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REVIEW ARTICLE

Duodenal emergencies: utility of multidetector CT with 2D multiplanar reconstructions for challenging but critical diagnoses

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Abstract

Duodenal pathology is an infrequent cause of acute abdominal pain for which patients present to the emergency department. Critical pathology on multidetector CT (MDCT) may be overlooked if the radiologist does not carefully evaluate the duodenum as part of the search pattern. Optimal MDCT protocols include intravenous contrast with multiplanar reconstructions (MPRs). A variety of etiologies ranging from infection to malignancy can involve the duodenum, for which interrogation with MPRs is most helpful given the anatomy and complex relationship with surrounding structures. The purpose of this review article is to highlight the importance of CT acquisition with multiplanar reconstructions and review the spectrum of emergent duodenal pathology, with the goal of ensuring accurate and timely diagnosis to best guide patient management.

Keywords Duodenum · Abdominal pain · Acute abdomen · Multidetector CT · Multiplanar reconstruction

Introduction

Emergency department patients with localized or diffuse abdominal pain are often imaged with multidetector CT (MDCT). In patients with acute onset of gastrointestinal symptoms such as pain, nausea, and vomiting, the differential diagnosis typically includes cholecystitis, choledocholithiasis, pancreatitis, gastritis or gastric outlet obstruction, and small bowel obstruction, but acute duodenal disease such as duodenitis or ulcer disease may be the cause. The spectrum of acute duodenal pathologies in adults includes infection, inflammatory disease, trauma, vascular pathology, malignancy, and late manifestation of congenital anomalies [1]. Detection and accurate characterization of acute duodenal pathology require careful inspection of this anatomic region using both axial images and multiplanar reconstructions (MPRs). An understanding of optimal MDCT technique and imaging findings in acute nontraumatic and traumatic duodenal pathology is imperative for quick diagnosis to triage patients to appropriate care.

MDCT technique

For acute abdominal pain patients, a CT scan of the abdomen and pelvis with multidetector, dual-source CT is routinely performed in our department. Acquisition parameters include 90–120 kVp and effective mAs according to CAREDOSE in portal venous phase (60 s) after intravenous contract injection of 80–120 cc nonionic IV contrast injected at the rate of 3–5 mL/s. The pitch is generally 0.6–2.0 depending on the protocol, which helps to lower image noise and to reduce respiratory artifact.

Positive oral contrast agents were traditionally used for the evaluation of the GI tract, but water as a negative oral contrast has emerged as the preferred contrast agent owing to ease of administration and improved depiction of mucosal and mural detail [2, 3]. Intravenous contrast is

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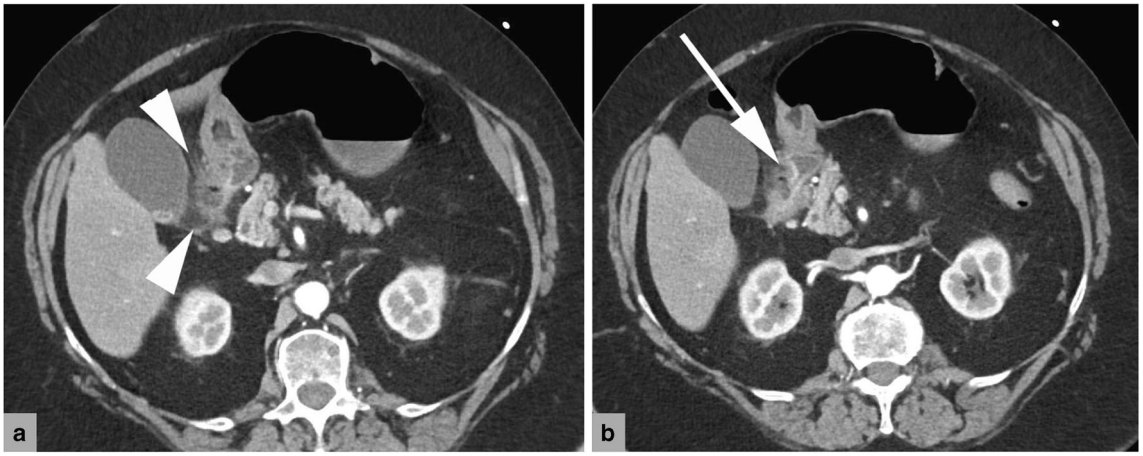

Fig. 1 Eighty-one-year-old woman with contained perforation from duodenal ulcer. **a** Axial IV contrast-enhanced CT shows periduodenal stranding and small periduodenal collection (arrowheads). **b** Use of thin sections enables delineation of communication with duodenal lumen (arrow). Emergency departments commonly perform CT with PO water rather than positive oral contrast. Thin sections, MPRs, and IV contrast and negative oral contrast facilitate visualization of gastrointestinal wall pathology

very important to delineate the duodenal wall and define the relationship of pathology to adjacent organs (pancreas, liver, biliary tract, right colon). When administered with IV contrast, PO water enables better visualization of the finer details of duodenal wall than positive oral contrast agents, facilitating identification of mucosal enhancement, fold thickening, submucosal edema, and focal abnormalities such as ulcer. Water is also better tolerated than positive contrast agents, and a faster administration time is helpful in the emergency setting [3]. If a perforation or fistula is suspected, then positive oral contrast is preferred; however, positive oral contrast is not necessary to make the diagnosis of duodenal perforation if IV contrast, thin sections, and multiplanar reconstructions are used (Fig. 1). Nonetheless, positive oral contrast can definitively confirm the diagnosis by demonstrating contrast leakage into the peritoneal or retroperitoneal cavity.

Multiplanar reconstructions should be performed for complete evaluation of the duodenum, details of which are shown in Table 1. High-quality MPRs and 3D rendering require use of narrow detector collimation and thin reconstruction sections [1]. For all the cases, default coronal and sagittal reformats are created at the console by the technologist and sent to PACS. In cases requiring tailored MPRs, additional double-oblique long and short-axis reformates of the duodenum, maximum intensity projection (MIP), and volume rendering (VR) are created by the radiologist at the work station using 0.75-mm thin axial slices, which are also sent with each case. The coronal plane shows the entire course of duodenum, while the sagittal plane demonstrates relationships to adjacent organs (pancreas, superior mesenteric artery) in the setting of a pathology. The axial and coronal sections best depict the relationship of the duodenal pathology with the ampulla.

Table 1 Multiplanar reconstruction parameters for detailed duodenal assessment

MDCT reconstruction parameters	Soft tissue	Thin sections
Slice thickness	3 mm	0.75 mm
Reconstruction spacing	3 mm	0.5 mm
Reconstruction kernel	B30f	B20f
Window width and level	410/10	410/10

Coronal and sagittal reconstructions created in soft tissue window at the console, 3-mm, and 0.75-mm volumes all sent to PACS

Fig. 2 Coronal MPR from IV contrast-enhanced CT of a 40-year-old man admitted with epigastric and chest pain due to duodenitis, represented by extensive periduodenal inflammatory fat stranding (arrowheads). Patient reported history of alcohol abuse, H. pylori, NSAID use, and GERD. Coronal reconstruction confirms diffuse duodenal wall thickening and inflammation while distinguishing it from pancreatitis

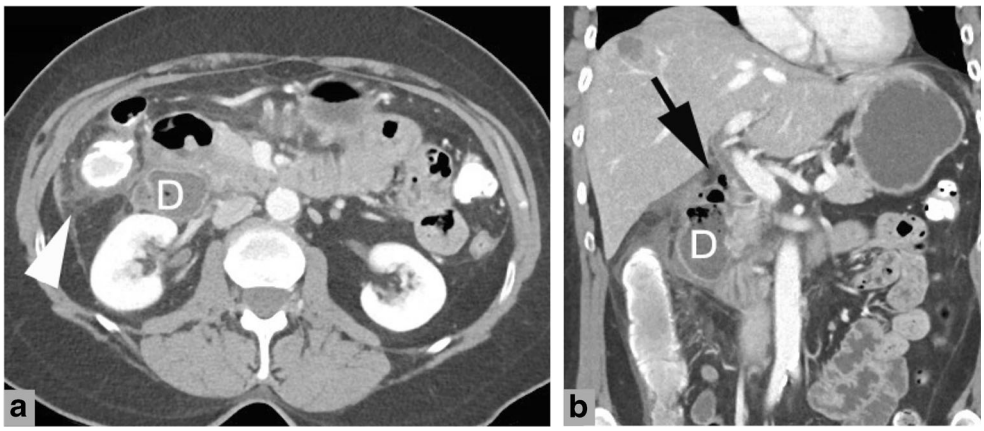

Fig. 3 Sixty-two-year-old woman presenting with sudden onset epigastric pain. Axial CT with IV and oral contrast (**a**) and coronal MPR (**b**) show obstructed and perforated duodenal diverticulum (D), with extensive mesenteric fat stranding (arrowhead) and extraluminal gas (arrow)

Acute duodenal pathologies

Infectious and inflammatory disease

Acute duodenitis may be the result of infectious or noninfectious causes. Noninfectious duodenitis is most often caused by secondary involvement from acute pancreatitis. Other common noninfectious causes include NSAID use and ingestion of hard liquor (Fig. 2) [1]. Crohn's disease rarely involves the duodenum [4]. Helicobacter pylori is the most common infectious cause of duodenitis invariably associated with concurrent or prior peptic ulcers [1]. With the proper history and demographics and in the correct clinical setting, infectious etiologies, such as giardiasis, can be considered especially as an opportunistic infection in an immunocompromised patient [1, 5]. The distinction of various infectious causes is difficult, as CT findings of wall thickening and periduodenal stranding are nonspecific.

Duodenal ulcers usually involve the duodenal bulb and are most commonly peptic ulcer [6]. Less common etiologies include Zollinger-Ellison syndrome. CT findings of Zollinger-Ellison include thickened rugal folds and multiple gastric nodules, and the causative gastrinoma (usually < 1 cm) is most often located in the gastrinoma triangle. [7]. Giant duodenal ulcers (> 2 cm) have a high risk of bleeding, perforation, and obstruction [6].

Diverticulitis typically occurs in the large bowel, but can appear anywhere in the GI tract where diverticula are present. The duodenum is second only to the colon for the location of diverticuli [8]. Duodenal diverticuli of variable sizes are most frequently located in the medial second portion near the site of insertion of the CBD and pancreatic ducts, but may also arise from the third and fourth portions. The windsock presentation is a congenital intraluminal diverticulum usually found in the second part of the duodenum near the ampulla that occurs in the presence of a web due to the lack of recanalization during embryogenesis [9]. Most duodenal diverticuli are asymptomatic, but patients can develop diverticulitis if the diverticulum neck becomes obstructed (Fig. 3) [10, 11]. Complications include duodenal obstruction due to increased intraluminal pressure and anterograde ballooning, peptic ulcer formation, as well as secondary pancreatitis and cholangitis. Duodenal diverticuli could be confused with either a pancreatic mass or an abscess, and when prior scans are available, comparison with older exams reveals the presence of a diverticulum to avoid this diagnostic error.

Owing to rich collateral vasculature, duodenal ischemia is rare [12]. Risk factors for all types of small bowel ischemia commonly include mesenteric artery atherosclerosis, medium and small vessel vasculitis, and traumatic causes. Also mechanical etiologies such as strangulation due to congenital bands, adhesions, and internal hernias reduce blood flow to sections of small bowel [13]. Pneumatosis of the duodenum is rare and should raise concern for ischemia, but can also be

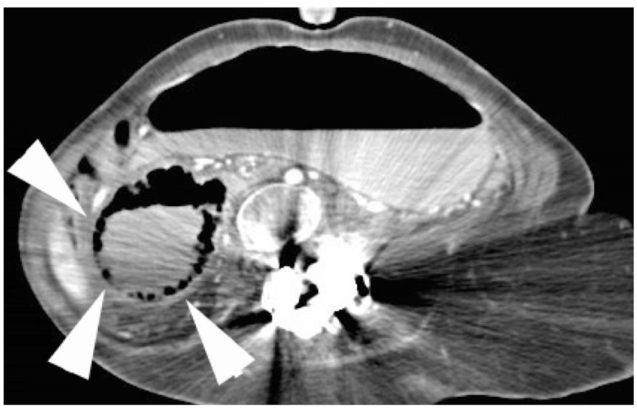

Fig. 4 Twenty-four-year-old woman with Rett syndrome presenting with abdominal distention and lactic acidosis. Axial CTs show pneumatosis (arrow) of the duodenum. Surgery found marked adhesions without evidence of duodenal necrosis

Fig. 5 Thirty-nine-year-old man presents with stab wound to the abdomen. Coronal MPRs from IV contrast-enhanced CT demonstrate **a** hemoperitoneum (arrowheads) tracking along the right paracolic gutter and **a**, **b** a few foci of extraluminal air (arrow) in subhepatic space. Laceration of the first portion of the duodenum was found intraoperatively

seen in the setting of severe infection and mucosal breakdown due to inflammation (Fig. 4).

Trauma

Duodenal trauma may result from penetrating (Fig. 5) or blunt injury. In blunt trauma, crushing of the duodenum against the vertebral body can cause contusion or transection especially of the second portion due to acute angulation and relative immobility in the retroperitoneum. Rapid deceleration in motor vehicle accidents is especially a risk factor for duodenal injury [14]. Duodenal hematoma can result from blunt abdominal trauma and is classically seen in seat belt injury. Peritoneal signs are frequently absent on physical exam because of the retroperitoneal location of the duodenum [15]. For this reason, it is essential to carefully inspect the duodenum in patients involved in motor vehicle accidents. Missed duodenal injuries can result in significant patient morbidity as well as mortality due to delay in diagnosis of resultant hemorrhage, ischemia, and peritonitis [15–18].

Duodenal perforation

Duodenal perforation may occur in the setting of peptic ulcer, diverticulitis, trauma, secondary to malignancy, or as a procedural complication. Iatrogenic perforation as a complication of endoscopic retrograde cholangio-pancreatography (ERCP) is usually suspected at the time of endoscopic examination (Fig. 6) [19, 20]. In these cases, the combination of procedural history and CT findings guide the diagnosis, with a characteristic pattern of gas in the retroperitoneum (Fig. 7). Duodenal perforation can occur in the setting of peptic ulcer disease (Fig. 1) and infrequently in duodenal diverticulitis (Fig. 3). CT findings of duodenal perforation include discontinuity in

Fig. 6 Fifty-year-old woman with significant post-procedure pain after ERCP. Axial image (**a**) and coronal MPR (**b**) from CT with IV contrast shows a collection of extraluminal gas (arrows) adjacent to the second and third segments of the duodenum with marked free fluid tracking throughout the right side of the retroperitoneum (arrows) demonstrating iatrogenic duodenal perforation at the site of the clip

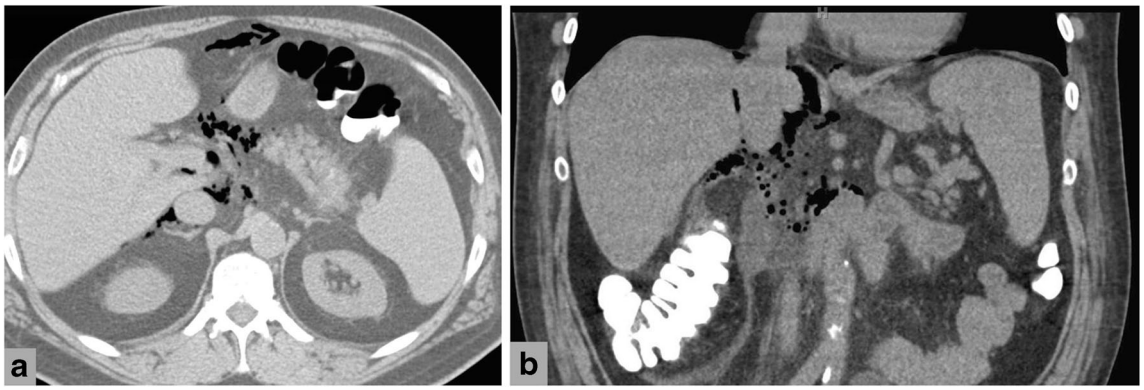

Fig. 7 Sixty-four-year-old male with abdominal pain after ERCP. Axial image (**a**) and coronal MPR (**b**) from CT without per oral or IV contrast show extraluminal gas representing a duodenal perforation. This is the characteristic pattern of retroperitoneal and intraperitoneal free air seen in the setting of duodenal perforation

the duodenal wall with associated wall edema and periduodenal stranding (Fig. 6), air bubbles in close contact with the duodenal rent, retroperitoneal air adjacent to the duodenum and extending into the mesentery and peritoneum, extravasation of oral contrast into retroperitoneum (if administered), and fluid in the retroperitoneum (more common) between the duodenum and pancreatic head [10, 17]. Location of free air can help diagnose the site of duodenal perforation. For example, free air crossing the midline and extending along the falciform ligament or ligamentum teres could be due to duodenal bulb perforation; free air in the lesser sac could be due to first or second part duodenal perforation, and air in the right anterior pararenal space or retropancreatic region could be due to third part duodenal perforation [17].

Vascular etiology

Duodenal hemorrhage can occur in the setting of ulcer disease, tumor, trauma, and gastroduodenal artery (GDA) pseudoaneurysm. The diagnosis is made with CT angiography (arterial and venous phase) acquisitions done with a rapid rate of intravenous contrast injection, thin collimation, and multiphase protocol, which enables depiction of IV contrast extravasation into the bowel lumen in the setting of active gastrointestinal bleeding (Fig. 8) as detailed above. Multiplanar reconstructions assist in locating the site of bleeding. In particular, the double-oblique plane in early arterial phase acquisition might best depict the extravasation blush, which changes configuration from arterial to venous phase in the setting of active bleeding [21]. Risk factors for gastroduodenal artery pseudoaneurysm include acute pancreatitis and pancreaticoduodenectomy with pancreaticojejunal leak, ulcers, or iatrogenic causes (surgery, endoscopy with biopsy) (Fig. 9). In cases of ongoing hemorrhage, visualization of bleeding is dependent on the rate and duration of bleeding as well as CT technique [21]. In patients with suspected gastrointestinal hemorrhage, IV contrast should be administered, and positive oral contrast must be avoided as it obscures

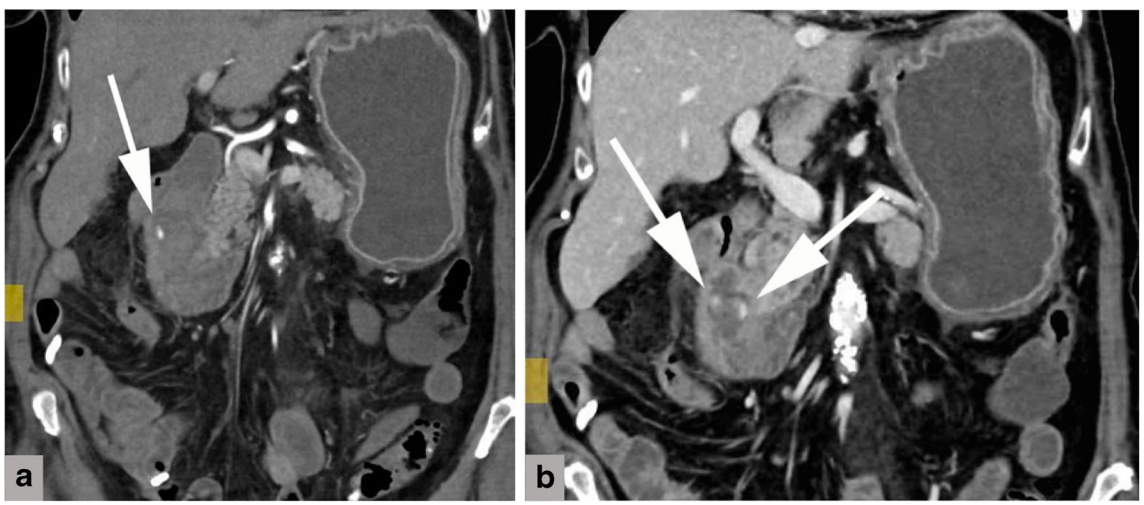

Fig. 8 Seventy-five-year-old woman, post-right hemicolectomy and partial duodenectomy who developed post-operative upper GI bleeding. Coronal arterial phase (**a**) and venous phase (**b**) IV contrast-enhanced CT revealed active hemorrhage (arrows) into the second portion, increasing from arterial to venous phase, as well as an intraluminal hematoma (H). Patient was managed with GDA coil embolization

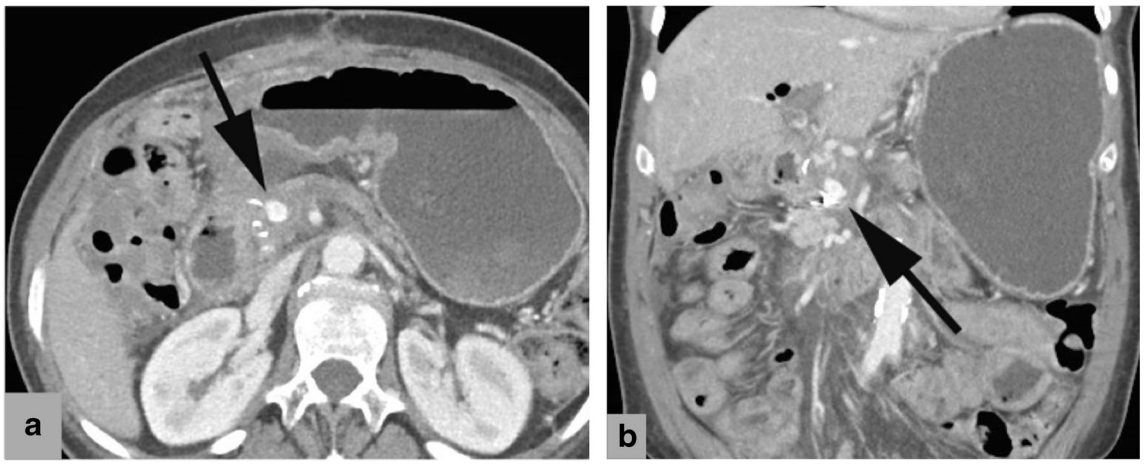

Fig. 9 Sixty-nine-year-old woman with 3 days of melena following pancreaticoduodenectomy. Source of hemorrhage is a GDA pseudoaneurysm (arrows) bleeding into the duodenum. The GDA stump should be carefully evaluated in axial (**a**) and coronal (**b**) planes on IV contrast-enhanced CT. The absence of hemorrhage into the duodenal lumen does not diminish the critical nature of this finding. This patient was asymptomatic at time of scan but, nonetheless, was sent directly to the ED. She decompensated soon thereafter due to acute rupture while being consented for interventional embolization. Later, she was successfully treated by IR coil embolization and discharged after several days

visualization of active bleeding [22]. An uncommon cause of duodenal hemorrhage is rupture of an untreated abdominal aortic aneurysm into the duodenal lumen or an aneurysm sac that continued to enlarge after endovascular stent placement (Fig. 10). The presence of gas in the aneurysm sac (arrowheads in Fig. 10) and a possible fistula track increases diagnostic confidence; however, this finding is not always identified despite the presence of an aortoenteric fistula.

Medium and small vessel vasculitis such as polyarteritis nodosa, Churg-Strauss syndrome, systemic lupus

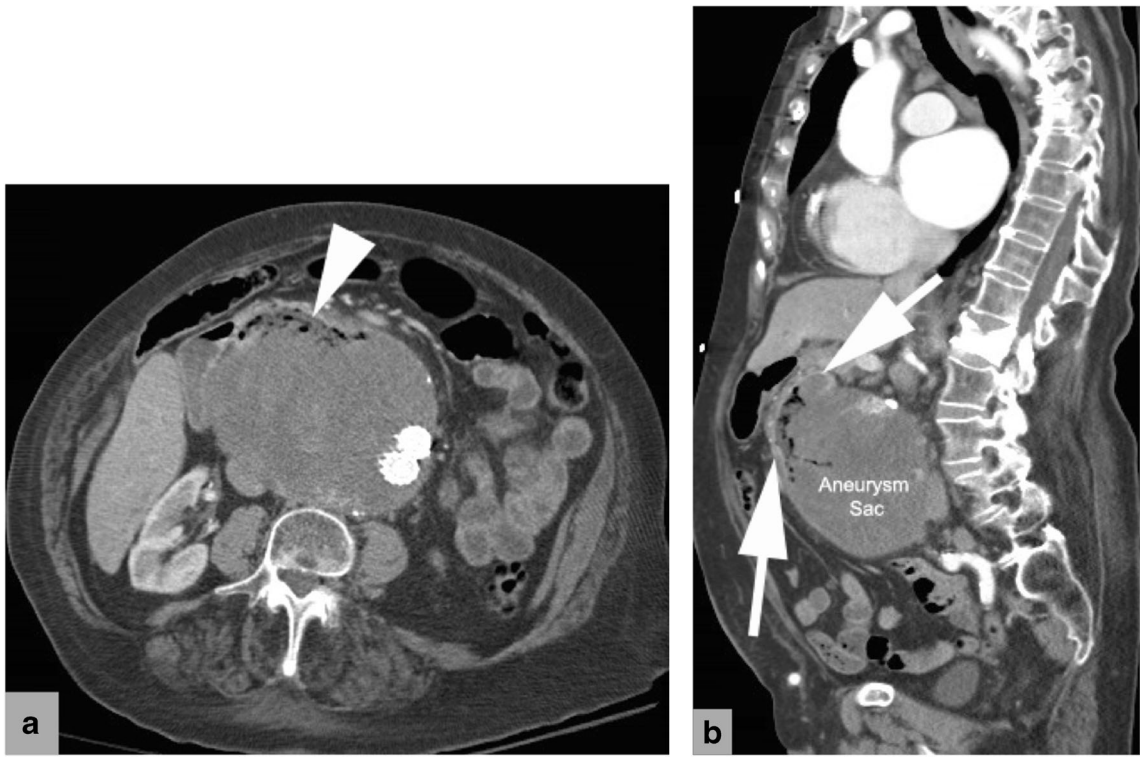

Fig. 10 Rare complication of abdominal aortic aneurysm of the excluded sac, which can occur before and after repair if EVAR is complicated by refractory endoleak. **a** Axial and **b** and sagittal MPR IV contrast-enhanced CT of an 87-year-old female with abdominal aortic aneurysm and post endoluminal repair and revision who presented with progressive weakness. She was found to be severely anemic with baseline hemoglobin of 6 g/dL due to aortoenteric fistula (arrow)

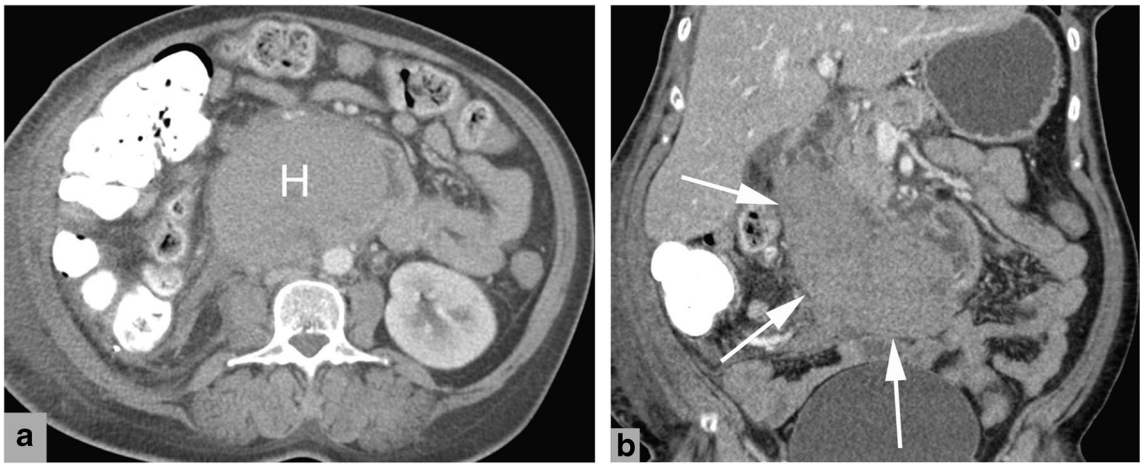

Fig. 11 Sixty-two-year-old woman on anticoagulant therapy presented with large duodenal hematoma (H, arrows) on axial (**a**) and coronal MPR (**b**) CT with IV contrast. Relationship to duodenum best depicted on coronal MPR. This finding may mimic pancreatic mass

erythematosus, and Henoch-Schönlein purpura can cause aneurysm, pseudoaneurysm, vessel irregularity, stenosis of mesenteric arteries and could be a cause of acute GI bleeding [13]. Important CT findings include duodenitis with the target sign and engorgement of the mesenteric vessels with comb sign. Characteristic endoscopic features include ischemic or necrotic enteritis and multiple ulcers sometimes with punched out margins [13]. Arteriovenous malformation such as duodenal angiodysplasia or hereditary hemorrhagic telangiectasia can be a cause of episodes of occult melena but rarely can cause acute bleeding with presentation to the emergency department [22]. Duodenal hematoma may also be seen with coagulation disorders or with anticoagulant therapies [17], and detailed extension is characterized by coronal MPR (Fig. 11). It is essential not to mistake this important diagnosis for a pancreatic mass.

Duodenal tumors

Acute duodenal obstruction can result from primary duodenal or other periampullary tumors. Clinical symptoms include nausea, vomiting, and the inability to tolerate oral intake. Approximately 20% of small bowel neoplasms arise in the duodenum [23]. The most common symptomatic benign neoplasm of the duodenum is a benign gastrointestinal stromal tumor (GIST) [2]. GIST appears as a heterogeneous mass, with varying degrees of enhancement based on the size, and can be exophytic or cause narrowing of the bowel lumen. An important differential for GIST is carcinoid tumor. Duodenal carcinoids (8% of GI carcinoids) are hyperenhancing lesions on arterial and portal venous phase appearing as intraluminal polyps or masses or circumferential wall thickening. Duodenal

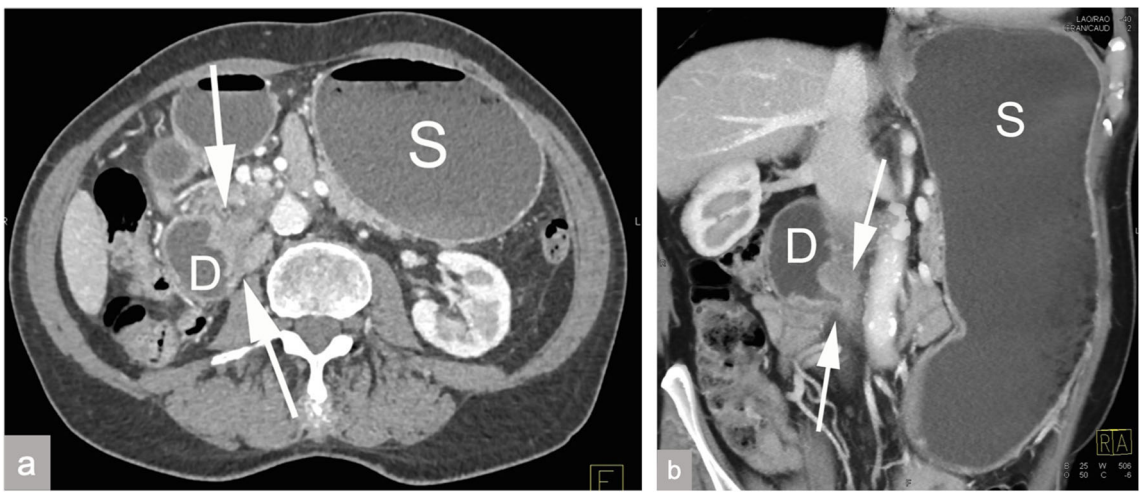

Fig. 12 Seventy-seven-year-old man with fatigue and nausea found to have obstructing duodenal adenocarcinoma. **a** Axial image and **b** coronal 3D rendering from IV contrast-enhanced CT show gastric outflow obstruction with upstream dilation of the more proximal duodenum (D) and stomach (S) due to constricting mass narrowing the transverse segment of the duodenum (arrow)

lipomas are benign lesions with smooth margins and negative Hounsfield unit measurement (− 20 to − 100 HU) which almost always is an incidental finding. Adenomas of the duodenum include tubular type, villous adenoma (malignant potential), and Brunner gland adenoma which can rarely be a cause of obstruction or bleeding [24, 25].

The most common primary malignancy of the duodenum is adenocarcinoma (Fig. 12), with 50–70% of small bowel adenocarcinomas occurring either in the duodenum or proximal jejunum [1, 26]. Lymphomatous involvement of the duodenum can occur with both primary duodenal lymphoma and involvement from systemic disease. The duodenum can also be obstructed by local extension of other malignancies, for example, pancreatic adenocarcinoma or gallbladder cancer [1, 27].

Other rare causes of obstruction include annular pancreas, strictures due to severe duodenal ulcers, and Bouveret syndrome (obstruction by gall stones following a cholecystoduodenal fistula) [1]. Duodenum is the most common site for GI amyloidosis and frequently presents as mass-like infiltrative lesion. CT findings consist of diffuse wall thickening, aneurysmal dilatation of duodenum, sometimes bleeding, intussusceptions, and obstruction [24].

Conclusion

Radiologists should routinely include the duodenum in their search pattern when patients in the emergency department are imaged for an acute symptomatology. Proper CT technique is essential to evaluate the duodenal wall and involvement of adjacent anatomic structures that includes the use of intravenous contrast, thin section acquisition, and multiplanar reconstructions. Understanding of the range of pathology that involves the duodenum and its CT manifestations will facilitate timely diagnosis and management.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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