

Small Bowel Imaging

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Introduction

The mesenteric small intestine is a difficult organ to examine. Long-term experience has shown that there are no shortcuts to achieving a reliable examination, and several parameters need to be respected if a confident diagnosis is to be made. These include: selection of patients, closely supervised studies, background data, image quality, familiarity with imaging findings and utilization of radiologic-pathologic correlations.

Thoughtful *selection of patients* by clinicians is essential to make radiologic examination cost-effective. *Closed supervised studies*, incorporating an adequate index of clinical suspicion, co-operation between a focused radiologist and a keen physician, expertise, and time are important. *Familiarity with imaging findings* and *image quality*, are necessary to guarantee demonstration of fine surface mucosal detail and transitional morphological changes. Applying the principles of *radiologic-pathologic correlation* to the interpretation of radiological findings offers a certain advantage and in association with the *background data* available, including localization and distribution of changes, extent of involvement, the solitary or multiple nature of the lesions present and the clinical history, enable a confident differential diagnosis.

Based on its long-term follow-up results and its high negative predictive value, *enteroclysis* has been shown as a most reliable screening examination for the assessment of possible small bowel disease.

Enteroclysis combined with computed tomography (CT) offers the advantages of both techniques. Distention of small bowel lumen and cross-sectional display are proven imaging qualities gained with CT enteroclysis. Available prospective data suggest that the technique is advisable in patients with obstructive symptoms, in patients with known or suspected malignancy and when assessing complications of small bowel Crohn's disease.

Magnetic resonance enteroclysis (MRE), a combined functional and morphological imaging method, has only recently been performed routinely in clinical practice with adequate image quality and sufficient small bowel distention (Fig. 1). Thus far, results have shown that the

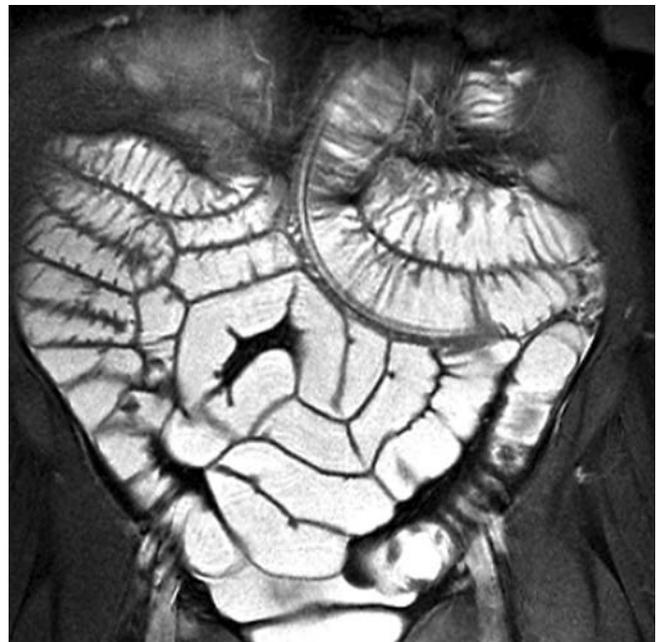


Fig. 1. Coronal true FISP section demonstrating small bowel at its entire length. The use of an iso-osmotic water solution as an intraluminal contrast agent resulted in homogeneous opacification of the bowel lumen. Note the increased conspicuity of the normal bowel wall due to the high resolution capabilities and total absence of motion

functional information provided by MRE equals that of enteroclysis alone, whereas the inherent advantages of an MR imaging approach over enteroclysis include detection of extra-luminal pathologic conditions, and detailed morphological evaluation of the bowel wall, as well as of the entire abdomen. Moreover, MRE has a distinct advantage over the currently available CT enteroclysis technique, due to its ability to provide real-time functional information.

Clinical entities that may require radiological investigation of the small intestine most frequently include Crohn's disease, small bowel neoplasms and Meckel's diverticulum.

Crohn's Disease

The most characteristic features of Crohn's disease of the small intestine are the variety of its radiological appearances and the multiplicity of radiological features often present in the majority of patients. Categorization of these radiological features has been defined in terms of stenotic and non-stenotic forms, active and chronic, early and late or advanced, or into superficial, transmural and extramural changes.

Most information on the sequence of progression of the pathological lesions in Crohn's disease is derived from radiological descriptions. The early lesions of Crohn's disease are: blunting, flattening, thickening, distortion and straightening of the valvulae conniventes. These changes are followed by discrete ulcers and by longitudinal and transverse ulcers. The stenotic phase eventually develops and the involved segment is transformed into a rigid, cast-like tube; fistulae may be seen at this stage. Deep ulcers precede sinuses and fistulae to other organs.

Discrete ulcers are seen as small collections of barium with surrounding radiolucent margins. Fissure ulcers are seen in profile and may penetrate deep into the thickened intestinal wall; small abscess cavities are occasionally seen at the base of deep fissure ulcers. Longitudinal ulcers running along the mesenteric border of the ileum are a characteristic feature of Crohn's disease, although they are only occasionally present. Cobblestoning is caused mostly by a combination of longitudinal and transverse ulceration. Discontinuous involvement of the intestinal wall shows either as skip lesions or asymmetry. Asymmetrical involvement of the intestinal wall produces the characteristic 'pseudodiverticulae' appearance. The pseudodiverticulae represent small patches of normal intestine in an otherwise severely involved segment. The involved segment contracts and the normal areas become pseudodiverticula. Inflammatory polyps (pseudopolyps) are occasionally seen in Crohn's disease and are seen as small discrete filling defects in a severely involved segment.

Cross-sectional imaging modalities offer an important complementary diagnostic perspective in patients with Crohn's disease, due to their ability to directly image the intestinal wall and surrounding mesentery and therefore to determine the extramucosal extent and spread of the disease process.

CT is being performed with increasing frequency and has been shown to be extremely valuable in documenting mesenteric disease, including fibrofatty proliferation, abscess or phlegmon formation, microadenopathy and in adequately evaluating perirectal and/or perianal extension of Crohn's disease. It has also been suggested that CT is the most sensitive means of demonstrating an enterovesical fistula. In addition, the ability of CT to simultaneously evaluate extraintestinal organs may allow the detection of concurrent hepatobiliary, urinary or musculoskeletal complications, that may well lead to significant changes in the management of the individual patient.

MRE is emerging as a valuable technique for the evaluation of small bowel in patients with Crohn's disease. Administration of 1.5-2 liters of iso-osmotic water solution through a nasojejunal catheter ensures bowel distention and facilitates identification of bowel wall abnormalities. True fast imaging steady-state free precession (FISP), half-acquisition Fourier-transformed single shot turbo spin echo (HASTE) and post-gadolinium T1-weighted 3D FLASH sequences can be employed in a comprehensive and integrated MRE examination protocol. The characteristic transmural lesions of Crohn's disease, such as bowel wall thickening, linear and fissure ulcers, and cobblestoning are accurately depicted by MRE, especially when using true FISP sequence (Fig. 2, 3). MRE is of equal value with conventional enteroclysis in assessing the number and extent of involved small bowel segments and in disclosing lumen narrowing and/or prestenotic dilatation. MRE has a clear advantage over conventional enteroclysis in demonstrating extramural manifestations and/or complications of Crohn's disease, including fibrofatty proliferation, mesenteric lymphadenopathy, sinus tracts and fistulae or abscesses. Disease activity may be accurately appreciated by contrast-enhanced 3D FLASH images, by gadolinium uptake in the wall of the involved seg-



Fig. 2. A 23-year-old female patient with active Crohn's disease (CDAI = 196). Coronal true FISP spot view demonstrates a distal ileum transmurally involved with a fissure ulcer (*arrow*). Increased mesenteric vascularity and fibrofatty proliferation is also noted

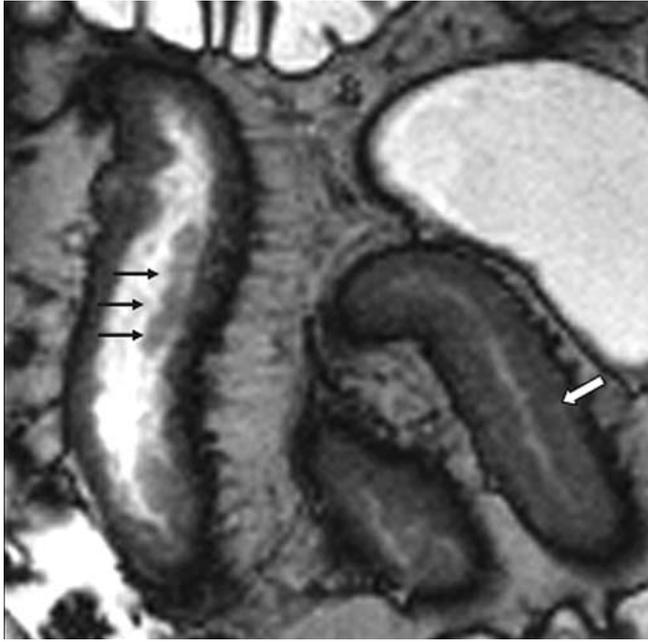


Fig. 3. Coronal true FISP spot view in a patient with Crohn's disease. Extensive wall thickening is demonstrated (*white arrow*) in an ileal loop, while cobblestoning is depicted as patchy areas of high signal intensity, sharply demarcated, along an adjacent affected segment (*arrows*)

ment (Fig. 4), while increased mesenteric vascularity is easily depicted on true FISP and 3D FLASH images. The clinical utility of MRE in Crohn's disease has not been widely established. At present, the method may be

suggested as a complementary diagnostic tool with advancing perspectives.

Neoplasms

Small intestinal neoplasms are surprisingly and universally rare. Documented rarity, further complicated by non-specific clinical presentation and a small index of clinical suspicion make their detection a challenge for both the physician and the radiologist. A mean symptoms-diagnosis interval up to three years for benign tumors and two years for malignant neoplasms has been reported. Inadequate radiologic examination or incorrect interpretation of radiological findings is estimated to account for an average of twelve months delay in diagnosing primary malignancies of the small intestine. Radiological appearances of these neoplasms, however, shown with enteroclysis and CT or MR imaging correlates almost perfectly with the morphological changes recognized in the gross pathology specimens. This ability to accurately image small intestinal neoplasms, independently of their size, anatomic localization and growth tendency, represents a major improvement in their diagnosis and management.

Adenocarcinoma

Adenocarcinoma appears to be the most common malignant neoplasm of the small intestine. It is a solitary lesion mostly located in the proximal small intestine. It is al-

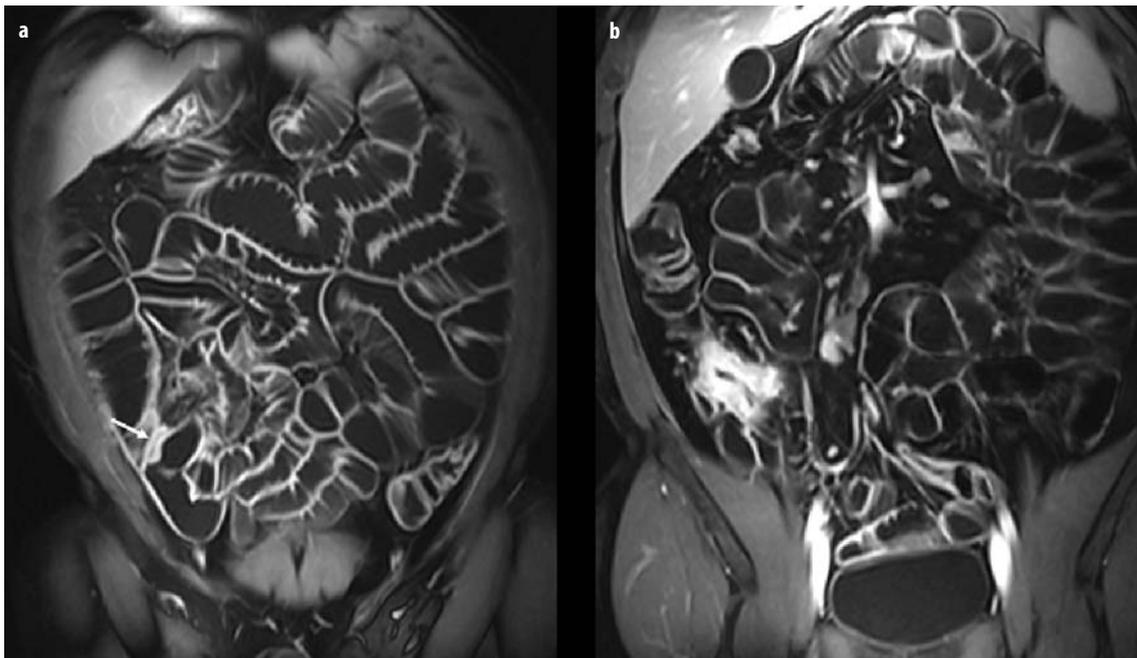


Fig. 4. Coronal FLASH image with fat saturation acquired 75 seconds after intravenous injection of gadolinium. Iso-osmotic water solution renders the lumen with low signal intensity, while normal intestinal wall presents with high signal intensity (*left*). In case of a hyperemic lesion (*right*), local increased gadolinium uptake generates this light bulb appearance

most always symptomatic, with non-specific clinical presentation and a dismal prognosis, mainly due to a late diagnosis. Its appearances on enteroclysis reflect its pattern of growth and include annular constricting lesions, filling defects, polypoid and/or ulcerated masses, or a combination of the above. Infiltrative adenocarcinomas are the most common type. Adenocarcinoma appears on CT as a solitary, focal, sharply outlined mass, causing thickening of the intestinal wall and narrowing of its lumen. The tumor may be homogeneous or heterogeneous when ulcerated and shows moderate contrast enhancement. Infiltration of the mesentery is seen with advanced disease, whereas associated lymphadenopathy is found in almost 50% of patients at presentation. Predominantly ulcerated adenocarcinomas may simulate lymphomas, malignant gastroduodenal stromal tumors (GISTs) or metastatic melanomas, whereas annular-type lesions will need to be differentiated from secondary adenocarcinoma, carcinoid, tuberculosis or Crohn's disease.

Lymphoma

Lymphoma represents 20% of primary small intestinal malignancies. Clinical presentation is variable, depending on whether involvement is primary or secondary, or whether it is preceded by other disorders, such as adult celiac disease, immunoproliferative disease or immunodeficiency syndromes. Radiological appearances mirror the pattern of growth. Enteroclysis can define a wide spectrum of features, including luminal narrowing with mucosal destruction, multiple intra-luminal polypoid filling defects, broad-based ulceration, aneurysmal dilatation, a large excavated mass and fistula formation. Infiltrative lymphomas may cause thickening of the intestinal wall without eliciting a desmoplastic reaction. A combination of different signs is rather frequent and multi-centricity of involvement is seen in almost one fourth of patients. CT appearances of intestinal lymphoma are also variable and may be categorized as aneurysmal, nodular, ulcerative and constrictive, while mesenteric involvement will usually feature as a conglomerate mass of mesenteric/retroperitoneal tissue, or a 'Sandwich-like' complex, due to encasement of vessels from enlarged mesenteric lymph nodes. Radiologic differential diagnosis include adenocarcinoma, Crohn's disease, and, less often, malignant GIST and metastatic melanoma.

Carcinoid

Carcinoid tumor is the most common neoplasm of the small intestine found at autopsy or incidentally during laparotomy. Almost 90% of lesions are located in the distal ileum, they may be multiple in approximately one third of cases, while coexistence with other primary malignancies is estimated to occur in another third of cases. The radio-

logical findings mirror the stage that the pathological process has reached at the time of examination. Primary ileal carcinoids usually feature as solitary, round, sharply-demarcated intramural filling defects. Luminal narrowing, usually asymmetrical, is present less often, whereas intestinal obstruction or intussusception is uncommon. Submucosal extension of the tumor will result in thickening of the valvulae conniventes and intestinal wall thickening. In the presence of extensive mesenteric fibrosis, diffuse luminal narrowing, fixation, angulation or kinking of intestinal loop(s) are also demonstrated. Carcinoid tumors are best recognized on CT on the basis of mesenteric findings. These include a discrete, uniform, soft tissue mass occasionally associated with linear soft tissue strands radiating into the surrounding mesentery in a stellate pattern, while displacing adjacent intestinal loops. Segmental intestinal wall thickening, ascites, hypervascular liver metastases, that are usually hypodense on precontrast scans, and occasionally dystrophic calcification in metastatic nodes or in liver metastases, may be also encountered.

Gastrointestinal Stromal Tumors (GISTs)

Histologically, GISTs are typically spindle cell tumors that have a prominent, nerve sheath tumor-like nuclear palisading pattern. Other GISTs may show prominent perinuclear vacuoles. GISTs may also have an epithelioid appearance, containing cells with round nuclei and abundant cytoplasm. It is now believed that GISTs are derived from the intestinal cells of Cajal. Recent application of immunohistochemical studies has revealed strong and uniform expression of the KIT (CD117, stem cell factor receptor) protein and CD34 in GISTs. This offers the possibility to accurately diagnose these tumors and separate them from other mesenchymal tumors of GI tract.

Benign GIST is the most common symptomatic benign neoplasm. Its type of growth is reflected in its radiological appearances. A broad-based, round or semi-lunar filling defect is usually seen with intraluminal tumors, while a mass effect on neighboring loops is seen with extraluminal benign GISTs. Dumb-bell type tumors combine features of both. Deformity of the intestinal wall, mucosal ulceration and signs of intussusception may also be seen. Despite their distinctive tendency to bleed, ulceration is rather infrequently demonstrated in intestinal benign GISTs, on enteroclysis. When seen, ulcerations are usually single, small, well-defined and round or linear in shape. Intussusception may be an additional feature of a benign GIST, easily depicted by either CT or enteroclysis. Besides enteroclysis, CT may contribute to the preoperative diagnosis of such neoplasms, by detecting unsuspected pathology and localizing it within the small bowel, or additionally characterizing pathology detected on barium studies. On CT, benign GISTs usually present as round, smoothly-outlined, homogeneous soft tissue masses, associated with the intestinal wall, while showing marked contrast enhancement. When large, such le-

sions may displace or deform adjacent small bowel loops.

Malignant GISTs grow slowly, predominantly extraluminally and eccentrically, and are prone to develop degenerative changes such as necrosis, hemorrhage, calcification, fistula or secondary infection. Determination of the malignant potential of GISTs is based on factors such as location, tumor size, degree of cellularity and pleomorphism, and presence or absence of necrosis. Small intestinal GISTs sized less than 5 cm are usually benign, regardless of their cellularity. However, GISTs greater than 10 cm in size and/or with mitotic counts greater than 5/50 high power field usually behave in a malignant fashion. Such tumors have a high risk for liver metastases and/or diffuse intra-abdominal spread. Bone and lung metastases are rare.

The radiologic appearances of malignant GISTs are fairly characteristic. On barium studies the main feature is frequently a large, extrinsic, non-obstructing mass displacing or distorting adjacent barium-filled loops of intestine. This may be associated with ulceration, cavitation or fistula formation. Less often, a GIST may appear as a large cavity filled with barium and it may be difficult to identify the connection between the small intestine and the cavity.

A CT scan may add considerably to the pre-operative evaluation of these tumors. CT can accurately demonstrate the size, shape and extent of the lesion, uniformity of densities and enhancing patterns, and it can depict the presence of liver, peritoneal or other metastases. CT is useful in the differentiation from other malignant tumors that often have a predominantly submucosal location and/or appear largely excavated, such as lymphoma or metastatic melanoma. The main differential diagnosis of malignant GISTs, however, includes their benign counterparts, benign smooth muscle or neurogenic tumors. CT criteria favoring malignancy include an irregular, lobulated, large-sized mass, heterogeneous tissue density, central liquefactive necrosis, seen as water density with or without air fluid level, ulceration or fistula formation. Liver metastases from malignant GISTs are large, necrotic or cystic in nature with peripheral or 'rim' enhancement, whereas peritoneal metastases may appear as widely distributed, multiple, round, smoothly-outlined, homogeneous satellite masses.

The signal intensity on MRI suggests that GISTs usually have no fibrotic component, and that the inner portion of these tumors does not usually contain blood products. Their signal intensity on MRI has been reported to be hyperintense compared to fat on T1-weighted image. They also show intense enhancement after gadolinium-chelate injection (Fig. 5).

GISTs are distinctive compared to other malignant small intestinal neoplasms as they have a greater tendency to grow extra-luminally, to develop large ulcers and therefore to bleed, and attain a large size without obstruction. They do not normally metastasize to the regional lymph node and they have a larger survival rate, even despite metastases.

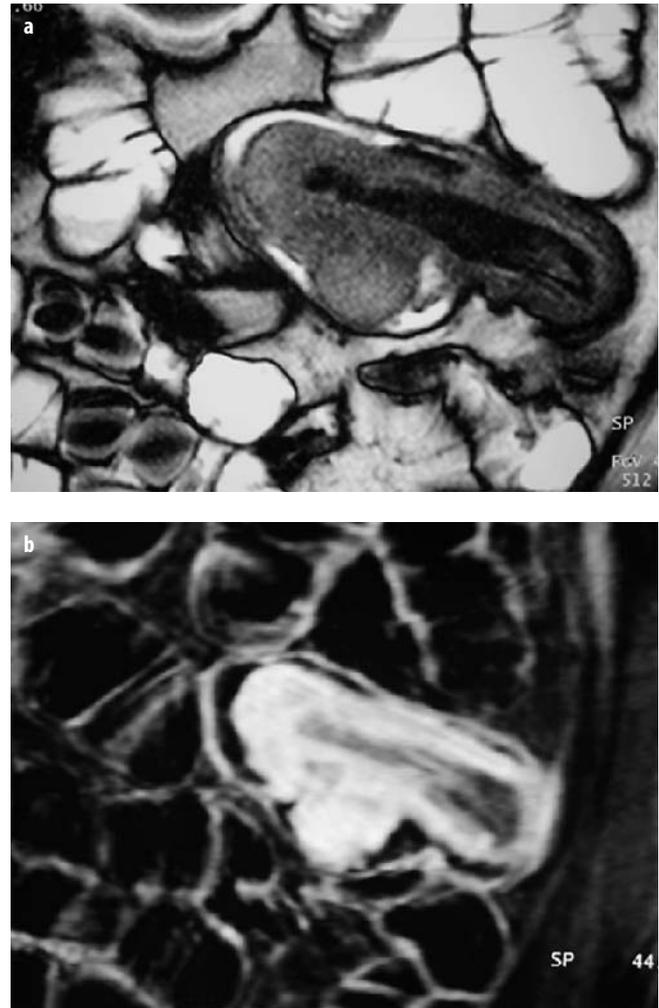


Fig. 5. MR enteroclysis showing jejunal intussusception due to a benign GIST tumor. A round well-circumscribed mass of intermediate signal intensity is shown in a coronal true FISP image (a). Post gadolinium coronal 3D FLASH image (b) demonstrates marked homogeneous enhancement of both the tumor mass and the viable intestinal wall

Meckel's Diverticulum

Meckel's diverticulum is the most common congenital anomaly of the small intestine, occurring in 1-3% of the population. It is mostly asymptomatic. One of the most common complications is lower gastrointestinal bleeding, which may be acute, life-threatening, chronic or intermittent, and is mostly due to ectopic gastric mucosa and peptic ulceration. Ectopic gastric mucosa is found in 15-20% of cases, in almost 90% of those who present with bleeding of the pediatric age group, but in only 7% of similar cases in adults.

Pre-operative radiological diagnosis of Meckel's diverticulum ranges from difficult to very difficult. Radionuclide imaging, the Meckel's scan, based on the affinity of the isotope technetium-99m pertechnetate for functioning ectopic gastric mucosa, has long been con-

sidered a most sensitive study. However, sensitivity varies with technique and age, and it is estimated to be around 60% for adults. False positive results do occur, at a disturbing frequency, in a number of conditions, whereas false negative results usually occur with symptomatic diverticula without ectopic gastric mucosa or acutely hemorrhaging diverticula.

Enteroclysis has been also suggested as a most reliable imaging technique for the pre-operative diagnosis of a Meckel's diverticulum. It usually shows a blindly ending sac of variable size, arising from the antimesenteric border of ileum. Additional characteristic findings include a gastric rugal pattern or a triangular fold pattern, at the base of the diverticulum. Careful fluoroscopy with compression is essential.

However, unsuccessful demonstration of a Meckel's diverticulum on enteroclysis despite a detailed examination is not unusual. The reasons for this include stenosis of the ostium, filling with intestinal contents, rapid emptying, or small size. CT has been reported to be of value in Meckel's diverticulitis and infracted Meckel's diverticulum.

Selective angiography is a well-established method for both non-hemorrhaging-negative scintigraphic, and for massively bleeding, diverticula. Extravasation of contrast into the bowel lumen is an expected angiographic finding in a patient with active bleeding. Very recently the importance of visualization and identification of the vitelline artery for the diagnosis of a Meckel's diverticulum itself, with or without active hemorrhage, has again been stressed.

Characteristic angiographic findings of selective or superselective catheterization will include: a) an abnormal

elongated vessel, originating from the ileal artery, without anastomotic branches to the ileal artery branches; and b) a group of dilated tortuous vessels at the distal portion of this artery, without branches.

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