MDCT and MR imaging of the jejunum

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KEYWORDS
Jejunum; Jejunal imaging; MDCT-enteroclysis; MR-enteroclysis; Enteroigraphy

Abstract  Recent refinements in cross-sectional imaging have dramatically modified the investigation of the jejunum. Improvements in multidetector row computed tomography (MDCT) and magnetic resonance (MR) imaging technology have made detection and characterization of jejunal abnormalities easier. Current options include MDCT and MR imaging using either enterography or enteroclysis. The goal of this pictorial review is to outline the current imaging techniques that are used to investigate the jejunum and illustrate the most common conditions that affect this small bowel segment with a specific focus on MDCT and MR imaging using enterography or enteroclysis. MR imaging used in conjunction with optimal jejunal distension appears as the modality of choice for the diagnosis of a wide range of jejunal abnormalities. MDCT remains the first line imaging modalities because of an acute presentation in a substantial number of patients.

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During recent years, the investigation of the jejunum has been subjected to marked changes. One of these is that the small bowel follow-through technique is now definitively and uniformly abandoned [1,2]. The second change is the advent of videocapsule endoscopy [3]. In the same time, refinements in multidetector row computed tomography (MDCT) and magnetic resonance (MR) imaging have resulted in dramatic improvements in diagnostic capabilities. The association of MDCT with optimal jejunal distention is the basic concept behind MDCT-enteroclysis and MDCT-enteroclysis [4,5]. Similarly, MR imaging used in conjunction with jejunal distension has proven efficacy for the diagnosis of a large range of jejunal conditions [6–11].

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http://dx.doi.org/10.1016/j.diii.2014.11.008
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Diseases of the jejunum have received little attention in the literature so far. They are relatively rare by comparison with ileal diseases and often have an acute presentation. Most of them are tumors, followed by inflammatory diseases, infections, malformations, and acute obstruction [12,13].

The goal of this pictorial review is to outline the current imaging techniques that are used to investigate the jejunum and illustrate the common conditions that affect this small bowel segment with a specific focus on MDCT and MR imaging using enterography and enteroclysis.

**Imaging techniques**

Regardless the imaging technique used, optimal analysis of the jejunum requires luminal distension of jejunal loops, intravenous administration of positive contrast material, and the use of thin section. To achieve optimal jejunal distension, enteral contrast agents can be administered using enteroclysis or enterography. However, optimal jejunal distension is best obtained with enteroclysis rather than with enterography [7,11]. Enteroclysis refers to the infusion of enteral contrast agent directly within the proximal jejunum through a nasojejunal tube. Enterography refers to the oral administration of relatively large amounts of enteral contrast material. To increase jejunal compliance, an antispasmodic drug is administered intravenously [2,4,7,11].

**MDCT-enteroclysis protocol**

MDCT-enteroclysis is performed during enteral distension obtained by means of water infused through a dedicated naso-jejunal tube advanced beyond the ligament of Treitz using a pressure-controlled electric pump at a rate of 100–160 mL/min [4,5]. The mean quantity of water is ≈2 L. Currently, MDCT-enteroclysis is routinely performed with 64-section or more MDCT scanners. A collimation thickness ≤0.6 mm allows submillimeter voxel reconstructions. MDCT-enteroclysis protocols have been described in details elsewhere [5,14]. In general, one single pass is obtained 50 s after the start of iodine administration, when jejunal wall enhancement is optimal. The adjunct of an arterial phase has no demonstrated benefit for the detection of jejunal tumor [14,15]. Axial images, multiplanar reconstructions (MPR) and maximum intensity projection (MIP) views are obtained to heighten confidence in diagnosis. Additional three-dimensional reconstructions are obtained in specific cases [16,17].

**MDCT-enterography protocol**

From a clinical point of view, MDCT-enterography has the same capabilities than MDCT-enteroclysis for the study of the mesentery and jejunum. The benefit of MDCT-enterography over MDCT-enteroclysis is due to the absence of tube placement, better patient tolerance and reduced examination time. However, in theory, the suboptimal small bowel distension observed in up to 19% of patients may potentially obscure discrete small bowel abnormalities [18]. But to date, there are no convincing studies in the literature that directly compared degrees of small bowel distension obtained with both techniques in the same patients. Consequently, the non-invasive nature of MDCT-enterography and its better tolerance, by comparison with MDCT-enteroclysis, have made it the first line examination in patients with suspected jejunal disease at many facilities.

Whereas plain water results in optimal jejunal distension at MDCT-enteroclysis, its use is not recommended for MDCT-enterography. MDCT-enterography is performed with neutral, slightly hyperosmolar enteral contrast agents to avoid obscuring subtle jejunal abnormalities and rapid absorption [19]. Water—methyl cellulose solution, water–polyethylene glycol solution, and VoLumen® (Bracco/E-Z-EM) can be used, with best results obtained for VoLumen® and water–polyethylene glycol solution [2]. Enteral contrast agent is usually given in three separate aliquots divided into three 450 mL doses administered every 15 min, beginning 60 min before scanning. An additional 500 mL of water is administered orally 15 min before scanning as previously described [20]. MDCT-enteroclysis images are obtained using the same image acquisition protocol than that described above for MDCT-enteroclysis.

**MR-enterography protocol**

MR-enterography is often preferred to MR-enteroclysis for the same reasons that make MDCT-enterography more popular than MDCT-enteroclysis. In addition, the continuous administration of enteral contrast agent that is needed for MR-enteroclysis is not always possible at many centers because high magnetic field compatible electric pumps are not available. However, MR-enterography yields lower degrees of small bowel distension than MR-enteroclysis and MR-enteroclysis is superior to MR-enterography for depicting subtle mucosal abnormalities [7]. However, MR-enterography has a well-established value for the evaluation of Crohn’s disease and yields acceptable degrees of sensitivity for the detection of jejunal tumors [21–23].

The patient fasts for at least six hours before MR-enteroclysis. A water–polyethylene glycol (PEG) solution or a 3% mannitol solution, with a volume of 1000–2000 mL, is ingested 45 min before MR-enterography [8]. More generally, MR-enterography can be performed using the same enteral contrast agents than those used for MR-enteroclysis, including water–mannitol solution.

Full details regarding MR-enterography protocol have been described elsewhere [8,21,22]. MR images are obtained using parallel imaging technique, which allows reducing acquisition time, blurring, susceptibility artifacts and chemical shift [2]. The basic MR protocol includes various sequences. T2-weighted MR images obtained with a single shot fast (or turbo) spin-echo sequence in the axial and coronal plane with 3–4 mm slice thickness. This sequence is termed either half-Fourier single shot spin-echo (HASTE) or single shot fast spin-echo (SSFSE) (Fig. 3). A short TE (60–90 ms) favors visualization of jejunal wall, adjacent structures and intraluminal fluids. This type of sequence can be used in conjunction with fat suppression technique [2]. Balanced gradient echo MR sequences, such as FIESTA (free induction echo stimulated acquisition), trueFISP (true free-induction with steady state precession) or BSSFP (balanced steady state free precession are used with a very short repetition time [TR = 3–5 ms]). Additional
coronal fat-suppressed three-dimensional low angle volumetric interpolated breath hold (3D VIBE) T1-weighted gradient echo MR sequence are obtained before and after intravenous administration of gadolinium-chelate.

**MR-enteroclysis protocol**

MR-enteroclysis is excellent diagnostic tool for the depiction of jejunal abnormalities [10,11]. Administration of an enteral contrast agent through a nasojejunal tube provides degrees of luminal distention similar to those achieved during MDCT-enteroclysis. Some authors advocate placement of patients in prone position because it results in abdominal self-compression, thus potentially improving distension of small bowel loops. But prone position is less tolerated than supine position by many patients.

The preparation for MR-enteroclysis is aimed at obtaining adequate cleansing of the small bowel and mirrors that are used for MDCT-enteroclysis. The enteral contrast agent is given through a naso-jejunal tube using the same protocol than for MDCT-enteroclysis, which implies radiation exposure and extra time for tube placement.

The MR sequences used for MR-enterography are the same than those used for MR-enteroclysis and include the same combination of sequences. Enteral contrast agents include plain water, water—methylcellulose suspension and water—polyethylene glycol solution. Water—methylcellulose solution provides optimal distension and appears as the ideal enteric agent for MR imaging. Water—methylcellulose solution is inexpensive and widely available and is one of the favored enteral contrast agents in many institutions. However, many researchers advocate the use of water—polyethylene glycol solution [2,11].

**Embryology, normal anatomy and variants**

The jejunum, which extends from the ligament of Treitz to the ileum, is the proximal segment of the mesenteric small bowel, representing approximately 40% of the small bowel. Embryologically, the jejunum originates from the midgut, which is divided into two portions (i.e., cephalic and caudal limbs). The jejunum derives from the cephalic limb, along with the lower duodenum and upper ileum. During intrauterine development lengthening of the midgut coexists with a twisting of the gut tube around the superior mesenteric vascular axis. After ten weeks, gut rotation results in the jejunum being positioned in the left side of the abdomen, which is the definitive location [24]. An impaired process of rotation of the midgut results in the so-called malrotation with a right-sided jejunum, usually associated with a superior mesenteric artery on the right side of the superior mesenteric vein (Fig. 1) [24,25].

Jejunal duplications are rare congenital abnormalities that present on MDCT and MR imaging as smooth, rounded, fluid-filled cystic or tubular structures with thin, slightly enhancing wall containing smooth muscle. These structures are either connected with or adjacent to the jejunum. Rarely, Meckel diverticulum may originate from the jejunum [26].

Vascular supply of the jejunum arises from superior mesenteric artery and venous drainage is made by superior mesenteric vein so that an impaired flow of these vessels results in jejunal suffering [16].

**Imaging presentation of jejunal diseases**

**Malignant jejunal tumors**

**Adenocarcinomas**

One third of small bowel adenocarcinomas develop in the jejunum, particularly in the first 30 cm. Adenocarcinoma is the most frequent jejunal tumor [27]. Most of them are well or moderately differentiated and the majority is discovered late with distant metastases. Risk factors include celiac disease and adenomatous polyposis [2,28]. Intussusception with jejunal obstruction can be the revealing symptom [29].

On MDCT and MR imaging, jejunal adenocarcinoma may present as a soft-tissue mass, an annular narrowing with irregular borders or as an ulcerated mass in 40% of the cases, with adjacent lymph nodes (Fig. 2) [2,4,5,8,11]. The circumferential thickening mirrors the so-called “applecore”

![Figure 1. A 26-year-old man presenting with nonspecific abdominal pain. a: MDCT of the abdomen in the axial plane shows small bowel loops (arrowheads) including jejunal loops in the right side of the abdomen whereas the left side of the abdomen (arrow) contains no small bowel loops; b: MDCT in the coronal plane confirms absence of small bowel loops in the right side of the abdomen (arrow), which is consistent with midgut malrotation.](image-url)
as described on conventional barium examinations (Fig. 2). Ulceration is strongly suggestive for the diagnosis of adenocarcinoma and well depicted on MDCT and MR imaging using enteroclysis or enterography. Usually, a short jejunal segment is involved by contrast with lymphoma. Progressive luminal narrowing results in partial or complete jejunal obstruction (Fig. 2). The tumor generally shows mild, heterogeneous and late enhancement after contrast injection because of predominant fibrous component [4,5]. Lymph node enlargement is less prominent in adenocarcinoma as it is in the setting of lymphomas [7].

Carcinoid tumors

Carcinoid tumors are well-differentiated endocrine neoplasms that represent 2% of all gastrointestinal tumors [30]. The jejunum is a rare location, the appendix and distal ileum being the most frequent locations. As they enlarge, carcinoid tumors may cause intussusception or obstruction. Histologically, distinction between benign and malignant carcinoid tumors is often difficult, unless metastases are present.

Asymmetric focal jejunal wall thickening is the first manifestation of jejunal carcinoid tumors so that tiny carcinoid tumors remain undetected on MDCT or MR imaging in the absence of adequate jejunal distension in 80% [14,31]. Depiction of small lesions is substantially improved owing to the use of enteroclysis or enterography and multiplanar views. Small carcinoid tumor presents as a rounded jejunal mass with smooth borders. The tumors may be mucosal or submucosal in appearance, without desmoplastic changes, and be indistinguishable from other tumors such as gastrointestinal stromal tumors (GISTs), adenomas and submucosal metastases. In some cases, mural segmental thickening may indicate associated jejunal ischemia.

Mesenteric metastases present as spiculated nodules with variable degrees of enhancement, in association with mesenteric stranding, retraction of the jejunal wall toward the root of the mesentery and thickening of the adjacent jejunal wall. Calcifications of mesenteric nodule are present in approximately 70% of cases and are very suggestive [14]. They are best depicted on MDCT and less visible on MR imaging [2,5,14]. Hepatic metastases are often hypervascular with marled enhancement after intravenous administration of contrast material [30].

MDCT-enteroclysis allows detection of virtually 100% of carcinoid tumors [4,14,15,32]. MDCT-enterography has also a potential for the detection of early tumors and delineating mesenteric extension, although its capabilities have not yet been fully addressed.

Using MR-enteroclysis or MR-enterography, the carcinoid tumor has signal intensity similar to that of the psoas muscle on T1-weighted images and similar or greater on T2-weighted images. The primary tumor shows mild or vivid enhancement whereas the mesenteric metastases usually show less pronounced degrees of enhancement [33]. The radiating strands of mesenteric metastasis show low signal on both T1- and T2-weighted images. Jejunal carcinoïd tumors may be nodular or present as a regional uniform bowel wall thickening with moderate or intense enhancement after gadolinium-chelate administration. Approximately 30% of primary carcinoïd tumors are not visible on MR imaging without enteral contrast agent but using MR-enteroclysis with intravenous administration of a gadolinium-chelate, the sensitivity reaches 93% for lesion detection [33].

Stromal tumors (GISTs)

GISTs are mesenchymal tumors of the gastrointestinal tract that express positivity for CD 117 by comparison with leiomyomas, leiomyosarcomas, schwannomas and neurofibromas, which do not expressed CD117 [2]. GISTs are usually solitary tumors. The jejunum is the third most common site of GIST, representing approximately 20% of all cases of GISTs. GISTs should be considered as at least low-grade malignancies. Jejunal GISTs most frequently originate from the muscularis propria but frequently involve the outer muscular layer, resulting in an exophytic growth. However, GISTs can be submucosal, subserosal or intraluminal, thus explaining great variations in MDCT and MR imaging presentation. Clinically, GISTs most often present as acute or chronic gastrointestinal bleeding.

On MDCT-enteroclysis and CT-enterography small GISTs (<5 cm) typically present as regular, round or lobulated
masses with homogeneous and relatively marked early enhancement (Fig. 3). Larger tumors are heterogeneous with central necrosis and more prone to extraluminal growth. Ulceration is a classical feature of large GISTs that may lead to fistulization. Calcifications are uncommon unless the tumor has been previously treated. GISTs are usually well-defined with smooth borders. Mesenteric fat infiltration as well as adjacent lymph nodes are uncommonly observed, and even for large tumors, [5].

On MR imaging, GISTs are usually hyperintense on T2-weighted MR images, with variable degrees of enhancement after intravenous administration of a gadolinium-chelate [34]. Areas of hemorrhage show hyperintensity on T1-weighted MR images. Smaller tumors usually have homogeneous and relatively intense enhancement, whereas larger tumors are heterogeneous with areas of necrosis that show poor or no enhancement [8,9,11,21].

Lymphomas
Small bowel lymphomas represent 20% of all primary gastrointestinal lymphomas. The distal ileum is the most common location of small bowel lymphoma although the jejunum is more predominantly involved in celiac disease patients [28]. Lymphoma may be primary or consists in secondary jejunal involvement in the setting of diffuse lymphomatous disease. Most of them are non-Hodgkin B-cell lymphomas.

On MDCT and MR imaging, jejunal lymphomas can be diffusely infiltrating with mural thickening of a long jejunal segment [35], or polypoid with protrusion into the jejunal lumen, or large and exophytic with adjacent lymphadenopathy and possibly fistulization. On MR and MDCT-enteroclysis or enterography, jejunal lymphoma may show luminal narrowing that rarely results in proximal luminal dilatation [36] or may cause aneurismal dilatation of a jejunal segment. A few cases of intussusception have been reported (Fig. 4) [8].

MR-enteroclysis and MR-enterography show abnormal thickening, smooth margins and luminal narrowing in association with loss of normal mucosal folds [37,38]. After intravenous administration of a gadolinium-chelate, lymphomas display moderate enhancement. Mesenteric fat
infiltration might be a feature suggestive for a high-grade non-Hodgkin subtype [39]. Involvement of a single segment greater than 10 cm suggests an underlying celiac disease [39].

Metastases

Jejunal metastases are more frequently associated with other intra-abdominal locations of the disease, whereas a single metastasis of the jejunum is relatively rare. Metastases develop through four major pathways including continuous spreading, intraperitoneal seeding, lymphatic and hematogenous spreads [8,11]. Jejunal metastases may occur by direct extension from a tumor originating from an adjacent organ such as pancreatic cancer. Hematogenous metastases to the jejunum from extra-enteric primary tumors are rare, mostly from melanoma, breast cancer, and lung cancer.

On MDCT and MR imaging, metastases that involve the jejunum by means of intraperitoneal seeding appear as small or large enhancing nodules along the serosal surface of the jejunum, mesentery, or omentum. MDCT and MR imaging using enterography and enteroclysis are superior to videocapsule endoscopy and other endoscopic techniques because jejunal metastases have an extraluminal location [40,41]. Metastases typically appear as mural nodules and may cause transient intussusception.

Benign jejunal tumors

Adenomas

Adenomas are the most common asymptomatic benign tumors of the small bowel and most often seen in the duodenum. Jejunal adenomas are rare but may have malignant potential. They appear as well-defined sessile or pedunculated soft-tissue masses, surrounded by clear fat planes. They show homogeneous, mild enhancement after intravenous administration of contrast material. Adenomas may protrude into the jejunal lumen but do not cause obstruction [5,8].

Polyposis syndromes

Polyposis syndromes that may affect the jejunum include Peutz-Jeghers syndrome (PJS), juvenile polyposis, Cowden disease, and Gardner syndrome. PJS is a genetic disorder with an autosomal dominant pattern of inheritance. PJS patients have multiple small bowel hamartomatous polyps that may mimic actual malignancies. These polyps are predominantly found in the jejunum [5]. The two main concerns in the management of PJS polyps are the long-term cancer risk and polypl-related complications. Most patients who satisfy the clinical criteria for diagnosis have a causative mutation in the STK11 gene, which is located at 19p13.3. It is currently admitted that PJS patients have an increased risk for many cancers, including small bowel cancers, with a lifetime incidence of malignancy approaching 60% [8]. Large PJS polyps (>15 mm) in the jejunum commonly manifest at an early age with gastrointestinal bleeding, anemia, and intussusception or obstruction.

Surveillance protocols remain debated. Endoscopy is performed to detect significant polyps (i.e., large polyps with a predisposition for intussusception or obstruction). Surveillance for the various cancers to which PJS patients are more prone to is an important part of management. There is a consensus upon the fact that regular surveillance helps identify and remove significant polyps, thus reducing the need for emergency laparotomy and preserving the small bowel. Significant polyps (i.e. those > 15 mm) may cause small bowel obstruction so that timely surveillance is needed to determine which polyps should be removed.

PJS polyps have a typical appearance on MDCT and MR imaging using enteroclysis or enterography. In theory, any of these techniques can be used to monitor patients with multiple polyps and plan the most appropriate approach, which may consist of endoscopic removal, enteroscopic or surgical removal, or a combination of different approaches.

MR-enterography is currently the favored technique because of lack of radiation and better tolerance [41–43]. TruFISP and gadolinium-enhanced fat-suppressed VIBE are the most useful MR imaging sequences for detecting jejunal polyps [8,41]. PJS polyps appear as hypointense filling defects on TruFISP images and typically show marked enhancement similar to that of the bowel wall mucosa after the intravenous administration of a gadolinium chelate.

Lipomas

Lipomas are relatively frequent mesenchymal small bowel tumors. They represent 20% of benign jejunal tumors. They originally develop from the submucosa and present as well-circumscribed masses. They are predominantly located in the ileum rather than in the jejunum. They are solitary lesions and always benign.

On MDCT, fat content with negative Hounsfield values (−100–100 HU) on MDCT is virtually pathognomonic for the diagnosis (Fig. 5) [5].

On MR imaging, they display high signal intensity on T1- and T2-weighted MR images, with drop in signal intensity on fat-suppressed sequences [5,44]. Lipomas are often depicted incidentally. However, they may enlarge and show necrosis, calcifications, or rarely cystic degeneration and ulcerations. They often cause transient intussusception, which is the most frequent revealing symptom.

Leiomyomas

Leiomyomas are mesenchymal tumors that originate from the muscularis propria of the small bowel. They often present as solitary tumors that predominantly develop in the jejunum and cause gastrointestinal bleeding. Macroscopically, they can develop into the lumen as subserosal tumors, but they can also have a bidirectional development, resulting in the so-called dumbbell leiomyomas. They do not express positivity for CD117, so that they are different from benign GISTs [5].

On MDCT-enteroclysis or enterography, jejunal leiomyomas usually presents as a well-circumscribed, submucosal, homogeneously enhancing spheroid or ovoid mass.

On MR-enterography or enteroclysis, leiomyoma shows homogeneous and moderate signal intensity with marked enhancement after intravenous administration of contrast material [5].
Vascular abnormalities

Jejunal vascular abnormalities consist of hemangiomas and vascular malformations [45]. Classification and denomina-
tion for jejunal hemangiomas and vascular malformations
are confusing and still controversial. Histologically, arterio-
venous hemangiomas (also called arteriovenous malforma-
tions) represent 85% of all vascular abnormalities. Other less
common vascular lesions include cavernous hemangiomas,
capillary hemangiomas, telangiectasias, angiectasias (also
called angiodysplasias, which are flat lesions made of
thin tortuous veins without internal elastic layer), venous
malformations, and more complex malformations such as
lymphangiomas. Vascular abnormalities are often found in
association with more diffuse diseases such as Rendu-Osler-
Weber syndrome and blue rubber bleb nevus syndrome (also
known as BEAN syndrome) [46].

Vascular abnormalities of the jejunum are rarely visible
on MDCT and MR imaging using enterography or enteroclysis
and mostly visible endoscopically [3,40]. Their depiction is
greatly improved when arterial phase is obtained [20].

In rare cases, they can be visible when they produce
mass effect on MR imaging, presenting as multiple, hyper-
intense, well-defined, round lesions on T2-weighted MR
images (Fig. 6) [46].

Jejunal lymphangiectasia

Jejunal lymphangiectasia is a rare condition. It can be
primary, resulting from a congenital lymphatic blockage,
or secondary, resulting from lymphatic involvement by an
underlying disease. The pathogenesis of localized jejunal
lymphangiectasia is unclear [5,40].

MDCT and MR imaging using enterography or enteroclysis
reveals a small nodular, well defined, broad-based, hetero-
genous mass with moderate or even absent enhancement
after intravenous administration of contrast material.

Crohn’s disease

Crohn’s disease is characterized by segmental, transmural
and granulomatous inflammation. The small bowel is the
most frequent location of Crohn’s disease but isolated jeju-
nal involvement is found in only 1% of patients [47]. MDCT
and MR imaging have the advantage of providing similar
information for small bowel involvement, as well as iden-
tifying extra-enteric complications and predicting surgical
approach when needed [48].

MDCT-enteroclysis has proven superiority over conven-
tional enteroclysis in depicting intra- and extra-mural
complications. Videocapsule endoscopy is better at the
detection of proximal or early mucosal disease, but
MDCT-enterography is better at detecting transmural and
extraluminal disease.

MR-enteroclysis is now the preferred imaging tech-
nique since it avoids ionizing radiation in young patients
who require frequent follow-up studies. MR-enteroclysis
is superior to MR-enterography for the depiction of jeju-
nal involvement in Crohn’s disease [7,11]. Characteristics
specific to Crohn’s disease include increased mesenteric
fat, skip lesions and fistulae, identifiable on cross-sectional
imaging (Fig. 7). One advantage of MR imaging is to better

Figure 5. A 91-year-old woman complaining from repeated and transient episodes of incomplete small bowel obstruction. a: MDCT in
the axial plane shows homogeneous, markedly hypoattenuating ovoid lesion (arrows) of the jejunum containing negative Hounsfield values,
which is virtually pathognomonic for jejunal lipoma; b: MDCT in the coronal plane confirms jejunal location of lipoma (arrow).

Figure 6. A 18-year-old man with blue rubber bleb nevus (BEAN) syndrome presenting with chronic gastrointestinal bleeding. T2-weighted HASTE MR-enterography in the axial plane shows hyperintense lesion (arrow) of the jejunum suggestive for jejunal
vascular malformation. The diagnosis was confirmed after surgical resection.
characterize fibrosis, depict submucosal edema and provide good correlation with clinical activity [49,50].

Signs of active disease at MR-enterography include jejunal thickening, spontaneous high signal intensity on T2-weighted MT images, marked mucosal enhancement and stratification on gadolinium-chelate enhanced T1-weighted. Submucosal fat accumulation can be observed in subacute or chronic stages. Fibrosis shows late enhancement on gadolinium-chelate enhanced T1-weighted images [51].

Celiac disease

Celiac disease results from sensitivity to gluten products leading to vilous atrophy of the small bowel in genetically susceptible individuals. Although a definitive diagnosis requires duodenal biopsy, typical findings at MDCT and MR imaging include small bowel dilatation, a reversal of the normal jejunouleal fold pattern, fold separation, and nonobstructing transient small bowel intussusception [28]. MDCT and MR imaging may be helpful for detecting complications such as lymphoma, and carcinoma [28]. Extra-intestinal complications such as lymphadenopathy and enteropathy associated T-cell lymphoma may be found.

MDCT and MR imaging using enteroclysis or enterography show vilous atrophy in the jejunum (seen as reversal of the normal jejunouleal fold pattern, with an increased number of ileal folds and a decreased number of jejunal folds) or dilatation of jejunal loops with absence of the valvulae conniventes [52,53]. Findings such as inflammatory thickening of the small bowel wall, lymphadenopathy, and mesenteric vascular engorgement also may be seen in patients with celiac disease [52]. Complications of the disease may include nonobstructive intussusception and ulcerative jejunoileitis with circumferential thickening of the small bowel wall. Cavitary mesenteric lymph node syndrome, which is characterized by fat-fluid levels, and the development of lymphoma or carcinoma, are rare associated conditions [4,52].

Diverticula and diverticulitis

Jejunal diverticula are mostly presented incidentally and usually have little clinical significance. Jejunal diverticulosis has a reported incidence of 2% on conventional small bowel barium studies and of 1.3%—4.6% at autopsy. Jejunal diverticulosis usually presents as a solitary diverticulum or as a few diverticula. A pan-jejunoileal diverticulosis is rare [54]. Diverticular disease is predominantly located on the jejunum (55%) followed by the ileum (38%). Chronic symptoms include nonspecific abdominal discomfort and malabsorption when bacterial overgrowth is present. Complications include inflammation, perforation, and obstruction.

Jejunal diverticulitis usually presents as a focal inflammatory mass on MDCT with periliteral stranding on MR imaging, with possibly loco-regional complications (Fig. 8) [55]. Of note, diverticula do not contain valvulae conniventes. Multiple smooth, rounded outpouchings of variable size may be seen, with a discrete "neck" or constriction at the base. This condition is often overlooked at cross-sectional imaging.

The differential diagnosis includes perforated neoplasm, foreign body perforation, jejunal ulceration from nonsteroidal anti-inflammatory drug (NSAID) use and Crohn’s disease. Asymptomatic patients with jejunal diverticulosis are managed conservatively. Surgical resection is restricted to patients with chronic symptoms or acute complications [55].

Ischemia

Thrombosis or occlusion of the proximal portion of superior mesenteric artery results in extensive ischemia of the small bowel, including the jejunum with a relatively poor prognosis in case of late diagnosis. Occlusion of small distal arterial branches has a better prognosis because it can be treated with a limited small bowel resection. Because ischemia is a life-threatening condition, which is diagnosed...
Figure 8. A 45-year-old man presenting with acute abdominal pain and fever. a: MDCT in the axial plane shows ovoid fluid- and gas-containing structure (arrow) developed from the jejunum. Adjacent fat stranding (arrowhead) is present. These findings are consistent with acute diverticulitis of the jejunum; b: MDCT in the coronal plane shows jejunal diverticula with thickened wall (arrow) in association with infiltration of adjacent fat (arrowheads), thus confirming acute jejunal diverticulitis.

Figure 9. A 66-year-old man presenting with acute abdominal pain. a: MDCT-enterography in the coronal plane shows marked thickening of jejunal wall that shows poor enhancement (arrowheads), in association with mesenteric infiltration (arrow) and thrombosis of jejunal vein (curved arrow); b: MDCT-enterography in the coronal plane shows portal vein thrombosis (arrow) and peritoneal effusion (arrowheads), confirming venous ischemia of the jejunum due to thrombosis of portal and superior mesenteric veins.

In an emergency setting, MDCT is the first line examination for the diagnosis and is performed without small bowel distension [56]. Venous occlusion may result from strangulated internal hernia, volvulus, venous thrombosis (Fig. 9) or rarely malignant infiltration of the mesentery [57,58].

MDCT findings include jejunal wall thickening in association with thickening of other small bowel segments, spontaneous increased attenuation of small bowel wall, poor enhancement of jejunal wall, intra-abdominal fluid effusion [56]. Parietal gas (i.e., pneumatosis intestinalis) indicates

Figure 10. A 57-year-old woman with immunodeficiency syndrome due to HIV infection presenting with abdominal pain. Jejunal biopsies revealed presence of *Strongyloides stercoralis*. a: MDCT-enterography in the axial plane shows edema of the jejunal wall (arrowhead) with marked enhancement of jejunal mucosa; b: MDCT-enterography in the coronal plane confirms thickening of jejunal wall (arrowhead) with submucosal edema in association with fixed jejunal loops (arrow); c: T2-weighted HASTE MR-enterography in the coronal plane shows fixed jejunal loops (arrowheads) with no visible valvulae conniventes.
severe disease. Gas may be found within the mesenteric or portal veins. Jejunal volvulus is characterized by the “whirl sign” of twisted and often engorged mesenteric vessels [57].

**Infection**

Jejunal infections are rarely diagnosed at imaging. The most frequent jejunal parasitic infection worldwide is *Ascaris lumbricoides*, which may be visible as a long, tubular defect within the jejunal lumen when positive enteral contrast agent is used [59]. Less common infections include angululiosis due to *Strongyloides stercoralis*, which results in jejunal wall thickening and marked mucosal enhancement (Fig. 10) and is more frequently observed in immunodeficient patients [60]. Jejunal tuberculosis is rare and the disease most commonly affects the ileum and the ileocecal junction [61]. Jejunal tuberculosis is usually associated with multiple hypo attenuating lymph nodes. Knowledge of clinical history and the results of biological tests are needed for a definite diagnosis of jejunal infection.

**Conclusion**

Jejunal diseases are not so uncommon. Improvements in MDCT and MR imaging technology have made their detection and characterization easier. MR imaging used in conjunction with optimal jejunal distension appears as the modality of choice for the diagnosis of a wide range of jejunal abnormalities. However, MDCT remains the first line imaging modality because of availability issues, because of an acute presentation in a substantial number of patients and finally because jejunal diseases are often depicted incidentally.

**Disclosure of interest**

The authors declare that they have no conflicts of interest concerning this article.

**References**


