Review

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Portal venous gas detection in different clinical situations

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Abstract

Portal Venous Gas (PVG) provides an important differential diagnosis in the diagnose of intrahepatic reflexogenic structures. This review article is intended to provide an overview of the current literature on the detection of PVG, its special forms and important differential diagnoses, it also shows possibilities for the diagnostic procedure in the case of sonographic detection of PVG.

Keywords: portal venous gas; ultrasound; aerobilia; intestinal ischemia

Introduction

Portal Venous Gas (PVG) provides an important differential diagnosis in the diagnose of intrahepatic ultrasound (US) reflexogenic structures [1]. It is characterized by hyperechoic gas reflexes within the portal venous system [1]. The appearance of PVG must be differentiated from diffuse parenchymal reflections on tissue structures like echogenic portal cuffing of varying etiology [2], cholangiofibromatosis (v. Meyenburg complexes) [3], and Caroli's syndromes associated with fibro polycystic diseases such as congenital hepatic fibrosis [4,5]. Moreover, US appearance of diffuse microcalcifications or other diseases like miliary tuberculosis [6] should also be considered. The diagnosis of gas in the liver is based on the detection of "moving reflectors" in the real-time examination and cannot be diagnosed on a single image. It must first be established as to whether gas is located in the liver parenchyma as an indication of the presence of pyogenic abscesses, in the biliary tract as an indication of the presence of an aerobilia, or definitely in the portal vein, with peripheral parenchymal reflexes caused by gas in the portal vein branches.

This review article is intended to provide an overview of the current literature on the detection of PVG, its special forms and important differential diagnoses, it also shows possibilities for the diagnostic procedure in the case of sonographic detection of PVG.

Review of the literature

The earliest case reports and studies of PVG date back to the 1950's [7,8]. Here the detection of PVG was often associated with severe clinical situations and a poor prognosis or even a terminal stage for the patient [8,9]. A review from 1977 on this topic analyzed 64 cases of PVG, 72% associated with bowel necrosis, 8% with ulcerative colitis, 6% with abdominal abscesses, and 3% for each with small bowel obstruction and gastric ulcer [10]. Further rare causes are presented in Supplementary Table I [8,10-31]. Thus, mesenteric ischemia and intestinal perforation are also the most common causes [32].

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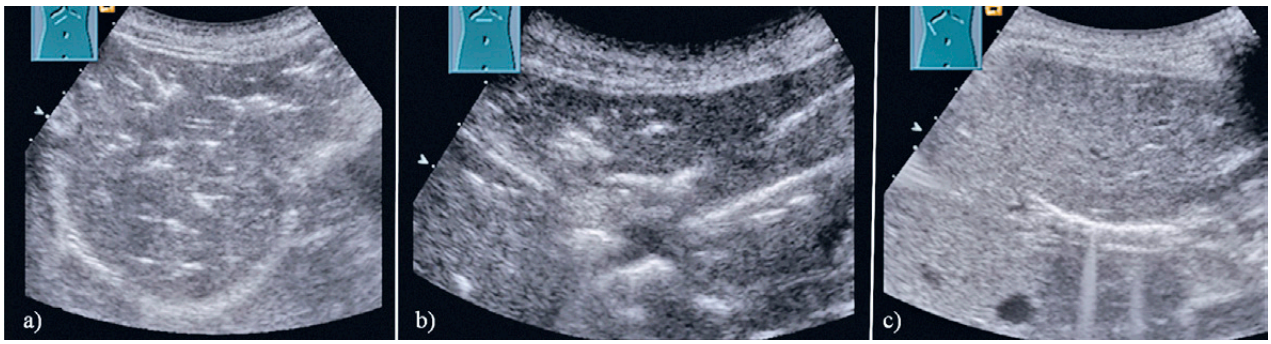

Fig 1. A 72-year-old female patient with "starry sky" liver after ERCP with inoperable pancreatic carcinoma. In the left lobe of the liver, "stars (a) and stripes (b)" pattern with moving air reflexes are seen. In the hepatic hilum section, gas can be seen in the ductus hepatocholedochus as in aerobilia (c).

The mortality rate was up to 90% in the earliest studies [8-10,33-35].

Because of more rapid treatment, an improved understanding of the etiologies [11] and with the wider use of imaging methods, PVG has also been observed as an incidental finding or in non-life-threatening situations [8,34,35], so that mortality rates are lower when compared to earlier observations (90% vs. 32%) [34-36]. In addition to intestinal ischemia and intestinal necrosis Alataby et al [13] described PVG after recurrent vomiting and Biphasic Positive Airway Pressure (BIPAB)-ventilation. In a retrospective analysis of 30 patients with imaging evidence of PVG, intestinal ischemia was the cause in 40% of the patients and 60% of PVG were due to other causes [17]. These included enteritis (33%), bowel distension (2%), pneumothorax (3.3%) or unknown causes (3.3%) [17]. A more recent analysis by Daneshment et al [8] of 10 years of data found 164 patients with PVG [8]. Thromboembolic events were here the most common cause (43%), followed by inflammatory causes (23%) and mechanical bowl obstruction (17%) [8]. In 15% of cases PVG can be idiopathic [34,35,37]. Further analysis of the different etiologies clearly shows that the mortality rate depends on the etiology [8]. Thromboembolic events were the most common causes (70/164) and bear also the highest mortality (72.8%). PVG caused by inflammatory processes (37/164) and "others" (28/164) (including idiopathic/incidentally causes and postinterventional) had a much lower mortality rate (21.6% and 14.3%) [8].

Nowadays there are multiple analyzes, reviews and case reports about PVG in imaging procedures. Nevertheless, larger case series and analyses are based on imaging evidence of PVG obtained by computed tomography (CT). US detection of PVG is mainly described in case reports or studies with small case numbers. Nelson et al defined CT-based "ABC"-criteria for the diagnostic and therapeutic procedure in different clinical situations when PVG is detected [38]. To our knowledge, US diagnostic criteria for the different clinical situations do not exist. With respect to Nelsons "ABC" criteria [38], Supplementary Table I presents some examples, with differentiation between causes that are acutely life-threatening emergency situations (pink), other clinically important causes (yellow) and incidental findings / idiopathic causes (green).

Clinical work-up: what to do in case of gas in the portal venous system?

The following "work-up" scheme and case presentations are intended to help the examiner to better differentiate harmless, severe and fatal causes of gas in the portal venous system using ultrasound and to interpret the observed findings correctly.

How to differentiate ultrasound appearance of portalvenous gas from other causes?

Important differential diagnoses of PVG includes aerobilia (fig 1), "long liver enhancement" of CEUS (fig 2), as well as diffuse reflections distributed on the liver, e.g., after chemoembolization (fig 3).

Aerobilia is a sonographic phenomenon that is frequently observed in daily clinical practice, for example after biliary interventions such as endoscopic retrograde cholangiopancreatography (ERCP) with interventions [39-41]. After ERCP with sphincterotomy aerobilia is due to a reflux of the gas and can be observed in 40-50% of the cases, and after balloon dilatation of the sphincter in 8% [41]. Aerobilia can be observed >10 years after a surgical sphincterotomy [42]. In these situations, aerobilia is likely to be an incidental finding without pathological significance. Infections of the bile ducts by anaerobic bacteria or a gallstone ileus present other rare cause for aerobilia [43,44]. Based on the patient's history and the breath-dependent movement of the gas in the patient's bile ducts, it can be differentiated from gas in the portal venous system [41,45].

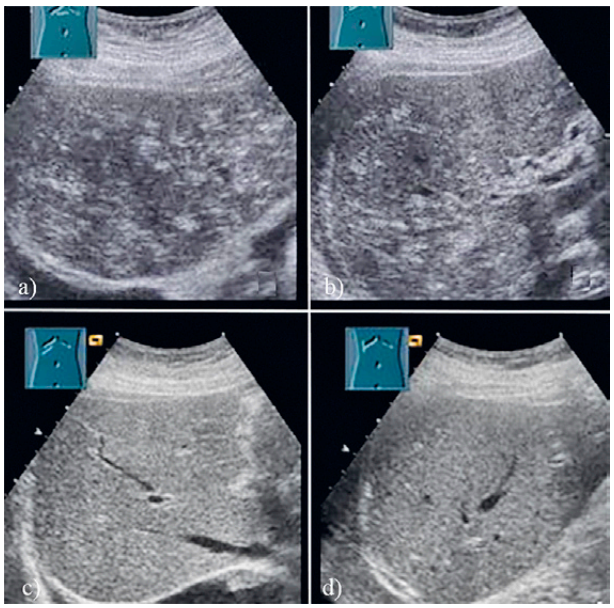

Fig 2. A 42-year-old female patient with breast cancer after CEUS examination. Figures a) and b) show the phenomenon of a long-lasting heterogeneous hepatic enhancement through the contrast agent (long liver enhancement). After 6 hours the phenomenon was no longer detectable (c and d).

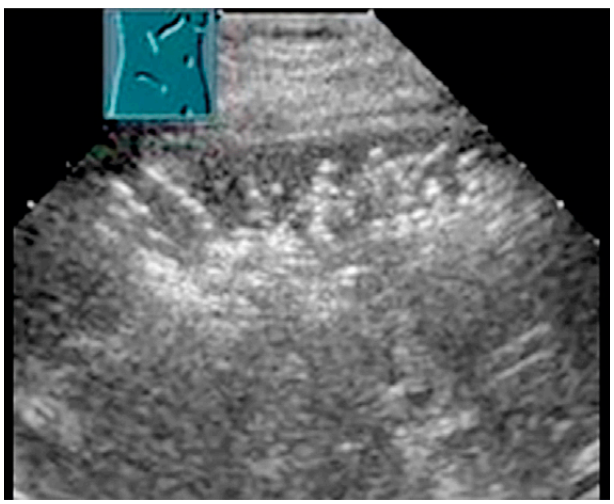

Fig 3. A 59-year-old female patient with a neuroendocrine pancreatic tumor and central liver metastases. A chemoembolization and afterwards an embolization of the left liver vessels with polyvinyl alcohol (PVA) particles was performed. In the final examination an insufficient arterial flow of the left liver lobe was observed. The patient presented himself for a sonographic follow-up with evidence of multiple ribbon-like reflexes, probably corresponding to emboli located in the liver arteries.

Procedure for clearly localized portal venous gas

PVG can be associated with emergency situations (e.g., bowel ischemia), other clinically important diagnoses like inflammatory processes (e.g., colitis ulcerosa) or as incidental finding or due to an idiopathic cause. The

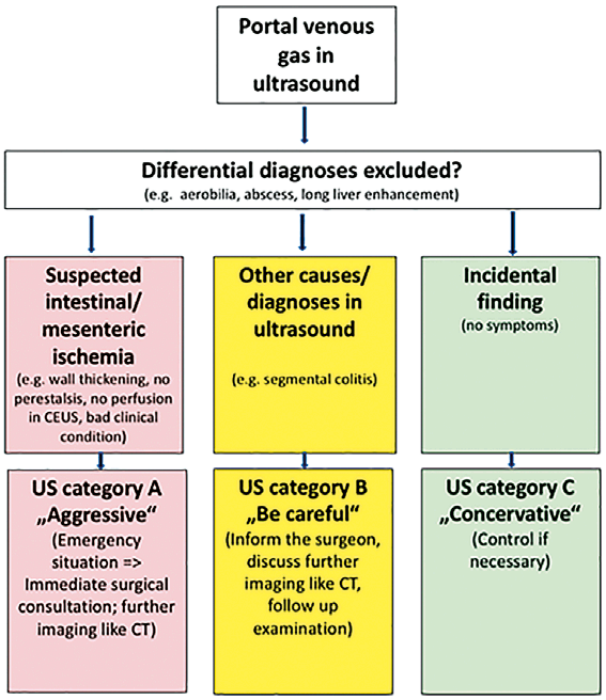

Fig 4. Suggestetion of a diagnostic work-up schematic when gas is found in the portal venous system in abdominal sonography adapted according to the abdominal radiograph and "ABC-scheme" by Nelson et al [38].

phenomenon of gas in the portal venous system requires an immediate clinical evaluation. It has to be clarified whether gas in the portal venous system is clinically relevant or whether this phenomenon is an incidental finding. According to the abdominal radiograph and CT-based "ABC"-scheme by Nelson et al [38], also for US the three categories A, B, and C should be distinguished (fig 4).

Ultrasound Category A
(based on the "ABC" scheme by Nelson, et al) [38]

Based on the Nelson criteria [38], the US detection of portal venous gas in "ultrasound category A" represents clinical often an emergency situation with unambiguous sonographic/clinical findings. The mortality of the underlying diagnoses in this category is high (72.5-75%) in CT-based studies [8,38]. Here, a bowel ischemia/necrosis was the most important diagnosis (40-70%; Supplementary Table I, pink column). Clinical criteria are abdominal pain [46], with the following differentiation. Pain due to ischemia is constant and intense and not dependent on palpation [46]. Patients can initially present with hyperperistaltic, vomiting and diarrhea [46]. In the advanced stage, with onset of intestinal necrosis, the patient presents appears critically ill with symptoms of shock

[47,48]. An elevated C-reactive protein (CRP), lactate dehydrogenase (LDH), serum lactate or a leukocytosis can be helpful to differentiate a thromboembolic event from other causes because both elevated white blood cells and increased lactate levels were significantly more frequently overserved in patients with thromboembolic events as compared to the other groups [8]. Leukocytosis develops before the elevation of serum lactate [46]. Nevertheless, theses markers are not necessarily increased [17,49]. The US findings of intestinal wall thickening combined with portal venous gas can be indicative for ischemic colitis [50]. At US abnormalities of the colon can be observed with a sensitivity of 93.5% in ischemic colitis, where the disease is mainly segmental and affecting the left-sided colon [51]. Additionally altered pericolic fat can be found [51]. Evidence of ascites or a lack of vascularization of the thickened intestinal wall in color Doppler US (80%) and contrast enhanced US may be associated with intestinal ischemia/necrosis [51,52]. Patients with these US and clinical findings should be seen by a surgeon immediately. Each patient needs an individual assessment as to whether further diagnostic tests using CT, or an immediate surgical intervention is necessary or whether a conservative approach is appropriate.

Ultrasound Category B
(based on the "ABC" scheme by Nelson, et al) [38]

The clinical presentation of patients "ultrasound category B" is different due to the wide range of diagnoses (e.g., pancreatitis, bacterial colitis) as the cause of the PVG (Supplementary Table I, yellow column). However, almost all of the underlying diagnoses are associated with abdominal pain.

In a CT-based study with 164 patients, inflammatory diseases made up approximately 23% of category B with a mortality of approximately 21.6% [8], which is in line with the findings of Nelson et al (mortality < 30%) [38]. Laboratory parameters such as elevated CRP, LDH and the white blood cell can be helpful when deciding on further diagnostics (e.g., CT). For elevated CRP, LDH or white blood cells, caution is advised with regard to the imaging findings. "Ultrasound category B" is the most difficult because causes other than necrosis have to be recognized (e.g., segmental colitis in Crohn's disease, acute pancreatitis) and correctly interpreted. Unfortunately, there is no uniform clinical and US presentation, so that in this category the clinical and US findings must always be interpreted individually. In our opinion a joint decision regarding the subsequent procedure (further imaging necessary, close-knit clinical/US control) should be made with the surgeons.

Ultrasound Category C
(based on the "ABC" scheme by Nelson, et al) [38]

In "ultrasound category C", PVG represents an incidental finding with no evident associated pathology (Supplementary Table 1, green column where some clinical scenarios in which PVG was found incidentally with no clear explanation/idiopathic are presented). Even if there are many individual case reports on incidental findings of PVG, this case corresponds to the group with the lowest (7-15%) proportion in CT-based studies [8,37], but also the lowest mortality (14.3%) [8].

In order to be considered as incidental finding, PVG should be not accompanied by further clinical or US pathologies. The patient should have no symptoms and the laboratory parameters such as CRP, leukocytes, lactate should be normal. Since US is a radiation-free and cost-effective method, a US follow-up should be performed. If PVG is no longer detectable and if there are still no symptoms, no further diagnostic evaluation is necessary. However, in case of PVG persistence, development new clinical symptoms and/or sonographic findings, the procedure for category B should be followed.

The next section presents three cases of PVG using US in three clinical situations: categories A (aggressive); B (be careful) and C (conservative), adapted based on the "ABC"-criteria proposed by Nelson et al [38] (fig 5-7).

Discussion

US is often the first imaging method in patients with abdominal symptoms [30]. Studies and case reports on the imaging evidence of PVG are predominantly CT-based, but over the years an increasing trend of reports of PVG detected on US were observed [53]. Although there are no analyses concerning the sensitivity and specifity of US in regard to the correct cause of PVG so far, the use of US in patients with PVG seems to have diagnostic potential. Even case reports described a temporary gas formation in the portal system, which was only visible on US but not on CT [34,35]. First data observed different patterns of PVG on US in association with different clinical situations, from what a "dot-like pattern" was associated with a "benign" – less live threading – clinical situation [54].

We also observed PVG on US in different clinical situations (category A, B, C) and presented our diagnostic and therapeutic management approaches in the sonographic diagnosis of PVG. The decisive factor was to correctly classify the patient in a category adapted from the CT-based "ABC" criteria of Nelson et al. An emergency situation (ultrasound category A) has to be identified im-

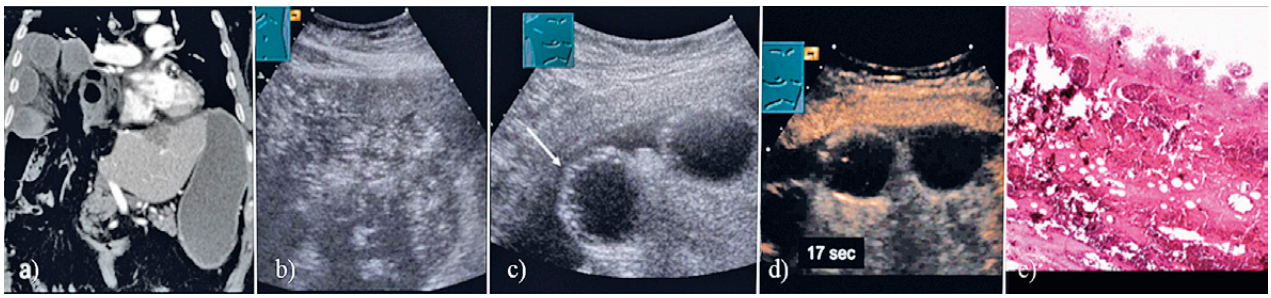

Fig 5. Example category A. A 60-year-old patient with cholangiocellular carcinoma in a palliative therapy situation presents with severe acute thoracic pain. A CT-scan was performed which revealed a right hemidiaphragmatic rupture with intestinal herniation into the thoracic cavity (a) (courtesy of Prof. Mahnken, Department of Radiology, University Hospital Marburg). The patient was managed conservatively. 12 h later an ultrasound was performed with the detection of gas in the portal venous system (b). Additionally, an enlarged, fluid-filled bowl loop without peristalsis, some interenteric ascites and hyperechoic air reflexes in the intestinal wall were observed (c). Contrast enhanced ultrasound (CEUS) showed no perfusion of the intestinal wall (d). The suspected diagnosis was an intestinal wall necrosis of the right colonic flexure due to invagination. A surgical resection of the completely necrotic bowel segment was undertaken and the diagnosis was confirmed on histopathological examination (e; courtesy of Dr. A Ramaswamy, Department of Pathology, University Hospital Marburg).

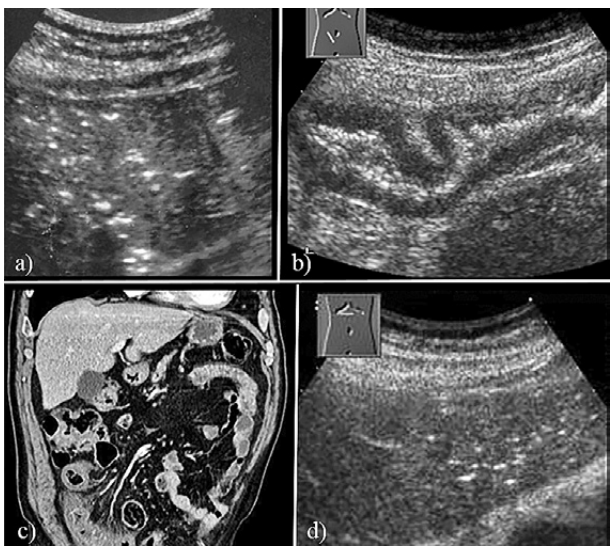

Fig 6. Example category B. A 60-year-old patient presented with abdominal pain in the right lower quadrant. Sonography in the emergency room showed gas in the portal system in the liver (a) and a pronounced segmental intestinal wall thickening (b) as in a segmental enteritis. An abdominal CT-scan 4 hours later confirmed the diagnosis of segmental enteritis, but no visible PVG in the portal venous system (c) (courtesy of Prof. Mahnken, Department of Radiology, University Hospital Marburg). A US follow-up examination showed a spontaneous regression of portal venous gas (d). A segmental hemorrhagic infarction was excluded by an exploratory laparotomy.

mediately to initiate decisive diagnostic and therapeutic measures. Thromboembolic events/intestinal ischemia with consecutive necrosis continue to be the most common diagnosis where PVG is detected (approx. 40% in more recent studies) and also with the highest mortality (72.8%) [8,30]. In a prospective pilot study, US detection of free fluid, PVG and an intestinal wall thickening were identified as predictors for surgical necrotizing enterocolitis (ultrasound category A) [49,55]. Moreover, data suggest that CEUS can also be helpful in the detection of intestinal ischemia/necrosis [56,57]. Nevertheless, with regard to the correct diagnosis of intestinal ischemia CT is the method of choice (sensitivity up to 96%, specifity up to 94%) [53,58,59].

Daneshment et al report that leukocytes and serum lactate are significantly higher in patients with a diagnosis of category A than in other causes [8]. But nevertheless, the diagnostic value of these laboratory parameters will only be of limited use in everyday clinical practice, as they were also increased in other clinically important differential diagnoses (e.g. inflammation) [8].

Other pathologies, which are associated with PVG in US category B, such as intraperitoneal abscesses and the ulcerative colitis, were observed in 11% and 4% in CT based studies [30]. But frequencies of the different etiologies vary [30]. US is an established examination method and the first imaging method for many diagnoses in this category (pancreatitis; enteritis, colitis) [60-62]. If the US findings are inconclusive (e.g., complications of pancreatitis) or in intraabdominal abscesses, CT may be necessary for further clarification [61,63,64]. The problem is that diagnoses in US category B can be sonographically associated with images similar to those in category A. In particular, a thickening of the intestinal wall can be observed in many diseases of the gastrointestinal tract such as ulcerative colitis or Crohn's disease [65,66]. In our opinion, laboratory parameters such as lactate and the patient's clinical condition (e.g., shock) can be helpful in differentiating the US criteria A from B.

In our suggested possible work-flow and diagnosis categories, US category C represents an incidental find-

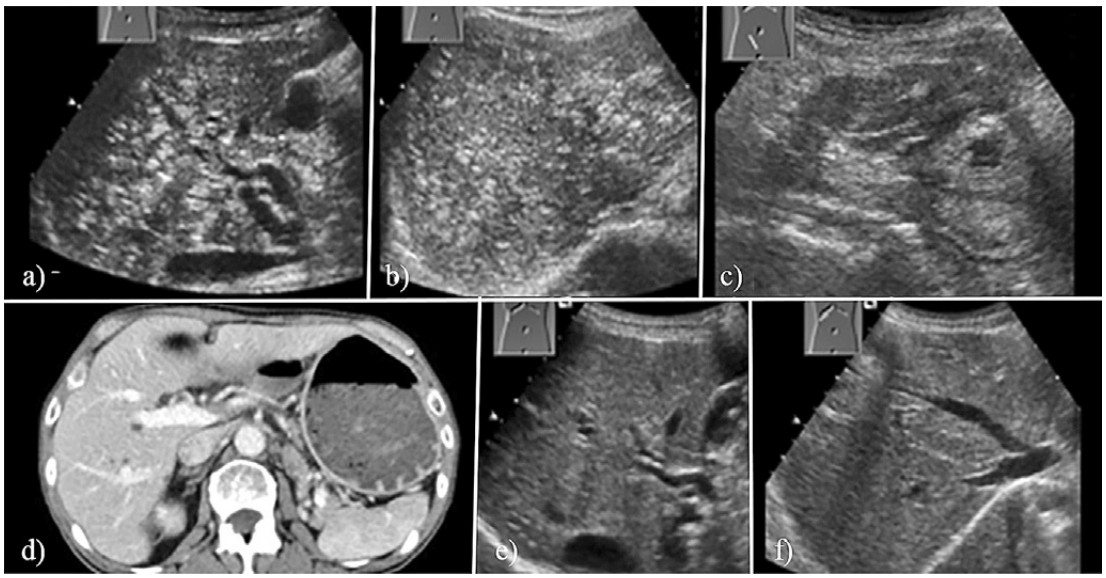

Fig 7. Examples category C. A 58-year-old patient with metastatic cervical carcinoma and peritoneal carcinoma presented with mild diffuse abdominal pain. Sonography showed gas in the portal venous system (a and b) and emphasized intestinal loops as in peritoneal carcinomatosis without evidence of further intestinal pathology. An abdominal CT-scan, performed two hours later, revealed gas in the portal venous vessels (d) (courtesy of Prof. Mahnken, Department of Radiology, University Hospital Marburg). Sonographic follow-up 24 h later (e and f) showed a complete regression of the PVG and the clinical condition of the patient improved spontaneously.

ing of PVG of no clear etiology (idiopathic). This observation is rare, so that there are no recommendations for imaging procedures or data on characteristic laboratory results.

Theoretically, emergency situations can also be detected on US, as on CT, by detecting portal venous gas. Nevertheless, the question naturally arises in which situations of category A and B an additional CT examination is needed. After detection of portal venous gas by US and where the findings are ambiguous (category A and B), an immediate CT should be performed. Close cooperation with the surgeons is necessary. A joint decision on the need for further imaging should be sought depending on the findings and the clinical condition of the patient. Ultimately, the further diagnostic and therapeutic approach should be decided individually for each patient.

In summary, caution is always required when detecting portal venous gas on ultrasound and it requires a conscientious examination and close cooperation with the surgeon in order to determine the optimal diagnosis and therapy for each individual patient.

Conflict of interest: none

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