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Chapter 5

Magnetic Resonance Imaging in patients clinically suspected of having appendicitis: a pictorial essay

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Submitted
Abstract

With an increasing availability of faster magnetic resonance imaging (MRI) hardware and software, the use of MRI in the evaluation of patients clinically suspected of appendicitis is a good alternative imaging technique, particularly when computed tomography is not desirable and ultrasonography is equivocal. There is a broad spectrum of differential diagnoses visible with MRI for patients clinically suspected of appendicitis.
Introduction

Magnetic resonance imaging (MRI) is rapidly emerging as a useful imaging modality for the evaluation of the gastrointestinal tract [1, 2]. The technology has a major advantage over computed tomography (CT) in that it does not use ionizing radiation. With present state-of-the-art MRI machines, sequences of the entire abdomen can be obtained in one breathhold, resulting in fewer artifacts due to breathing or peristalsis. Fast sequences last roughly 20 seconds and, normally, most patients can perform this without a problem. The T1, T2, and fat-suppressed images are the sequences used most often, and intravenous contrast is not necessary. A phased array coil is recommended for an improved signal-to-noise ratio.

Limitations of MRI include poorer spatial resolution compared to CT, increased sensitivity to motion-related artifacts, and limited compatibility with equipment used in intensive care and patient monitoring. Imaging with CT is many times faster than MRI, even when the latter is performed with fast gradient-echo sequences. Therefore, CT is more suitable for the diagnostic imaging of an acutely ill patient who may be unable to cooperate and lie still for the duration of MR image acquisition. Finally, most radiologists are more familiar with the appearance of acute abdominal and pelvic conditions on CT scans than MRI features, and their lack of familiarity with the latter is a hindrance to the use of MRI in an emergency setting. A frequently encountered problem with MRI is availability, especially after normal business hours. For this reason, we use a simple imaging protocol of T1, T2, and T2 fat-suppression breathhold sequences, which are easy to use and learn, quick, and, according to our experience, sufficient to detect or rule out appendicitis [3].

MRI interpretation of the appendix

The MRI criteria for a normal appendix is a diameter of 6 mm or less, or a diameter of more than 6 mm without evidence of peri-appendiceal inflammatory changes [4].
The normal appendix can be seen with MRI in up to 90% of nonpregnant patients [4, 5] and 80-90% of pregnant women [2, 6] (Fig. 1).

The MRI criteria for appendicitis are an enlarged appendix with a diameter of 7 mm or more and signs of peri-appendiceal inflammatory changes, such as fat stranding (Fig. 2), phlegmon, or a frank abscess (Fig. 3) [4]. The presence of peri-appendiceal inflammation, visualized as band-like areas of high signal intensity on T2 fat-suppressed images and low signal on T1-weighted images, supports this diagnosis. Peri-appendiceal inflammation is better appreciated with the use of fat saturation pulses, as high-signal-intensity fluid may be missed within the hyperintense fat on images acquired without fat saturation. The thickened wall of the inflamed appendix is readily visible on T2-weighted images due to the contrast provided by the high-signal-intensity fluid in the lumen and high signal intensity of the peri-appendiceal fat. An appendicolith can sometimes be visible with MRI as a focal area of low signal intensity in the appendiceal lumen with all sequences (Fig. 4).

Patients with more subacute perforation may present with an abscess cavity in
the right lower quadrant. Abscess cavities may be seen as a fluid collection with a well-defined wall (Fig. 3).

**Fig. 2 Acute appendicitis** in a 22-year-old male. The US was equivocal, but (a) CT showed retrocecal appendicitis (arrow) with peri-appendiceal changes. (b) Axial T1, (c) T2, and (d) T2fs, and (e) coronal T2 and (f) T2fs-weighted MR images show an enlarged appendix (arrow) with a thickened wall of relatively low signal intensity (c) and peri-appendiceal inflammatory changes with high signal on T2-weighted images and low signal on T1-weighted images. C = cecum, a = appendix.

An **appendiceal mucocele** is a rare entity that accounts for less than 1% of appendectomies [7]. Mucoceles from either benign or malignant mucinous neoplasms represent the majority of appendiceal tumors detected with imaging, and the clinical presentation and imaging findings can sometimes mimic acute appendicitis [8]. The mucinous contents within the mucocele have high signal intensity on T2-weighted images (Fig. 5). Although a fluid-filled appendix may be seen in both acute appendicitis and appendiceal mucoceles, the former is typically associated with wall thickening and peri-appendiceal inflammation. Enlargement of the appendix beyond 15 mm in diameter should be viewed with suspicion, and careful attention should be paid to other findings that may indicate the presence of a neoplasm [9].
**Fig. 3** Appendicular abscess in a 28-year-old patient. (a) US, (b) non-contrast CT, and (c) MRI with axial T1 and (d) T2fs images show appendicitis (white arrow) and peri-appendicular changes with an abscess (arrowheads). Using MRI the abscess appears filled with pus, which has a high signal on T2- and low signal on T1-weighted MR images.

**Fig. 4** Appendicolith with appendicitis in a 20-year-old patient. (a) US shows an enlarged appendix (arrowheads) and an appendicolith (arrow) in a patient suspected of appendicitis. (b) Transverse T1-, (c) coronal T2-, (d) and transverse T2fs-weighted images show an enlarged appendix with an appendicolith (arrow). The appendicolith has low signal intensity on both T1- and T2-weighted images. Peri-appendiceal areas of high signal intensity on T2-weighted images and low signal intensity on T1-weighted images represent periappendicitis. C = cecum.
Although isolated Crohn’s disease of the appendix is a rare entity reported in less than 0.2% of patients clinically suspected of appendicitis [10], it should be considered in the preoperative differential diagnosis of patients with right lower quadrant pain and a protracted preoperative course that mimics acute appendicitis. Disease recurrence elsewhere in the alimentary tract is uncommon. Imaging findings can show marked wall thickening, hypo-echoic upon ultrasonography (US) with signs of transmural inflammation. Mostly no appendicolith is seen (Fig. 6).

Differential diagnosis

Right-sided diverticulitis

In contrast to sigmoid diverticula, which are acquired and usually multiple, right-sided colonic diverticula are mostly congenital and solitary. Not surprisingly, in view of its congenital character, right-sided colonic diverticulitis can be detected at any age with a peak prevalence in patients aged 35-45 years [11, 12]. Due to the more
**Fig. 6 Crohn's appendicitis** in a 20-year-old woman. (a) Axial and (b) coronal US show an enlarged appendix of 16 mm (arrowheads) with a marked hypoechoic wall surrounded by hyperechoic mesenteric fat. There is no fluid or appendicolith seen in the appendix. (c) Axial T1-, (d) T2-, and (e) T2fs-weighted MR images show an enlarged appendix with markedly thickened walls of partially high signal intensity on the T2-weighted images. Histopathology revealed a granulomatous appendicitis compatible with Crohn's appendicitis. C=cecum.

**Fig. 7 Cecal diverticulitis** in a 28-year-old woman with clinically suspected appendicitis. (a) US shows a diverticulum (arrow) arising from the cecum (indicated by C), surrounded by hyperechoic non-compressible inflamed fat (arrowheads). (b) The corresponding CT image shows the inflamed diverticulum with surrounding fat stranding. (c) Axial T1- and (d) T2-weighted MR images at the corresponding level show an inflamed diverticulum surrounded by inflammatory changes in the mesenteric fat.
frequent use of US and CT and increasing awareness of the imaging features of right-sided diverticulitis, it is currently diagnosed more often and is reported in 3% of patients clinically suspected of having appendicitis [13]. The presenting symptoms are misleading and lead, in the majority of cases, to a presumed diagnosis of appendicitis, or an appendiceal mass when a palpable mass is present [12]. Right-sided diverticulitis has a benign natural history and surgical intervention can be avoided in the vast majority of patients [13]. Reliable diagnosis of right-sided diverticulitis is possible with US [13], CT [14], or MRI [15] (Fig. 7).

Fig. 8 Epiploic appendagitis in a 31-year-old woman with right lower quadrant pain suspected of having appendicitis. (a) US shows a hyperechoic ovoid fatty mass (arrowheads) with a hypoechoic rim, adjacent to the colon ascendens surrounded by hyperechoic noncompressible fat, painful on compression. (b) The coronal T2-, (c) T1-, and (d) axial T1-, (e) T2-, and (f) T2fs-weighted images show an area with inflammatory changes (arrowheads) adjacent to the colon ascendens. The central portion of this area is ovoid in shape and contains fat, surrounded by inflammatory reactive changes. C= cecum.
Epiploic appendagitis, omental infarction

Epiploic appendices are pedunculated adipose protrusions on the serosal surface of the colon. An epiploic appendix may incidentally undergo infarction followed by secondary inflammatory changes, a process that has been named epiploic appendagitis [16]. Segmental omental infarction has a pathophysiology similar to that of epiploic appendagitis, with the infarcted fatty tissue being part of the omentum [17]. Presenting symptoms are nonspecific and may lead to a presumed clinical diagnosis of appendicitis when located in the right lower quadrant [18]. Epiploic appendagitis or omental infarction are reported to be present in more than 1% of patients suspected of appendicitis [18-20], and epiploic appendagitis and omental infarction are self-limiting diseases. A reliable diagnosis of epiploic appendagitis can be made with US, CT, or MRI, mostly by detecting an inflamed fatty mass (Figs. 8-9) [21-23].

Fig. 9 Omental infarction in a 38-year-old man with clinically suspected appendicitis. (a) US shows an area directly under the abdominal wall with hyperechoic non-compressible fat (arrowheads) in the region of maximum tenderness. This region does not seem to be connected to the colon. (b) Axial CT confirms the inflammatory changes in the abdominal fat with fat-stranding. (c) Axial T2- and (d) T2fs-weighted images show the inflammatory changes against the abdominal wall (arrowheads), which appear somewhat triangular in shape. C = cecum.
Mesenteric adenitis

Mesenteric adenitis is believed to be of viral origin, although enlarged mesenteric nodes can be secondarily caused by other conditions, such as infections, Crohn’s disease, or neoplasms. In young patients especially, enlarged and painful lymph nodes located in the right lower abdomen can mimic appendicitis. In approximately 10-29% of negative laparotomies, enlarged mesenteric lymph nodes are found [24-30]. The explanation for this variation may be that the criteria for an enlarged lymph node is subjective; the surgeon decides perioperatively whether he finds a lymph node to be enlarged. This situation may lead to both an over- and underestimation of the incidence of mesenteric lymphadenitis. The enlarged mesenteric lymph nodes are clearly shown by MRI (Fig 10).

Meckel’s diverticulitis, ileal diverticulitis

Meckel’s diverticulum is the most common congenital abnormality of the gastrointestinal tract. The structure is a blind-ending pouch of variable size originating from the terminal ileum region and sometimes extending to the umbilicus. Meckel’s diverticulitis occurs in less than 2% of appendectomies [31] and, when incidentally found at appendectomy, a diverticulotomy should be performed [32]. The inflamed

Fig. 10 Mesenteric adenitis in a 8-year-old boy clinically suspected of appendicitis. (a) US shows multiple hypoechoic enlarged lymph nodes (arrowheads) in the right abdomen, and a normal appendix with some lymphoid hyperplasia was detected as well (not shown). (b) Axial and (c) coronal T2fs-weighted MR images show multiple enlarged lymph nodes (arrowheads) in the right abdomen with high signal intensity. Follow-up US studies showed spontaneous resolution of the enlarged lymph nodes.
Meckel’s diverticulum may be visualized with CT or US in most patients, appearing as a blind-ending pouch of variable size with surrounding mesenteric inflammation. The location of the diverticulum may vary from the right lower quadrant to the mid abdomen [33, 34]. Visualization of Meckel’s diverticulum and its complications with MRI is comparable to US and CT findings, an inflamed diverticulum arising from the terminal ileum (Fig. 11) [35].

![Fig. 11](image)

**Fig. 11 Meckel’s diverticulitis** in a 69-year-old man suspected of appendicitis. (a) US shows a diverticular-like structure (arrow) with surrounding hyperechoic fatty changes in the right lower abdomen. (b) CT in the coronal oblique reconstruction shows that the diverticulum arises from the terminal ileum. (c) Axial T1-, (d) T2-, and (e) coronal T2fs- and (f) T2-weighted MR images clearly show the inflamed diverticulum (arrow) with surrounding fat stranding (arrow-heads). I = ileum, C = cecum.

**Infectious ileocecalitis, Crohn’s disease**

Ileocecal Crohn’s disease or infectious ileocecalitis can mimic appendicitis-like symptoms, especially if abdominal pain is the major presenting symptom and diarrhea is mild or absent. Imaging may prevent both unnecessary therapeutic
delay and unnecessary surgery [36-38]. In infectious ileocecitis or ileocecal Crohn’s disease, imaging may show a thickened terminal ileum (Fig. 12). In Crohn’s disease with transmural signs of inflammation, fistula, or abscesses, enlarged lymph nodes and, sometimes, prestenotic small bowel dilatation may be seen [39]. The diagnosis of bacterial ileocecitis is confirmed by stool culture or serology.

![Fig. 12 Crohn’s disease](image)

**Fig. 12 Crohn’s disease** in a 19-year-old woman who presented clinically with acute appendicitis. (a) Axial CT shows a thickened terminal ileum without evident surrounding inflammatory changes. (b) Axial T2-, (c) T2fs-, and (d) coronal T2-weighted MR images show a thickened terminal ileum (arrowheads) with transmural inflammatory changes in the surrounding mesenteric fat. (e) Enteroclysis showed typical abnormalities of the ileocecal region compatible with ileocecal Crohn’s disease. C= cecum.

**Intussusception**

Intussusception is relatively rare in the adult population and differs substantially from pediatric intussusception. Most adult cases of intussusception identified at surgery are caused by a definable structural lesion, a substantial proportion of which are malignant, particularly in the colon. Patients with intussusception may or may not be symptomatic, and symptoms can be acute, intermittent, or chronic, making clinical
diagnosis difficult, and when located in the right lower abdomen, it can clinically mimic appendicitis. Computed tomography is widely regarded as the modality of choice for diagnosing intussusception in adults, but ultrasound and MRI have also been used effectively [40-42]. The appearance of a bowel-within-bowel configuration, with or without contained fat and mesenteric vessels, is pathognomonic (Fig. 13).

**Fig. 13 Intussusception** in a 14-year-old boy clinically suspected to have appendicitis. (a) US shows a donut-like lesion in the cecal region with the aspect of an intussusception. The arrowheads point at both the outer cecal walls. (b) Transverse T1-, (c) T2-, (d) T2fs-, and (e) coronal T2-weighted MR images clearly show the ileocecal intussusception as a mass within the cecal pole. (f) Barium enema confirms the intussusception. There was a good result after hydrostatic reposition. No underlying abnormality was found at follow-up.

### Sigmoid diverticulitis

Acute colonic diverticulitis of acquired diverticula typically occurs in patients older than 60 years of age. In some patients with acute colonic diverticulitis, the pain may be localized in the right lower quadrant due to acquired right-sided diverticula or a long sigmoid that makes a right-sided curve into the right lower quadrant. This condition
may be confused clinically with other conditions, usually acute appendicitis. An accurate diagnosis of acute colonic diverticulitis and its complications can be made with CT, US, or MRI [43-47]. Normally, multiple diverticula are encountered in the colon, with signs of peridiverticular inflammation at the spot of localized tenderness and pain where an inflamed diverticulum can be seen (Fig. 14).

**Fig. 14 Sigmoid diverticulitis** in a 71-year-old man with acute pain in the right lower abdomen, clinically suspected of being appendicitis. (a) US shows a thickened colonic wall (arrows) with surrounding inflammatory changes. No appendix is visible. (b) CT shows a thickened sigmoid wall (arrowheads), multiple diverticula, and surrounding inflammatory changes. (c) MRI T1-weighted axial image shows a thickened sigmoid (arrows) with multiple diverticula and surrounding inflammatory changes. (d) Barium enema shows the sigmoid making a curve to the right side, which explains the localized pain in the right lower abdomen and the clinical suspicion of acute appendicitis. Later, a sigmoid resection was performed and histopathology confirmed chronic sigmoid diverticulitis.

**Gynecological conditions**

In women of the fertile age group, the negative appendectomy rate is above average, (up to 50% in women) and has been accepted in the hope of preventing perforation [48]. Gynecological diseases may mimic appendicitis because of the proximity to the
female pelvic organs. Ultrasound plays an important role in the evaluation of patients with acute pelvic pain. Gynecological examination and transvaginal ultrasound are difficult or impossible in girls and young women who have not started their sexual life, and CT is not a method of choice in this age group because of the ionizing radiation. A reliable method to exclude or detect gynecological acute diseases seems to be MRI (Fig. 15) [49-53].

**Fig. 15 Hemorrhagic cyst** in a 26-year-old woman with right lower quadrant pain suspected of being appendicitis. (a) Axial T1-, (b) T2-, (c) T2fs-, and (d) coronal T2-weighted images show a cystic lesion (arrowheads) with a hematocrit effect in the dependent portion of the cyst. The sediment is of intermediate signal intensity on T1-weighted images and relatively low signal intensity on T2-weighted images, representing a subacute hemorrhage.

**Adnexal Torsion**

Adnexal torsion most commonly occurs in the first three decades of life. The disorder most frequently involves an ovary and the corresponding fallopian tube. Early diagnosis is critical for saving the ovary and US is the modality most commonly used. The features of CT and MRI for adnexal torsion include ovarian enlargement with stromal edema, thickening of the twisted fallopian tube, smooth thickening of the wall of the cystic ovarian mass, ascites, and uterine deviation to the side of torsion (Fig. 16) [50]. Less common findings include hemorrhage in the thickened tube, hemorrhage within the adnexal mass, and hemoperitoneum. An associated benign
ovarian cyst or benign neoplasm is seen in most cases.

**Fig. 16 Ovarian torsion in a 38-year-old woman with right lower quadrant pain.** (a) US, (b) axial T1-, and (c) coronal T1- and (d) T2fs-weighted MR images show an at least 7 cm large ovarian cyst (arrowheads) with some free fluid surrounding it (arrow). Ovarian torsion was confirmed at surgery.

**Pelvic Inflammatory Disease**

Pelvic inflammatory disease most commonly originates from infection that ascends from the fallopian tubes. The disease is seen in sexually active patients and manifests as nonspecific low abdominopelvic pain. Immediate antibiotic treatment is the therapy of choice. Ultrasonography only poorly depicts the changes characteristic of pelvic inflammatory disease, other than an abscess or hydrosalpinx. Compared with US, MRI provides superior depiction of adnexal edema [52, 53]; the T2-weighted fat-saturated images show parametrial signal hyperintensity due to edema. An adjacent fluid-filled tubular structure with internal debris, which represents an inflamed fallopian tube, can be seen. Hydrosalpinx, which may manifest with acute lower abdominal pain, is well depicted with MRI (Fig. 17).
Fig. 17 Tuboovarian abscess, pelvic inflammatory disease, and pyosalpinx in a 20-year-old female with acute pelvic pain, predominantly localized in the right lower abdomen, on clinical grounds that appendicitis could not be ruled out. (a) Axial T1-, (b) T2-, (c) T2fs-, and (d) coronal T2fs-weighted MR images show a multilocular cystic lesion with thickened walls (arrow). A hydrosalpinx is seen on both sides (arrowheads), and dependent debris in the cystic lesions and pyosalpinx is visible. There is marked edema in the surrounding fatty tissues.

Urological conditions

Urinary tract infections and stones account for 2-7% of all negative laparotomies in patients suspected of appendicitis [24-30]. Urine analysis and radiographs may give the correct diagnosis but may also be inconclusive. The detection of hydronephrosis, pyelonephritis, and renal calculi is possible with US, CT, or MRI (Figs. 18-20) [54, 55].

Rectus sheath hematoma

Rectus sheath hematoma can occur spontaneously or after a muscle strain or coughing, and a non-palpable hematoma, in particular, can mimic the clinical signs of appendicitis. In patients examined for suspected appendicitis, the abdominal wall should also be studied to exclude a nonpalpable rectus sheath hematoma. In cases in which a hematoma is found, an unnecessary appendectomy can be prevented [56]. The detection of rectus sheath hematoma is possible with US, CT, or MRI (Fig. 21) [56, 57].
**Fig. 18** Lobar nephritis in a 16-year-old girl with suspected appendicitis. (a) US shows a diminished corticomedullar differentiation (arrowheads) at the lower lobe of the right kidney, representing the area of maximum pain. Clinical confusion was caused by a somewhat ventrocaudal position of the right kidney. (b) Axial and (c) coronal T2fs-weighted MR images show a wedge shaped area of high signal intensity in the lower lobe of the right kidney with discrete swelling due to edema, representing the lobar nephritis.

**Fig. 19** Ureteral stone in a 28-year-old man with right lower quadrant pain. (a) The axial T1-weighted MR image shows an intraluminal low signal intensity defect in the right distal ureter. (b) Coronal T2fs-weighted MR image shows a somewhat dilated right ureter (arrow) with a distal low signal intensity filling defect (arrowhead). (c) The plain abdominal X-ray confirms a small stone in the right distal ureter (arrow).

**Fig. 20** Right-sided Hydronephrosis in a 25-year-old pregnant woman with right lower quadrant pain for several days, possibly appendicitis. (a) US shows hydronephrosis of the right kidney (p = pyelum) due to compression of the right ureter (arrow) by the gravid uterus against the iliac vessels at the level of the sacral promontory, (b) as shown in the T2fs-coronal MR image. (c) There is a dysplastic left kidney as shown on coronal T2fs MR image (arrowheads). After placement of a double-J catheter in the right ureter, symptoms quickly subsided.
**Fig. 21** Non-palpable rectus sheath hematoma in a 72-year-old man with right lower quadrant pain. The patient did not use anticoagulant therapy. (a) US shows a hypo-hyper-echoic mass in the musculus rectus abdomen (arrowheads). (b) T2- weighted axial and (c) coronal MR images show a thickened musculus rectus abdominis (arrowheads) on both sides, with lobulated areas of high signal intensity and low signal intensity, representing hemorrhage.

**Conclusion**

Although acute appendicitis is the most common disease of the appendix, the appendix can be involved in a wide range of diseases. Diseases other than acute appendicitis may produce signs and symptoms indistinguishable from those of acute appendicitis. The use of US, CT, and MRI can provide important information for the diagnosis and evaluation of patients clinically suspected of appendicitis. Radiologists need to understand the full spectrum of appendiceal abnormalities and mimickers of clinical appendicitis, their underlying pathologic changes, and associated imaging findings.
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