
3. Right lower abdomen: to assess the ileocecal junction

This approach allows an overview of whether bowel obstruction is present and which segments are involved [22, 24, 25].

A lateral approach to access the small bowel with the probe may be necessary to get a view of the fluid-filled part of dilated intestinal segments, if there is significant air anterior in dilated bowel loops [22].

In patients with clinical signs of SBO, the presence of a dilated and fluid-filled stomach can be easily detected via a subxiphoidal approach or a translienal view on the gastric fundus [24, 25]. In gastric outlet or duodenal obstruction, only these parts of the gut are dilated. This approach is also useful to assess the need for prompt placement of a nasogastric tube.

Sonographic features of SBO have been variably reported [13, 26–34]. However, most studies diagnose SBO in the presence of dilated (> 2.5–3 cm) fluid-filled bowel loops, sometimes with hyperechoic spots of gas moving within the fluid, over a length of at least 2–3 bowel loops or > 10 cm. The dilated bowel loops may have a mildly thickened wall and thickened valvulae conniventes (normally up to 2 mm).

Acute mechanical obstruction is characterized by increased peristaltic activity with to-and-fro motion of the bowel contents that may decrease later, as the length of time of obstruction increases. This is usually associated with an increased presence of corpusculated and semisolid content. However, peristaltic movements may also vary according to the segment of the bowel involved, being more frequent proximally and less likely in the distal small bowel.

The detection of collapsed bowel loops distal to a stenosis is a further important sign to assess in patients with SBO, in particular to help locate the site of obstruction. This is usually successfully done by identifying the collapsed descending colon or terminal ileum [22, 27, 35].

The GIUS criteria for LBO are still not well defined. Usually, LBO appears as an abrupt transition from a dilated (> 4.5 cm) to a non-dilated colonic segment, sometimes with liquid content in the right colon and solid stools in the left colon [32, 36]. However, due to abundant gas in the obstructed colon, it is frequently not possible to measure the diameter and to get a complete overview.

STATEMENT 1

Small bowel obstruction may be diagnosed by GIUS in the presence of dilated (> 2.5–3 cm) fluid-filled bowel loops over a length of at least 2–3 bowel loops or > 10 cm.

Consensus levels of agreement: A+ 15/16; D– 1/16

STATEMENT 2

Increased peristaltic to-and-fro movement of small bowel loops and the detection of collapsed intestinal segments distal to a stenosis are important signs of mechanical bowel obstruction.

Consensus levels of agreement: A+ 16/16

Level and cause of obstruction

The level of SBO can be demonstrated using GIUS, by following the course of the dilated bowel up to the transition point, namely the point between the dilated proximal, and the collapsed distal loop. The level of obstruction is usually the distal and terminal ileum, if the transition point is in the right iliac fossa and lower quadrants or the jejunum and proximal ileum, if the transition point is observed in the upper quadrants and left hypochondrium. The level of the SBO may be also suggested by assessing the pattern of valvulae conniventes in the dilated segment, which are more numerous in the jejunum than the ileum.

The identification of the transition point may allow the cause of the SBO to be diagnosed. Specific sonographic lesions, such as intussusception, tumors, Crohn's disease, ascariasis, bezoars, foreign bodies, and external hernias, can be demonstrated. The presence of hyperechoic content due to ingested particles mixed with gas, just above the stricture, called the "feces sign", may be helpful in detecting the site of obstruction [22, 37].

Adhesions are the most frequent cause of SBO (accounting for up to 80 % of cases [12]) but are also the most difficult cause to detect by GIUS. Abdominal wall adhesions can be diagnosed by detecting the loss of normal visceral sliding, with loss of longitudinal movement of the intra-abdominal viscera caused by respiratory excursions of the diaphragm. This sign has a sensitivity of 75–97 % and specificity of 69–92 % for the diagnosis of adhesional obstruction [38–40]. However, the accuracy of GIUS in detecting deep visceral adhesions, and in particular in the context of SBO is not well documented.

External hernias may be easier to detect. The diagnosis of obturator hernias in particular is difficult and only a few cases of US diagnosis of SBO due to an obturator hernia have been reported [41, 42]. The diagnosis of internal hernias is technically challenging.

Sonographic criteria for diagnosis of intestinal intussusception include the doughnut sign (namely a thickened hypoechoic stratified outer layer with a central hyperechoic core) or a multiple-concentric-rings sign (a mass with multiple alternating hypoechoic and hyperechoic concentric rings) in a transverse scan and a sandwich or fork sign on the longitudinal scan [43]. Tumors and Crohn's disease are sonographically characterized by a thickened bowel wall. Tumors appear as a short segmental hypoechoic thickening, with irregular margins (in particular lymphomas and adenocarcinomas) or as a hypoechoic mass (GISTs and carcinoids) [9]. In Crohn's disease the thickened bowel wall is more frequently located in the terminal ileum and is regular and concentric if not complicated with fistulas or inflammatory masses. However, GIUS differentiation may be difficult [44]. Ascariasis, bezoars, foreign bodies, duplication cysts, and endometriosis are rare causes of SBO. Their different appearances have been reported in the literature [45–48].

In LBO, it is often difficult to assess the cause of obstruction, particularly when obstruction is due to a volvulus or short fibrous stricture. GIUS may sometimes reveal the presence and cause of obstruction such as a thickened bowel wall due to tumors, inflammatory bowel diseases or diverticulitis.

STATEMENT 3

The level of large or small bowel obstruction can be assessed by GIUS by identifying the transition point between dilated proximal bowel and collapsed distal bowel.

Consensus levels of agreement: A+ 16/16

STATEMENT 4

The cause of bowel occlusion may be detected by GIUS at the transition point.

Consensus levels of agreement: A+ 13/15; A– 2/15

STATEMENT 5

Adhesions to the parietal peritoneum can be diagnosed by detecting the loss of normal visceral sliding in the course of respiratory movements. Deep adhesions are frequently undetectable.

Consensus levels of agreement: A+ 14/16; A– 1/16; I 1/16

Sonographic signs of complication

Complications such as strangulation and bowel necrosis occur in up to 15–30 % of patients with bowel occlusion and lead to risk of perforation and sepsis [12]. From the practical point of view, the detection of ischemia in the presence of obstruction, is one of the most important decisions in patients with bowel obstruction, to identify patients who require early surgery. Sonographic findings suggesting the need for surgery include intraperitoneal free fluid, bowel wall thickness > 4 mm, decreased or absent peristalsis in documented mechanical obstruction, absence or reduced bowel wall perfusion at Doppler sonography or with IV contrast-enhanced ultrasound (CEUS) and, in advanced stages free intraperitoneal gas indicating bowel perforation [27, 35, 49–51]. However, after the encouraging preliminary results with the use of first-generation contrast agents, no further studies have confirmed whether CEUS can accurately detect ischemia in the presence of bowel strangulation [52–54]. Currently the authors acknowledge that these GIUS signs have low accuracy in predicting complicated SBO associated with critical ischemia and therefore CT scanning plays a more crucial role for this purpose.

STATEMENT 6

GIUS detection of intraperitoneal free fluid, bowel wall thickness > 4 mm, decreased or absent peristalsis, absent or reduced bowel wall perfusion, and/or free intraperitoneal gas may suggest complication and a need for surgery.

Consensus levels of agreement: A+ 16/16

Differential diagnoses

Real-time assessment of GIUS makes it possible to differentiate between mechanical and functional SBO. The absence of peristalsis or bowel movements (failure to detect peristalsis for > 5 minutes), over a long and fluid-filled intestinal segment, is more typical for adynamic or paralytic ileus. Ischemia of the small intestine may also present as an adynamic ileus. Real-time GIUS assessment is a unique tool for discriminating mechanical SBO from adynamic ileus, with greater accuracy than CT scan and abdominal plain X-rays [13]. Infectious viral enteritis and celiac disease are also characterized by a large amount of fluid within the bowel and often by increased peristaltic activity. However, they can be differentiated from SBO by different clinical presentation, the lack of small bowel distension and the absence of a transition point [9]. LBO must be differentiated from some functional disorders such as fecal impaction and pseudo-obstruction [22]. The possibility of significant portal or hepatic vein thrombosis should also be considered in cases with ileus and free intraperitoneal fluid.

STATEMENT 7

Real-time assessment of peristalsis by GIUS helps to differentiate mechanical from adynamic small bowel ileus, as the absence of bowel movements is typical for adynamic ileus.

Consensus levels of agreement: A+ 16/16

Comparison of US with other imaging methods and diagnostic strategy

The accuracy of GIUS in diagnosing SBO has been assessed in several systematic reviews with meta-analysis showing an overall sensitivity of 90–92.4 % and specificity of 96–96.7 % [55]. The accuracy of GIUS in the detection of SBO is comparable to that of computed tomography (CT) showing a sensitivity of 87 % and specificity of 81 %, and is superior to that of plain X-ray (sensitivity 75 % and specificity 66 %) [13, 55]. The accuracy of GIUS in defining the site of obstruction is likely between that of CT scan and abdominal plain X-ray.

The causes of obstruction can be diagnosed more reliably by CT scan, in particular internal hernias and volvulus. The accuracy of CT and GIUS in detecting deep adhesions is disappointing, but CT is better at guiding management in cases with negative or inconclusive sonographic findings. CT is of particular benefit for the detection of complicated bowel obstruction and the need for urgent surgery. Abdominal plain X-rays do not play a significant role in this regard [20, 56].

In the emergency department, bedside sonography or point-of-care ultrasound (POCUS) can be performed by physicians with limited sonographic experience after a relatively short training and practice period and may be very useful as a first diagnostic tool in patients with suspected SBO, substantially decreasing the time to diagnosis [57–60]. Moreover, in patients with sonographic signs of SBO, the presence of a dilated and fluid-filled stomach can be easily detected, allowing quick and safe placement of a nasogastric tube.

GIUS may also be very helpful for the follow up of conservatively treated patients with SBO and CT scan used as and when required. In patients with SBO complicated by hypovolemic shock, US follow-up may guide and manage the resuscitation of these patients. Changes in bowel features and the diameter of the inferior vena cava may correctly guide the overall management, hydration, and timing of surgery.

On account of its accuracy, and particularly its high specificity, GIUS has been recommended as the preliminary step for the management of acute abdomen and in the diagnosis of suspected small bowel obstruction, especially in young and pregnant patients [13, 61, 62]. It may be appropriately combined with CT scan, which is more accurate in defining the site, organic cause and severity of obstruction.

STATEMENT 8

GIUS and CT are the imaging methods of choice in patients with bowel obstruction and both methods are superior to plain film.

Consensus levels of agreement: A+ 16/16

STATEMENT 9

GIUS should be the first imaging method to determine if bowel obstruction is present or not. In cases of conservatively managed patients, repeated GIUS may be helpful for follow-up.

Consensus levels of agreement: A+ 15/16; A– 1/16

Gastrointestinal Perforation

Clinical presentation

Gastrointestinal perforation is a rare cause of acute abdominal pain representing about 1 % of presentation to emergency departments [2, 63]. Typical causes of perforation include peptic ulcer, inflammatory disease like diverticulitis, ischemic bowel disease, blunt or penetrating trauma, iatrogenic factors, foreign body or neoplasm [64].

Sudden onset of severe abdominal pain is typical of a hollow organ perforation [63, 65]. On clinical examination, patients usually present with abdominal guarding (board-like rigidity), and tenderness. Fever with leukocytosis, tachycardia and shock can also develop. The clinical presentation may range from only mild symptoms to acute abdominal pain [63]. This depends on many factors, including the site of perforation, the amount of leakage of intestinal contents and spontaneous self-sealing [63, 66]. Symptoms may also be delayed or non-specific in elderly and immunocompromised patients and due to pre-existing diseases, including liver cirrhosis with ascites, which may obscure the acute situation [66].

Pneumoperitoneum (free intraperitoneal gas) is the main and most important sign of gastrointestinal perforation and surgical treatment is most likely indicated when present. Prompt diagnosis of gastrointestinal perforation is important due to its high mortality [63, 67–69]. GIUS is frequently used as the initial diagnostic tool for evaluation of patients with acute abdomen [4–6, 63]. Although the presence of gas can considerably limit ultrasound examination, detection of gas collections has become an important element of ultrasound imaging.

STATEMENT 10

Clinical presentation of patients with gastrointestinal perforation is variable and cross-sectional imaging methods like GIUS or CT are necessary for prompt diagnosis.

Consensus levels of agreement: A+ 14/16; A– 1/16; D+ 1/16

Examination technique and sonographic signs of free perforation

Early experimental studies have shown US to be a reliable method to detect air in the peritoneal cavity [70–72]. Although convex probes with frequencies of 1–6 MHz most often enable the detection of pneumoperitoneum, linear probes with frequencies of 7–15 MHz allow better visualization of small gas bubbles and differentiation of intraluminal gas from extraluminal gas [67–69, 73].

Most examination protocols include scans in the epigastrium (supine position) and in the right hypochondrium (left lateral position) [4, 5, 63, 65, 67, 69]. A global examination protocol that included scans in the epigastrium, right and left hypochondrium, umbilical area in supine position and right hypochondrium in left lateral position proved slightly superior to a "2-scan fast exam" (epigastrium and right hypochondrium) [63, 73].

Pneumoperitoneum is often described in the literature as an enhancement of the peritoneal stripe (equivalent to a sharp echogenic line) and as hyperechoic foci with reverberation and ring-down artifacts ("dirty shadowing"). This is most often and best visible between the anterior surface of the liver and the abdominal wall [40, 67]. The movement of gas (shifting phenomenon) is a typical sign of free intraperitoneal air [40, 67]. This can be illustrated by different maneuvers:

- By changing the patient's position from supine to left lateral, free abdominal gas can be displaced [5].
- When free abdominal gas in the epigastrium obscures the left liver lobe and adjacent abdominal structures, simple application and following release of pressure with the ultrasound probe displaces the gas and the liver appears and disappears (like the opening and closing of a curtain) [5].
- The scissors maneuver is a similar procedure with application and then release of slight pressure on the abdominal wall with the caudal part of the linear probe [74].

In patients with perforated peptic ulcer, free gas may typically be found along the posterior surface of the liver and in the fissure for the ligamentum teres [66, 75]. Echogenic or "dirty" free fluid in the peritoneal cavity is a result of gastric or enteric contents that contain food particles and tiny gas bubbles [69].

Other indirect signs of perforation are: bowel wall thickening, bowel dilatation, free fluid (with fibrinoid septa), and alteration of adjacent mesenteric fat [5, 65, 76].

STATEMENT 11
A hyperechoic line or hyperechoic foci with reverberation artifacts between the anterior surface of the liver and the abdominal wall are characteristic for pneumoperitoneum.
Consensus levels of agreement: A+ 16/16

STATEMENT 12
The movement of gas by different maneuvers is a typical sign of free gas in the abdominal cavity.
Consensus levels of agreement: A+ 16/16

STATEMENT 13
Free fluid with bright echoes, bowel wall thickening and altered mesenteric fat may be indirect signs of gastrointestinal perforation.
Consensus levels of agreement: A+ 14/16; A– 1/16; I 1/16

There are only a few reports describing sonographic signs of pneumoretroperitoneum [64, 66, 77–79]. Pneumoretroperitoneum is a rare complication of invasive endoscopic procedures like ERCP or colonoscopic polypectomy. However, it can also occur because of trauma, inflammation or neoplastic processes [77–79]. The perforation site is typically located in regions, where the bowel is attached to the extraperitoneal space such as the duodenum, the rectum and rectosigmoid junction, the ascending or descending colon [40]. Endoscopic sphincterotomy with retroperitoneal perforation causes hyperechoic gas collections especially around the right kidney, the duodenum and the pancreatic head. The kidney or the great retroperitoneal vessels can be obscured completely by gas ("vanishing vessels"). Extraperitoneal gas can also be visible in the anterior or lateral abdominal wall along the peritoneum. In contrast to intraabdominal gas, a shifting phenomenon is not observed [77–79]. CT is probably the best imaging tool for demonstrating the real extent of extraperitoneal perforations, but comparative studies are missing.

STATEMENT 14
Pneumoretroperitoneum typically obscures retroperitoneal organs and vessels and movement of gas is usually not present.
Consensus levels of agreement: A+ 15/16; I 1/16

Contained perforation and abscesses

Sometimes a perforation of the hollow viscus may be limited to the retroperitoneal space or the mesentery. Typical examples are contained perforations in cases of diverticulitis (most often to the mesosigmoid) [6]. On the other hand, adhesions in a previously operated abdomen or as a consequence of former peritonitis, or the capability of the body to seal off inflammatory processes, can result in localized inflammation reducing the risk of diffuse peritonitis [66]. This typically occurs in cases of appendicitis and also in penetrating gastric/duodenal ulcers [80].

Irregular areas of extraluminal gas trapped in the adjacent mesentery or small fluid collections with hyperechoic echoes and hyperechoic alteration of the adjacent fatty tissue are visible on GIUS [6, 81]. Slight thickening of adjacent bowel loops, thickening of the local peritoneum and fluid in the peritoneal cavity may also be present [5, 65].

Abscesses may also be as a result of a fistula in Crohn's disease or a result of penetrating foreign bodies [44, 81, 82]. Especially non-radiopaque foreign bodies as the cause of perforation are better visible on US [82].

STATEMENT 15
Contained perforations appear as peri-intestinal areas of gas or as gas-containing fluid collections using ultrasound.
Consensus levels of agreement: A+ 15/16; D– 1/16

Pitfalls and differential diagnoses

Pneumoperitoneum without gastrointestinal perforation is also a recognized scenario. Rupture of subserosal gas bubbles in pneumatosis cystoides intestinalis is an example of this. Other routes of air penetration into the peritoneum are phrenic defects, perivascular sheaths along mediastinal vessels and the female genital tract [83–87]. The most common cause of pneumoperitoneum without perforation is abdominal surgery [84]. In the postoperative situation, interpretation of free abdominal gas is difficult. Pneumoperitoneum usually can be visible for 2–5 days after surgery and sometimes may be observed for several weeks, but the amount of gas usually decreases with time [77, 88–91]. Postoperative pneumoperitoneum is more prevalent in asthenic patients, in the presence of intraperitoneal drains, and after open laparotomy compared with laparoscopy [89]. The clinical setting is crucial for deciding if intraperitoneal air is due to a ruptured hollow viscus, an intraabdominal abscess or residual gas after operative intervention [89, 91]. An increasing amount of gas, imaging signs of peritonitis, elevated inflammatory parameters and clinical deterioration indicate complications [84, 91]. However, postoperative residual gas in the peritoneal cavity provides a good opportunity for training in the GIUS examination technique.

There are also artifacts and anatomical situations that may result in misinterpretation. Examples are overlying rib reflections, ring-down artifacts from adjacent air-filled lungs, intraluminal gas in aperistaltic bowel loops, and interposition of the colon [5, 65, 66, 73, 77, 92]. For differentiation of pneumoperitoneum and

Chilaiditi syndrome, the distance of the gas from the diaphragm, the smoothness of its surface and the continuity with the intestine below the liver are helpful [92]. Gas inside the intestine can be differentiated from free gas, by demonstration of the enteric wall between the peritoneum and the gas and the curving of the bowel wall.

STATEMENT 16

Pneumoperitoneum detected with GIUS can also be a consequence of other causes not related to gastrointestinal perforation.

Consensus levels of agreement: A+ 15/15

Comparison of US with other imaging methods and diagnostic strategy

Until the era of CT and sonography, abdominal radiography was the method of choice for the detection of pneumoperitoneum. Different signs and optimized technique were used for detection of small amounts of free intraperitoneal gas [93, 94]. However, various studies have shown that plain film with a sensitivity of 55–85 % is not sufficient for reliable diagnosis of gastrointestinal perforation [63, 65, 93]. Especially small perforations or well contained perforations may be missed [95].

Different studies have shown that the sensitivity of US is superior to that of abdominal radiography for the diagnosis of pneumoperitoneum [5, 63, 65, 73, 96, 97]. CT has the best overall sensitivity for the detection of free intraperitoneal gas [66, 98–101].

Moreover, in contrast to US and CT, plain films fail to diagnose most other acute abdominal conditions.

Modern management requires more information than the presence of pneumoperitoneum, such as the site and cause of perforation, indicating that plain film is not adequate even in positive cases [66, 98, 102]. GIUS is often the first imaging modality in patients presenting at the emergency department [4–7, 63]. An inconclusive or negative GIUS should be followed by CT, especially in the context or suspicion of gastrointestinal perforation [103]. In particular cases, GIUS may be helpful in addition to CT by demonstrating intraperitoneal fluid with fine bright echoes representing microbubbles and fibrinoid septa which are not visible on CT.

STATEMENT 17

GIUS and CT should be the favored imaging methods in cases of suspected gastrointestinal perforation, because the sensitivity of abdominal plain films is not sufficient and alternative diagnoses are usually not shown.

Consensus levels of agreement: A+ 13/16; A– 1/16; D+ 2/16

STATEMENT 18

CT is the most sensitive method for demonstrating pneumoperitoneum and especially pneumoretroperitoneum.

Consensus levels of agreement: A+ 15/15

Ischemic bowel disease

Clinical presentation

The spectrum of intestinal ischemia is broad and ranges from self-limited ischemic colitis to fatal intestinal infarction. It can develop in cases of arterial embolism or thrombosis, in patients with varying degrees of arterial stenosis or venous thrombosis, in situations of low cardiac output, in patients with permeable vessels, and in younger patients as a consequence of vasculitis [104–106]. Patients present with a wide spectrum of clinical symptoms. Classically, acute mesenteric ischemia (AMI) is associated with a dramatic onset of severe abdominal pain disproportionate to physical exam findings. A subsequent pain-free interval followed by sepsis and multiple organ failure is characteristic of AMI [104, 107, 108]. Unfortunately, mesenteric ischemia often presents with non-specific symptoms resulting in delayed diagnosis and poor outcome [104]. Pain may be accompanied by nausea, vomiting, gastrointestinal hemorrhage, leukocytosis, high level of lactate, and acidosis [108]. Postprandial epigastric pain, nausea, diarrhea and weight loss often occur in patients with chronic mesenteric ischemia [104]. Common symptoms of ischemic colitis are hematochezia, persistent diarrhea, and abdominal pain.

Acute arterial mesenteric ischemia

Most cases of intestinal ischemia are caused by arterial embolism or thrombosis, with impairment of blood flow in the superior mesenteric artery, which supplies the small bowel and right colon. CT angiography is considered the "gold standard" for the evaluation of patients with intestinal ischemia [104, 107].

The short initial hyperperistaltic phase is usually not observed by GIUS [109]. It is followed by thickening of the intestinal wall, decreased peristalsis and increased intraluminal secretions within the involved segments, as well as peritoneal fluid. However, these signs are nonspecific, and the examination is often complicated by increasing amounts of intraluminal air [110].

If the obstruction is near the origin of the superior mesenteric artery, color Doppler can show the absence of flow in the vessel [111]. However, a proximal occlusion does not prove AMI and conversely a patent proximal artery does not exclude occlusion of distal portions of mesenteric vessels. In selected cases CEUS may be helpful in this situation [52–54]. In the late phase, US may reveal a fluid-filled lumen, bowel wall thinning, extraluminal fluid and absent peristalsis [112]. Thickening of the bowel wall is rare in acute arterio-occlusive transmural small bowel infarction, where the necrotic small bowel may typically show a "paper thin wall" [2, 111, 113–115]. The final stage in bowel infarction is characterized by the presence of pneumatosis intestinalis and gas in the portal vein.

STATEMENT 19
CT angiography is the reference diagnostic technique for acute mesenteric ischemia.
Consensus levels of agreement: A+ 16/16

STATEMENT 20
Small bowel ischemia can be considered in the presence of thickening of the intestinal wall, decreased peristalsis and increased intraluminal secretions within the involved segments, although these signs are non-specific.
Consensus levels of agreement: A+ 15/16; A– 1/16

Non-occlusive mesenteric ischemia

Non-occlusive mesenteric ischemia (NOMI) causes varying degrees of damage to the bowel wall. Ischemic disease in the elderly should always be considered in the presence of hypoechoic segmental small bowel wall thickening with blurred stratification (expert opinion). In the acute stage color Doppler signals are only barely visible while in the subacute stage moderate hypervascularization may be detected when reperfusion of the bowel develops. Using contrast-enhanced ultrasound (CEUS) ischemic bowel segments are characterized by hypoperfusion of the bowel wall, while segments without intestinal ischemia show normal enhancement within the bowel wall [6, 52, 67, 69]. It may be very difficult to demonstrate necrotic patches present in cases of non-occlusive small bowel ischemia. However, the lack of perfusion in bowel segments proves vascular occlusion and imminent or already present gangrene of the bowel wall [52, 69]. In the presence of reperfusion there may be perfusion demonstrated in relation to the serosal and mucosal aspects of the bowel wall. The use of CEUS in expert hands may be highly sensitive in the demonstration of bowel ischemia [52].

STATEMENT 21
CEUS can be considered in expert hands in cases of suspected small bowel ischemia to demonstrate hypo- or non-enhancement of the bowel wall.
Consensus levels of agreement: A+ 15/16; I 1/16

Acute venous mesenteric ischemia

Superior mesenteric vein occlusion causes vascular engorgement, mucosal edema and hemorrhage of the bowel wall, with extravasation of fluid into the peritoneal cavity. US may show an intestinal wall of the involved bowel segment with homogeneously hypoechoic thickening as a result of edema, decreased peristalsis, intraluminal secretions and perienteric free fluid [4, 112]. Bowel wall thickening will be more pronounced in cases of bowel ischemia caused by occlusion of mesenteric veins than in cases caused exclusively by occlusion of mesenteric arteries [65, 115].

Chronic mesenteric ischemia

Chronic mesenteric ischemia is only briefly mentioned in the context of intestinal emergencies. In chronic ischemia of the small bowel, stenotic or occlusive lesions in the celiac and/or mesenteric arteries are found. In 95 % of cases, it is caused by arteriosclerosis and is more frequent in elderly people, due to disease of two of the three vessels. It is considered evidence of significant stenosis, if duplex scanning of the celiac artery yields a peak velocity (PV) > 200 cm/s and end-diastolic velocity (EDV) > 55 cm/s, and if the SMA PV is > 275–300 cm/s and EDV > 45 cm/s [4, 6, 65, 69, 114, 116, 117]. The extent of collateral vessels plays an important role, but collaterals cannot be reliably displayed using US only.

STATEMENT 22
Doppler US of splanchnic vessels should be used to assess high peak systolic or end-diastolic velocities in suspected stenosis of the celiac and/or mesenteric arteries.
Consensus levels of agreement: A+ 16/16

Ischemic colitis

Ischemic colitis (IC) is the most common form of intestinal ischemia and the second most frequent cause of lower gastrointestinal bleeding. Two presentations of IC have been described: a gangrenous form associated with transmural necrosis, with a high mortality rate (10–20 % of the cases), and a transient form that is characterized by reversible segmental involvement limited to the mucosa or submucosa and benefits from conservative management (80–90 %) [70, 118]. IC is the result of an acute decrease in colonic blood perfusion, which may be either occlusive or non-occlusive at the origin. The incidence of non-gangrenous forms is likely underestimated since clinical presentation is often non-specific [70–72, 118–120]. Colonoscopy is often considered the diagnostic test of choice in establishing the diagnosis of IC. However, the histopathologic diagnosis may be unreliable unless mucosal gangrene is observed [70, 118]. Non-occlusive ischemic colitis typically affects the colon in a segmental fashion, with the splenic flexure, descending colon, and sigmoid colon most commonly involved.

US is a sensitive technique for the early detection of IC, as it can detect early changes in the colonic wall [68, 121]. US typically shows circumferential hypoechoic thickening of the bowel wall, variable loss of mural stratification, and abrupt transition from the ischemic to the normal bowel segment. Color Doppler flow may be absent or diminished in the bowel wall especially in the initial phase. An ischemic cause should be suspected in an appropriate clinical setting (elderly patients with sudden abdominal pain, with diarrhea or rectal bleeding), if sonographic examination detects wall thickening of a long colon segment (> 10 cm), particularly on the left side, with barely visible or no color Doppler signals [67, 73, 121–123]. These findings have a high positive predictive value (90 %) for the diagnosis of IC [65, 124]. In reversible cases blood flow can be detected on Doppler US and it represents reperfusion of the gut wall, as a result of the resolution of ischemia

[125]. CEUS may be used to assess perfusion in the bowel wall if there is any uncertainty in assessment with Doppler US (expert opinion). The altered perienteric fat has been associated with severe transmural necrosis [68, 121, 122, 126]. IC, in the absence of transmural necrosis, is a self-limiting disease with quick recovery of the mucosal lesions. Consequently, the finding of a normal bowel wall in the sonographic follow-up examination reinforces the diagnosis of IC [68, 121]. The absence of improvement in sonographic follow-up studies is associated with transmural necrosis and needs further evaluation with other imaging or endoscopic techniques to confirm the diagnosis and exclude neoplasia [68, 121].

US and CT have a similar diagnostic performance in ischemic colitis, except for detection of intestinal pneumatosis, a rare and late finding with a poor prognosis, that is easily identifiable on CT, but is difficult to identify by US [65, 106, 115, 127].

STATEMENT 23

US and CT have similar diagnostic performance in ischemic colitis.

Consensus levels of agreement: A+ 13/15; A– 1/15; D+ 1/15

STATEMENT 24

GIUS has a high positive predictive value for the diagnosis of ischemic colitis in patients in whom it is clinically suspected.

Consensus levels of agreement: A+ 16/16

Diagnostic strategy

When clinical presentation is highly suspicious of AMI, CT angiography is the method of choice and should be performed immediately.

However, abdominal ultrasound is often the first imaging method that patients undergo when they present with nonspecific symptoms. Therefore, GIUS plays an important role in directing patients with sonographic signs of ischemia for immediate further CT evaluation and intervention. In transient forms of bowel ischemia, US can be used to assess the course of the disease.

Summary

The positive predictive value of US in experienced hands is comparable to CT in the diagnosis of urgent abdominal conditions [103]. A strategy with ultrasonography in all patients and computed tomography only after negative or inconclusive ultrasonography gives the highest sensitivity for detecting urgent conditions and avoids radiation in half of patients [20, 103]. However, in clinically suspected AMI, CT angiography should be the first imaging method. In the workup of patients with acute abdominal pain, abdominal radiography should be replaced by US and CT [20, 103, 128].

Conflict of Interest

AH: Speaker honoraria: Takeda.
GM: Speaker honoraria: Abbvie, Alfa Sigma, Janssen-Cilag.
KN: Speaker honoraria Takeda, MSD, MEDA AS and Ferring Pharmaceuticals.
AHi: Speaker honoraria Canon.
CFD: Speaker honoraria: Bracco, Hitachi, GE, Mindray, Supersonic, Pentax, Olympus, Fuji, Boston Scientific, AbbVie, Falk Foundation, Novartis, Roche. Advisory + Board Member: Hitachi, Mindray, Siemens + Research grant: GE, Mindray, SuperSonic, Youkey.
OHG: Speaker honoraria: AbbVie, Bracco, Almirall, GE Healthcare, Takeda AS, Meda AS, Ferring AS, Allergan + Consultant fee: Bracco, GE Healthcare, Takeda and Samsung.
KD: nothing to disclose.
CS: nothing to disclose.
TR: nothing to disclose.

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