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Anatomical variants and pathologies of the vermex

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Abstract

The appendix may demonstrate a perplexing range of normal and abnormal appearances on imaging exams. Familiarity with the anatomy and anatomical variants of the appendix is helpful in identifying the appendix on ultrasound, computed tomography, and magnetic resonance imaging. Knowledge of the variety of pathologies afflicting the appendix and of the spectrum of imaging findings may be particularly useful to the emergency radiologist for accurate diagnosis and appropriate guidance regarding clinical and surgical management. In this pictorial essay, we review appendiceal embryology, anatomical variants such as Amyand hernias, and pathologies from appendicitis to carcinoid, mucinous, and nonmucinous epithelial neoplasms.

Keywords

Appendix; Appendicitis; Appendiceal neoplasm; Appendix embryology

Introduction

The appendix, or vermiform appendix, is a routinely evaluated structure during emergency imaging. Etymology derives from the Latin “vermiform” which translates to “worm-shaped,” its common morphological appearance. Its endocrine cells produce amines and hormones to assist with various biological control mechanisms, whereas the lymphoid tissue is involved with maturation of B lymphocytes and production of IgA antibodies [s–3 ml of mucus daily [2].

Emergency radiologists need to identify and evaluate the appendix. In suspected acute appendicitis, computed tomography (CT) is the modality of choice with greater than 90–95 % sensitivity and specificity. Ultrasound (US) is preferred for children and during pregnancy. Noncontrast magnetic resonance imaging (MRI) can be a second-line test during pregnancy [3].

Familiarity with the anatomy and anatomical variants is helpful in identifying the appendix. Knowledge of the variety of pathologies afflicting the appendix and their imaging characteristics is useful for accurate diagnosis and appropriate guidance regarding clinical and surgical management.

Histology

Appendiceal histology mimics the colon from epithelium to the lamina propria, to the muscularis mucosa, to the submucosa, to the muscularis externa, and finally, to the serosa. The epithelium is comprised of simple columnar cells with mixed enterocytes, goblet cells, and membranous cells. Discrete invaginations of the epithelium form crypts which contain enteroendocrine cells. Individual crypts are separated by the lamina propria, which contains more lymphoid nodules than the colon [1].

Embryology

Embryology of the appendix is helpful in appreciating normal anatomy from variants (Fig. 1). In utero, development is intimately related to that of the midgut. At 4 weeks, the midgut, supplied by the superior mesenteric artery, herniates into the umbilical cord. The foregut and hindgut do not herniate due to retention bands. At 5 weeks, the prearterial segment of the midgut returns into the abdomen as the gut rotates counterclockwise. The appendix is histologically visible by 8 weeks of gestation. By 12 weeks, the postarterial segment has reduced and the cecum is in the upper abdomen with a 270° gut rotation. The gut continues to stretch as parts of primitive mesentery fuse to fix the duodenum, ascending and descending colon to the posterior abdominal wall.

As the cecum forms, the appendix emerges as a bud off of the cecum. Elongation of the colon separates the cecum and the appendix. As the appendix is pushed ahead of the cecum, it adopts various positions, seemingly at random. No current literature has explained this process [2].

Anatomy

The appendix can have a variable length, ranging from 5 to 35 cm, average of 9 cm [2]. The origin is relatively constant, typically arising near the ileocecal valve (Fig. 2), from the posteromedial cecal border or from the cecal fundus [1]. From there, the appendix can have a variable course, retrocecal being most common [2]. Alternative routes include retroileal, preileal, pelvic, cross midline, and as far as into the hepatorenal recess (Fig. 3).

A rare course into an inguinal hernia, also known as an Amyand hernia (Fig. 4) has been described, typically right sided. Patients are frequently older men although pediatric cases are found in literature.

Congenital malformations are uncommon. Agenesis has been reported, although confusion with hypoplasia or intramural location may complicate actual incidence rates. Duplication and even more rarely triplication have been reported. Diverticula infrequently occur, with a potential for diverticulitis. A mucosal fold may partially cover the appendiceal orifice, known as Gerlach's valve [2]. An enlarging gravid uterus may elevate the cecum and the appendix out of the pelvis such that the right upper quadrant should also be reviewed for evaluation of appendicitis [4].

Vascularity and lymphatics

The appendix is supplied by the appendicular artery, a branch of the ileocolic artery (Fig. 5), and contained within the mesenteriolum (the mesentery of the appendix). There is additional vascular supply from branches of the anterior and posterior cecal arteries to the base of the appendix. Venous drainage is into the ileocolic and right colic veins. Lymphatic drainage is into the ileocolic lymph nodes adjacent to the superior mesenteric artery [2].

Normal imaging appearance

On CT, a normal appendix has thin walls and a less than 6-mm wall-to-wall diameter (Fig. 6). It may be filled with air or contrast material, whereas a fluid-filled appendix may indicate pathology. Periappendiceal fat stranding suggests inflammation. CT nonvisualization rates have been reported up to 14 % [5].

On ultrasound, the normal appendix appears as a compressible blind-ending tubular structure and may be filled with feces, fluid, or air. Normal diameter measures less than 6 mm from serosa to serosa (Fig. 7) [6]. In many cases, five layered alternating bands of echogenicity can be identified corresponding with the serosa, muscularis propria, submucosa, muscularis mucosa, and the epithelium.

On MRI, the normal appendix is visualized as a T1 and T2 hypointense structure that measures less than 6 mm in diameter (Fig. 8). Wall thickness is normally less than 2 mm. Abnormal surrounding fat signal or fluid within or around the appendix suggests pathology [4].

Pathology

Acute appendicitis

Appendicitis is the most common acute abdominal emergency in the USA [2] with 250,000 annual cases, a 7 % lifetime risk [5]. It commonly affects 10–20-year-old patients [2], males being more common [5]. Classic clinical symptoms include periumbilical pain migrating to the right lower quadrant, nausea, and anorexia [7].

Appendiceal lumen obstruction, often secondary to fecaliths, is the predominant factor in the pathogenesis of appendicitis. Other causes of acute appendicitis include obstructing seeds, worms, inspissated barium, and hypertrophy of lymphoid tissue. Acute appendicitis is typically treated with immediate appendectomy [2].

Traditionally, acute appendicitis was a clinical diagnosis; however, CT evaluation is now standard of care. Preoperatively, CT scans have increased from 18 % in 1996 to 93 % in 2006 with a false-positive rate up to 10 % and a false-negative rate as low as 0 % [7]. Thinner reconstruction sections have been shown to improve visualization and confidence in diagnosing appendicitis [8].

Alternatively, ultrasound and MRI can be used in children or in pregnant patients. A recent study reported a sensitivity of 74.2 % and a specificity of 97 % of ultrasound evaluation of acute appendicitis in adults [7]. MRI has a reported sensitivity of 100 % and specificity of 94 % in pregnant patients [4].

CT findings include greater than 6 mm in wall-to-wall diameter, wall enhancement or thickening, and periappendiceal inflammation (Fig. 9). Appendicoliths may be visualized. Periappendiceal fluid collections, phlegmon, abscess, extraluminal gas, adenopathy, or adjacent bowel wall thickening may also be seen [5].

US findings include a noncompressible appendix greater than 6 mm in diameter (Fig. 10). Mural thickness greater than 3 mm also suggests appendicitis. Tip appendicitis may occur where the base of the appendix may be normal; hence, thorough analysis is mandatory [6].

MRI findings include greater than 7 mm diameter, greater than 2 mm wall thickness, and T2-weighted fluid intensity intraluminal contents. T2-weighted hyperintense periappendiceal fat stranding and fluid may be present [4].

Amyand hernia (Fig. 11) with appendicitis occurs with four subtypes. Subtype 1 entails a normal appendix (0.28–1 % incidence) within an inguinal hernia, whereas subtypes 2–4 involve acute appendicitis within an inguinal hernia (0.07–0.13 % incidence). Type 2 involves acute appendicitis without inflammation. Type 3 involves acute appendicitis with abdominal wall or peritoneal inflammation. Type 4 involves appendicitis with related or unrelated abdominal pathology [9]. Appendicitis within a femoral hernia is known as a de Garengeot hernia. A spigelian hernia (through the linea semilunaris) with appendicitis has also been reported [10].

Carcinoid of the appendix

Carcinoid tumor is the most common primary appendiceal neoplasm, 60 % of all appendiceal tumors, although rare, with an incidence of 0.3–0.9 % in appendectomy specimens. They are often benign [11]. They commonly occur in young adults [12]. They frequently occur at the appendiceal tip where most endocrine cells reside. Often asymptomatic, associated acute appendicitis can occur [12].

Imaging findings of appendiceal carcinoids are relatively limited, due to the typically small size of tumors, primary location in the distal appendix, and low rate of complications. On CT, carcinoid tumor may be visualized as a focal soft tissue mass with enhancement, with or without calcifications. Rarely, a mucocele may be seen. Alternatively, an infiltrative pattern with diffuse mural thickening may be present [12]. Sonographically, carcinoids typically manifest as a hypoechoic round mass at the tip. On MRI, carcinoid tumors are visualized as a T1 isointense and T2 isointense-hyperintense mass with contrast enhancement. Appendicitis secondary to carcinoid tumor results from obstruction at the base of the appendix (Fig. 12); however, the carcinoid tumor itself may not be appreciated [12].

Treatment for carcinoid tumors less than 2 cm is appendectomy. For carcinoids larger than 2 cm, a right hemicolectomy is recommended due to increased risk of right colonic mesenteric lymph node metastases. Right hemicolectomy is also recommended for smaller carcinoid tumors with evidence of lymphatic or vascular spread or in close proximity to the cecum [11].

Goblet cell carcinoid tumors (GCCTs) are low-grade malignancies nearly exclusive to the appendix. They represent an intermediate entity between carcinoid tumor and adenocarcinoma [12]. Focal mucinous adenocarcinoma with malignant features can develop within GCCTs (Fig. 13). GCCTs tend to occur in older patients (typically sixth decade) and represent less than 15 % of all appendiceal neoplasms. Clinical presentation may include abdominal pain or acute appendicitis [13]. CT findings include infiltrative pattern with diffuse mural thickening. Metastatic disease to the peritoneum and ovaries may be present [12]. Acute appendicitis can occur secondary to diffuse infiltration, which causes a fibrous proliferation reaction and resultant obstruction of the appendiceal lumen [13].

Mucinous epithelial neoplasms

Epithelial neoplasms are less common than appendiceal carcinoids, but are more often detected on imaging due to larger size and higher complication rate. Mucinous epithelial neoplasms are the most common which include benign adenoma, cystadenoma, and neoplastic mucocele. Malignant mucinous epithelial neoplasms include mucinous cystadenocarcinoma [12].

Mucinous epithelial neoplasms, benign or malignant, tend to develop mucoceles, which only describe a mucin-filled appendix. Mucoceles have a variety of other neoplastic and nonneoplastic etiologies [12]. Incidence of mucoceles has been reported as 0.2–3 % in appendectomy specimens [14, 15]. Regardless of etiology, mucoceles are seen four times more often in women with mean age of 55 years [14]. Myxoglobulosis is a mucocele variant

characterized by multiple translucent globules filling the appendix with eventual calcifications [15].

Mucocele may be asymptomatic or present with right lower abdominal pain [14]. Complications include superinfection, intussusception, torsion, and right ureteral obstruction. Appendicitis secondary to mucinous neoplasms is less likely compared with most other appendiceal neoplasms [12]. Characteristic imaging finding of a mucocele is a cystic mass in the region of the appendix. Curvilinear or wall calcifications are highly suggestive of mucocele and can eventually lead to a “porcelain appendix” [15].

On CT, mucinous cystadenoma presents as a well-encapsulated, near water density mass in the right lower quadrant, with or without rim calcifications, and usually no surrounding inflammation. Sonographically, there is variable echogenicity with through-transmission. Acoustic shadowing from mural calcifications may be present. On MRI, mucinous cystadenomas are visualized as a fluid intensity nonenhancing mass (Fig. 14). Differential considerations include ovarian cyst, enteric duplication cyst, mesenteric cyst, Meckel’s diverticulum, hydrosalpinx, and abscess [12, 15]. A mucocele with an air-fluid level or intraluminal gas suggests superinfection. Mucocele wall thickening and irregularity with adjacent fat stranding may suggest inflammation or malignancy [12].

Mucinous cystadenomas can be treated with appendectomy. Mucinous cystadenocarcinomas, on the other hand, represent a malignant entity and require right hemicolectomy if resectable. Tumor extension of mucinous cystadenocarcinoma into the peritoneal cavity can lead to pseudomyxoma peritonei, the accumulation of gelatinous material throughout the peritoneum. On imaging, diffuse heterogeneous peritoneal locules with displacement of viscera and a scalloping effect on solid organs is visualized [12]. Pseudomyxoma peritonei associated with appendiceal cystadenocarcinoma portends a poor prognosis, with a reported 20 % 5-year survival rate [15].

Colonic-type epithelial neoplasms

Appendiceal nonmucinous epithelial neoplasms include adenomas and colonic-type adenocarcinomas. Colonic-type adenomas had a frequency of 2 %, while colonic-type adenocarcinomas had a frequency of 7 % among appendiceal neoplasms [12]. Colonic-type adenocarcinomas usually occur in older patients and often present with acute appendicitis secondary to malignant luminal obstruction [12].

Imaging findings are not well cited. On CT, a focal mass without mucocele formation may be present. Alternatively, CT findings may mimic appendicitis with a subtle infiltrating mass and more prominent periappendiceal inflammatory change (Fig. 15) [12]. Marked enlargement of the appendix (>1.5 cm) is suspicious. Differential considerations include carcinoid spectrum tumors and lymphoma.

Colonic-type epithelial neoplasms should be differentiated from colon cancer causing appendicitis. Although primary neoplasms of the appendix often cause appendicitis, colon cancer obstructing the appendix with resultant appendicitis is rare. Cecal adenocarcinoma represents less than 1 % of all appendicitis cases. Approximately 10 % of colorectal cancer

presents in the cecum [16]. Imaging may demonstrate a cecal mass clearly invading the appendix or obstructing the appendiceal orifice with resultant appendicitis (Fig. 16).

Miscellaneous neoplasms of the appendix

Nonepithelial neoplasms of the appendix are rare. Lymphoma can involve the appendix and present with appendicitis. Ganglioneuromas and paragangliomas can involve the appendix, with an association between diffuse ganglioneuromatosis and neurofibromatosis type 1. Gastrointestinal stromal tumors are the most common mesenchymal tumor of the appendix. Smooth muscle tumors such as leiomyomas and less commonly leiomyosarcomas have been reported to arise from the appendix. In patients with acquired immunodeficiency syndrome, Kaposi sarcoma of the appendix can occur [12].

Miscellaneous nonneoplastic pathologies of the appendix

Other less common nonneoplastic appendiceal pathologies occur. For example, foreign bodies in the appendix have been reported in children. Parasites such as *Enterobius vermicularis* (pin worms) can be found within the lumen of the appendix, with a reported incidence of pinworms in resected appendices in the pediatric population of 0.6–13 %. Isolated intussusception into the cecum or as part of ileocolic intussusceptions can occur. In 0.2 % of ileocolic intussusception cases, the appendix acts as a pathologic leadpoint. Isolated torsion of the appendix can similarly occur incidentally or secondary to underlying pathology [17].

The appendix can be secondarily involved by colonic pathology. In cystic fibrosis, chronic distention of the appendix can result from abnormally thickened stool. Crohn's disease and ulcerative colitis can involve the appendix, rarely in isolation. Total colonic Hirschsprung disease can result in neonatal acute appendicitis. Adjacent inflammation from neutropenic colitis and tubo-ovarian abscess can result in inflammatory change of the appendix [17].

Conclusion

The appendix may demonstrate a perplexing range of normal and abnormal appearances. Reviewing the expected location and course of the appendix as well as anatomical variants may facilitate detection on emergency imaging. Broad knowledge of common and rare pathologies that afflict the vermiform appendix can aid in formulating thoughtful differentials and guiding clinical management.

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Fig. 1.

Embryology of the appendix. At 4 weeks, the midgut herniates into the umbilical cord. At 5 weeks, the prearterial segment of the midgut returns into the abdomen first as the gut rotates counterclockwise. By 12 weeks, the postarterial segment has already reduced and the cecum lies in the upper abdomen with a 270° gut rotation. The gut continues to elongate with fusion of parts of primitive mesentery to fix the duodenum, ascending and descending colon to the posterior abdominal wall. As the cecum forms at the distal segment of the umbilical loop, the appendix appears as a bud off the cecum (drawing by David Rini, MFA, Art as Applied to Medicine, Cellular and Molecular Medicine, Johns Hopkins School of Medicine 2012)

Fig. 2.
Origin of the appendix as visualized on CT near the ileocecal valve (*arrow*)

Fig. 3.
Unusual course of the appendix (*arrows*) in the upper abdomen into the hepatorenal fossa on
a CT and **b** abdominal ultrasound

Fig. 4. Amyand hernia, subtype 1. Axial (**a**) and coronal (**b**) IV and PO contrast-enhanced CT demonstrates a normal appearing appendix coursing into a right inguinal hernia (*arrow*)

Fig. 5.
Vascular supply to the appendix via the appendicular artery (*arrows*), demonstrated on 3D-reconstructed sagittal oblique contrast-enhanced CT

Fig. 6. Normal appearance of the appendix on CT. The normal appendix (*arrow*) is filled with air or contrast and has thin walls and a <6-mm wall-to-wall diameter

Fig. 7.

Normal ultrasound appearance of the appendix (*arrows*). A blind-ending tubular structure with five layered alternating bands of echogenicity that can be sonographically identified corresponding with the serosa, muscularis propria, submucosa, muscularis mucosa, and the epithelium (not shown). Normal diameter of the appendix measures less than 6 mm from serosa to serosa

Fig. 8. Normal MRI appearance of the appendix, visualized as a T2 hypointense tubular structure, that measures less than 6 mm in diameter with wall thickness less than 2 mm, and surrounded by fat with normal homogeneous signal (*arrow*)

Fig. 9.

A 20-year-old woman with right lower quadrant pain. **a** Axial IV and PO contrast-enhanced CT demonstrates a dilated appendix (*arrow*) filled with fluid and coursing to the right adnexa, consistent with appendicitis. **b** Endovaginal transverse image of the right adnexa demonstrates a tubular, approximate 1-cm, blind-ending pouch with multilayered hypoechoic and hyperechoic bands and increased through-transmission due to fluid consistent with appendicitis (*arrow*). **c** Doppler ultrasound demonstrates hyperemia within the appendix wall (*arrow*)

Fig. 10. Acute appendicitis on ultrasound. Sagittal (**a**) and transverse (**b** without compression and **c** with compression) transabdominal sonographic images demonstrating an approximate 1-cm noncompressible appendix (*arrow*). Note alternating bands of echogenicity. No periappendiceal abscess is present

Fig. 11.

Acute appendicitis in an Amyand hernia. **a** Axial IV and PO contrast CTscan demonstrates a dilated tubular mass in the right inguinal canal with adjacent fat stranding compatible with acute appendicitis (*arrow*). **b** Sagittal IV and PO contrast-enhanced CT demonstrates acute appendicitis (*arrows*) within an Amyand hernia with an associated large scrotal fluid collection (*asterisk*)

Fig. 12.

A 48-year-old man with right lower quadrant pain. **a** Coronal IV and PO contrast-enhanced CT demonstrates thickening of the appendix and periappendiceal inflammation (*arrows*). **b** Axial IV and PO contrast-enhanced CT demonstrates a discrete soft tissue nodule within the fluid-filled lumen (*arrow*), suspicious for neoplasm. Pathology reveals a carcinoid tumor

Fig. 13.

Primary appendiceal neoplasm of the carcinoid spectrum. **a** Axial IV and PO contrast-enhanced CT demonstrates a hypodense mass arising from the appendix and extending into the right adnexa (*arrows*). Sagittal **(b)** endovaginal ultrasound performed 8 months later for right adnexal pain demonstrates a 1.2-cm blind-ending heterogeneous tubular structure in the right adnexa (*arrows*). MRI **(c)** demonstrates a T1 hypointense, T2 hyperintense, heterogeneously enhancing mass extending to right adnexa (*arrows*). Pathology was compatible with mixed goblet cell carcinoid-carcinoma of the appendix

Fig. 14.

A 53-year-old female with right lower quadrant pain. **a** Right lower quadrant transabdominal ultrasound demonstrates an enlarged appendix (*arrows*). Axial (**b**) and coronal (**c**) IV contrast-enhanced CT scan demonstrates a tubular cystic mass in the right lower quadrant (*arrow*). Axial images from pelvic MRI demonstrate a T2 hyperintense (**d**), nonenhancing on T1 fat sat image (**e**) cystic mass in the right lower quadrant (*arrow*). Pathology was compatible with a mucinous cystadenoma

Fig. 15.

A 73-year-old female with right lower quadrant pain. Axial (**a**) and coronal (**b**) IV and PO contrast-enhanced CT demonstrated dilated fluid-filled appendix with extensive appendiceal inflammation (*asterisk*). There is an abrupt transition between the fluid in the lumen and soft tissue density at the base (*arrow*), suspicious for an obstructing mass. Pathology was compatible with colonic-type adenocarcinoma of the appendix

Fig. 16.

A 73-year-old male presenting for follow-up after periappendiceal abscess drainage. Coronal (**a**, **b**) and axial (**c**) IV and PO contrast-enhanced CT scan demonstrates circumferential thickening of the cecum (*arrow*), extending into the appendix (**b**). Diffuse periappendiceal inflammation is also present (*asterisk*). Findings are compatible with cecal adenocarcinoma invading the appendix with resultant appendiceal perforation