Chapter 30: The Appendix

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KEY POINTS

Key Points

1. Inflammation of the appendix is a significant public health problem with a lifetime incidence of 8.6% in men and 6.7% in women, with the highest incidence in the second and third decade of life.[6] While the rate of appendectomy in developed countries has decreased over the last several decades, it remains one of the most frequent emergent abdominal operations.

2. The natural history of appendicitis is unclear, but it appears that progression to perforation is not predictable and that spontaneous resolution is common, suggesting that nonperforated and perforated appendicitis may, in fact, be different diseases.

3. C-reactive protein, bilirubin, Il-6, and procalcitonin have all been suggested to be helpful in the diagnosis of appendicitis, specifically in predicting perforated appendicitis.

4. Perforated appendicitis can be managed either operatively or nonoperatively. Immediate surgery is necessary in patients that appear septic, but this is usually associated with higher complications, including abscesses and enterocutaneous fistulae, due to dense adhesions and inflammation.

5. Single incision appendectomy has not been shown to improve outcomes, including cosmetic outcomes, in prospective randomized studies and has been suggested to have a higher incisional hernia rate.

6. While there is no evidence clearly evaluating long-term outcomes of patients undergoing incidental appendectomy with an asymptomatic appendix, the risk of adhesions and future complications after an appendectomy has been suggested to be higher than the risk of future appendicitis and increased economic costs. An incidental appendectomy is currently not advocated.

7. Older adult patients are at a higher risk for complications due to their premorbid conditions, and it is prudent to obtain definitive diagnostic imaging prior to taking patients to the operating room.

8. Patients with uncomplicated appendicitis do not require further antibiotics after an appendectomy, while patients with perforated appendicitis are treated with 3 to 7 days of antibiotics.

9. The most common mode of presentation for appendiceal carcinoma is that of acute appendicitis. Patients also may present with ascites or a palpable mass, or the neoplasm may be discovered during an operative procedure for an unrelated cause.

HISTORY

Although anatomists such as Vesalius and Leonardo Da Vinci had written about the appendix, Claudius Amyand in the early 18th century was the first surgeon to describe a successful appendectomy.[1] In subsequent centuries, significant progress was made in the diagnosis and management of appendicitis, especially after Chester McBurney advocated for early appendectomy in his 1889 publication.[2] Famously, the magician Harry Houdini died of a ruptured appendix after suffering a blow to his abdomen. Following the introduction and widespread use of antibiotics in the 1940s, mortality rates improved further. In 1982, Kurt Semm, a gynecologist, reported on the first laparoscopic appendectomy, which is now the most widely adopted

technique.

EMBRYOLOGY, ANATOMY, AND HISTOLOGY

Previously considered a vestigial organ, the appendix is now linked to the development and preservation of gut-associated lymphoid tissue (GALT) and to the maintenance of intestinal flora. It has been suggested that appendectomy is associated with increased *Clostridium difficile* infections and increased subsequent cancer (colon, esophageal) as a result of microbial alteration, although this is currently unproven.[3] The protective effect of an early appendectomy against development of ulcerative colitis has been proposed to be mechanistically linked to the release of dimeric forms of IgA from plasma B cells and the Th2 response mediated by IL-13–producing natural killer T cells.[4]

The appendix, along with the ileum and the colon, develops from the midgut and first appears at 8 weeks of gestation. As the gut rotates medially, the cecum becomes fixed in the right lower quadrant, thus determining the final position of the appendix. The appendix is a true diverticulum of the cecum as it contains all the histological layers of the colon, although certain differences in the irregularity of crypts remain. The average appendix measures 6 to 9 cm and derives its blood supply from the appendicular branch of the ileocolic artery. Visceral innervation occurs along the superior mesenteric plexus (T10-L1) and the vagus nerves. The appendix is intraperitoneal and retrocecal in location, but it can be pelvic (30%) and retroperitoneal (7%).[5] Grossly, the appendiceal base can be identified by tracing the convergence of the cecal taeneia.

ACUTE APPENDICITIS

Inflammation of the appendix is a significant public health 1▶ problem with a lifetime incidence of 8.6% in men and 6.7% in women, with the highest incidence occurring in the second and third decade of life.[6] While the rate of appendectomy in developed countries has decreased over the last several decades, it remains one of the most frequent emergent abdominal operations.[7]

The etiology of appendicitis is perhaps due to luminal obstruction that occurs as a result of lymphoid hyperplasia in pediatric populations; in adults, it may be due to fecaliths, fibrosis, foreign bodies (food, parasites, calculi), or neoplasia.[5,8–10] Early obstruction leads to bacterial overgrowth of aerobic organisms in the early period, and subsequently, it leads to mixed flora. Obstruction generally leads to increased intraluminal pressure and referred visceral pain to the periumbilical region.[10] It is postulated that this leads to impaired venous drainage, mucosal ischemia leading to bacterial translocation, and subsequent gangrene and intraperitoneal infection. *Escherichia coli* and *Bacteroides fragilis* are the most common aerobic and anaerobic bacteria isolated in perforated appendicitis.[11,12] This sequence is not inevitable, however, and some episodes of acute appendicitis may resolve spontaneously. Due to 2▶ differences in epidemiology, nonperforated and perforated appendicitis are considered different diseases.[13] Additionally, since not all nonperforated appendicitis progresses to perforations, it is suggested that the pathogenesis of the two conditions may be different.

CLINICAL DIAGNOSIS

History

It is important to elicit an accurate history from the patient and/or family, in the case of pediatric patients. Inflammation of the visceral peritoneum usually progresses to the parietal peritoneum, presenting with migratory pain, which is a classic sign of appendicitis (likelihood ratio+, 2.06 [1.63–2.60]).[14] Inflammation can often result in anorexia, nausea, vomiting, and fever (Table 30-1). Regional inflammation can also present with an ileus, diarrhea, small bowel obstruction, and hematuria. Pertinent negative history (including menstrual) must be obtained to rule out other etiologies of abdominal pain.

Table 30-1

Signs and symptoms of appendicitis

	TRUE POSITIVE LIKELIHOOD RATIO	95% CONFIDENCE INTERVAL	TRUE NEGATIVE LIKELIHOOD RATIO	95% CONFIDENCE INTERVAL
Duration of symptoms (hours)	1.01	0.97–1.05	0.94	0.62–1.42
>9	0.96	0.90–1.04	1.19	0.87–1.63
>12	0.65	0.47–0.90	1.47	1.14–1.90
>24	0.49	0.36–0.67	1.20	1.08–1.34
>48				
Fever	1.64	0.89–3.01	0.61	0.49–0.77
Gastrointestinal dysfunction	1.27	1.14–1.41	0.59	0.45–0.77
Anorexia	1.15	1.04–1.36	0.72	0.57–0.91
Nausea	1.63	1.45–1.84	0.75	0.69–0.80
Vomiting				
Pain				
Pain migration	2.06	1.63–2.60	0.52	0.40–0.69
Pain progression	1.39	1.29–1.50	0.46	0.27–0.77
Direct tenderness	1.29	1.06–1.57	0.25	0.12–0.53
Indirect tenderness	2.47	1.38–4.43	0.71	0.65–0.77
Psoas sign	2.31	1.36–3.91	0.85	0.76–0.95
Rebound	1.99	1.61–2.45	0.39	0.32–0.48
Percussion tenderness	2.86	1.95–4.21	0.49	0.37–0.63
Guarding	2.48	1.60–3.84	0.57	0.48–0.68
Rigidity	2.96	2.43–3.59	0.86	0.72–1.02
Temperature (degrees centigrade)	1.57	0.90–2.76	0.65	0.31–1.36
>37.7	1.87	0.66–5.32	0.89	0.71–1.12
>38.5				
White blood cells (10^9/L)				
≥10	4.20	2.11–8.35	0.20	0.10–0.41
≥15	7.20	4.31–12.00	0.66	0.56–0.78
C-reactive protein (mg/L)				
>10	1.97	1.58–2.45	0.32	0.20–0.51
>20	2.39	1.67–3.41	0.47	0.28–0.81

Conclusions: Individually, disease history, clinical findings, and laboratory tests are weak. But when combined, they yield high discriminatory power.

Data from Andersson RE: Meta-analysis of the clinical and laboratory diagnosis of appendicitis, *Br J Surg.* 2004 Jan;91(1):28-37.

Physical Examination

Most patients lay quite still due to parietal peritonitis. Patients are generally warm to the touch (with a low-grade fever, ~38.0°C [100.4°F]) and demonstrate focal tenderness with guarding. McBurney's point, which is found one-third of the distance between the anterior superior iliac spine and the umbilicus, is often the point of maximal tenderness in a patient with an anatomically normal appendix. Certain physical signs with their respective eponyms can be helpful in discerning the location of the appendix: *Rovsing's sign*, pain in the right lower quadrant after release of gentle pressure on left lower quadrant (normal position); *Dunphy's sign*, pain with coughing (retrocecal appendix); *obturator sign,* pain with internal rotation of the hip (pelvic appendix); *iliopsoas sign,* pain with flexion of the hip (retrocecal appendix). In addition, pain with rectal or cervical examinations is also suggestive of pelvic appendicitis.

Laboratory Findings

Patients with appendicitis usually have leukocytosis of 10,000 cells/mm^3, with a higher leukocytosis associated with gangrenous and perforated appendicitis (~17,000 cells/mm^3). C-reactive 3▶ protein, bilirubin, Il-6, and procalcitonin have all been suggested to help in the diagnosis of appendicitis, specifically in predicting perforated appendicitis.[14,15] The authors believe that a white blood cell (WBC) count and a C-reactive protein are two appropriate lab tests to obtain in the initial work up of appendicitis; a pregnancy test is also essential in women of childbearing age. Lastly, a urinalysis can be valuable in ruling out nephrolithiasis or pyelonephritis.

Imaging

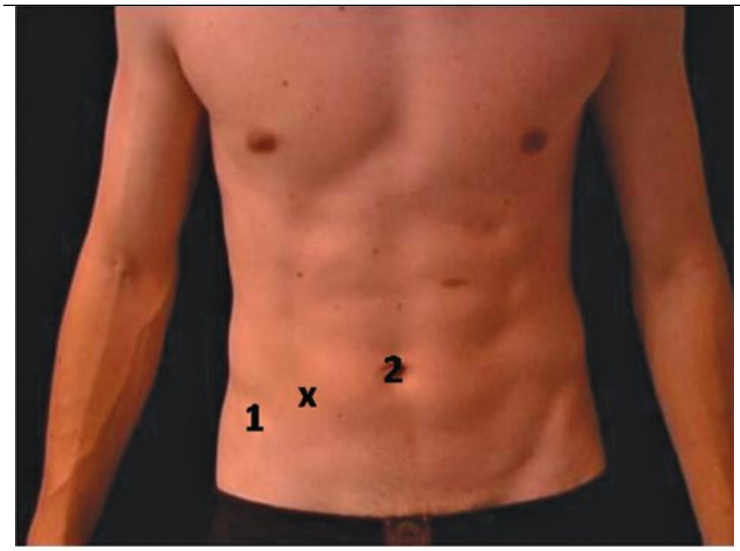
Imaging is often utilized to confirm a diagnosis of appendicitis because a negative operation rate is acceptable in <10% of male patients and <20% of female patients. Routine use of cross-sectional imaging somewhat reduces the rate of negative laparotomies. Imaging studies are most appropriate for patients in whom a diagnosis of appendicitis is unclear or who are at high risk from operative intervention and general anesthesia, such as pregnant patients or patients with multiple comorbidities. Commonly utilized imaging modalities include computerized tomography (CT), ultrasound (US), and magnetic resonance imaging (MRI).

CT Scan

A contrast-enhanced CT scan has a sensitivity of 0.96 (95% confidence interval [CI] 0.95–0.97) and specificity of 0.96 (95% CI 0.93–0.97) in diagnosing acute appendicitis.[16,17] Features on a CT scan that suggest appendicitis include enlarged lumen and double wall thickness (greater than 6 mm), wall thickening (greater than 2 mm), periappendiceal fat stranding, appendiceal wall thickening, and/or an appendicolith (Fig. 30-1). While there remains a concern of ionizing radiation exposure with a CT scan, typical low-dose CT scans result in exposure of 2 to 4 mSv, which is not significantly higher than background radiation (3.1 mSv).[18] Recent trials have also suggested that although low-dose CT scans of 2 mSv do not generate high-resolution images, using these lower resolution images does not affect clinical outcomes.[19] Intravenous contrast is generally preferred in these studies, but it can be avoided in patients with allergies or low estimated glomerular filtration rate (less than 30 mL/minute for 1.73 m^2). Several meta-analyses have suggested that CT scan is more sensitive and specific than ultrasound in diagnosing appendicitis.

Figure 30-1.

McBurney's point. 1 = anterior superior iliac spine; 2 = umbilicus; x = McBurney's point.



Source: F.C. Brunicardi, D.K. Andersen, T.R. Billiar, D.L. Dunn, L.S. Kao, J.G. Hunter, J.B. Matthews, R.E. Pollock: Schwartz's Principles of Surgery, 11e

Ultrasound

Ultrasonography has a sensitivity of 0.85 (95% CI 0.79–0.90) and a specificity of 0.90 (95% CI 0.83–0.95).[20] Graded compression ultrasonography is used to identify the anteroposterior diameter of the appendix. An easily compressible appendix <5 mm in diameter generally rules out appendicitis. Features on an ultrasound that suggest appendicitis include a diameter of greater than 6 mm, pain with compression, presence of an appendicolith, increased echogenicity of the fat, and periappendiceal fluid.[21] Ultrasound is cheaper and more readily available than CT scan, and it does not expose patients to ionizing radiation, but it is user-dependent and has limited utility in obese patients. In addition, graded compression is usually painful for patients with peritonitis. A comparison of the efficacy of ultrasound v. CT scan is found in Table 30-2.

Table 30-2

Meta-analyses comparing CT scan and US outcomes

		AUTHOR					SUMMARY
		TERASAWA	WESTON	DORIA	AL-KHAYAL	VAN RANDEN	
Year		2004	2005	2006	2007	2008	
No. of studies		22	21	57	25	6	
No. of patients	CT US Total	1172 1516 2688	NR NR 5039	NR NR 13697	NR NR 13046	NR NR 671	
Sensitivity	CT US	94% (CI: 91%–95%) 86% (CI: 83%–88%)	97% (CI: 95%–98%) 87% (CI: 85%–89%)	94% (CI: 92%–97%) 88% (CI: 86%–90%)	93% (CI: 92%–95%) 84% (CI: 82%–85%)	91% (CI: 84%–95%) 78% (CI: 67%–86%)	CT more sensitive than US in five of five meta-analyses
Specificity	CT US	95% (CI: 93%–96%) 81% (CI: 78%–84%)	95% (CI: 93%–96%) 93% (CI: 92%–94%)	94% (CI: 94%–96%) 93% (CI: 90%–96%)	93 (CI: 92%–94%) 96 (CI: 95%–96%)	90% (CI: 85%–94%) 83% (CI: 76%–88%)	CT more specific than US in four of five meta-analyses
Positive predictive value	CT US	NR NR	94% (CI: 92%–95%) 89% (CI: 87%–90%)	NR NR	90% (CI: 89%–92%) 90% (CI: 89%–91%)	NR NR	CT has superior positive predictive value in one of two meta-analyses
Negative predictive value	CT US	NR NR	97% (CI: 96%–98%) 92% (CI:91%–93%)	NR NR	96% (CI: 95%–97%) 93% (CI: 92%–94%)	NR NR	CT has superior negative predictive value in both meta-analyses
Accuracy	CT US	NR NR	NR NR	NR NR	94% (CI: 93%–94%) 92% (CI: 92%–96%)	NR NR	CT is more accurate in the one study reporting results

CI = confidence interval; CT = computed tomography; NR = not reported; US = ultrasonography.

MRI

MRI of the abdomen has a sensitivity of 0.95 (95% CI 0.88–0.98) and specificity of 0.92 (95% CI 0.87–0.95) for identification of acute appendicitis.[22] MRI is an expensive test that requires significant expertise to perform and interpret and is usually recommended in patients for whom the risk of ionizing

radiation outweighs the relative ease of obtaining a contrast CT scan, i.e., pregnant or pediatric patients.

Differential Diagnosis

Causes of acute abdominal pain that are often confused with acute appendicitis include acute mesenteric adenitis, cecal diverticulitis, Meckel's diverticulitis, acute ileitis, Crohn's disease, acute pelvic inflammatory disease, torsion of ovarian cyst or graafian follicle, and acute gastroenteritis. Frequently, no organic pathology is identified. Obtaining an antecedent history of a viral infection (mesenteric adenitis or gastroenteritis) and a cervical exam in women (exquisite tenderness with motion in pelvic inflammatory disease) are essential before planning any intervention. Detailed menstrual history can distinguish *mittelschmerz* (no fever or leukocytosis, mid-menstrual cycle pain) and ectopic pregnancies.

MANAGEMENT OF APPENDICITIS

Uncomplicated Appendicitis

The preferred approach to manage patients with uncomplicated appendicitis is an appendectomy. Several recent randomized trials and cohort studies have examined the role of nonoperative management of adult patients with appendicitis.[23,24,25] In each of these well-designed studies with noninferiority as the endpoint, patients were randomized to either receiving antibiotics or undergoing an appendectomy, which was frequently performed open. A majority of the patients in the nonoperative arm received intravenous antibiotics for a short course followed by a course of a fluoroquinolone and metronidazole, or oral amoxicillin/clavulanic acid.[23,26,27] Meta-analysis of the published data found that 26.5% of patients in the nonoperative group required an appendectomy within 1 year. In addition, the rate of adverse events following antibiotics therapy was higher (relative risk [RR] 3.18, 95% CI 1.63–6.21, $P = 0.0007$), and patients who recurred presented more frequently with complicated appendicitis (RR 2.52, 95% CI 1.17–5.43, $P = 0.02$).[28,29] Currently, conservative management can be offered to informed patients using techniques of shared decision-making, but it is not the standard modality of management of appendicitis, except in patients with significant phobia of surgery.[30] Societal costs and long-term implications of the conservative strategy have not yet been completely evaluated.

Timing of Surgery

Emergent surgery is often performed in patients with appendicitis, but studies have evaluated the performance of urgent surgery (waiting less than 12 hours) in a semi-elective setting after administering antibiotics upon admission. The studies did not reveal any significant difference in outcomes, except for a slightly longer hospital stay in those undergoing urgent surgery.[31–33] Currently, delaying surgery less than 12 hours is acceptable in patients with short duration of symptoms (less than 48 hours) and in nonperforated, nongangrenous appendicitis.

Approach of Surgery

Numerous meta-analyses comparing laparoscopic to open appendectomy have demonstrated relative equivalence of the techniques, with laparoscopic appendectomy resulting in a shorter length of stay (LOS), faster return to work, and lower superficial wound infection rates, especially in obese patients.[34,35] Open appendectomy results in shorter operative times and lower intra-abdominal infection rates.[36] Costs of the two techniques are relatively similar because of the offset of costs in laparoscopic techniques by shorter LOS. In the United States, laparoscopic appendectomies are increasingly utilized.[37]

Complicated Appendicitis

Perforated and gangrenous appendicitis and appendicitis with abscess or phlegmon formation are considered complicated conditions. Patients with perforated appendicitis usually present after 24 hours of onset, although 20% of patients present within 24 hours. Such patients are often acutely ill and dehydrated and require resuscitation. Usually, the perforated abscess is walled off in the right lower quadrant, although retroperitoneal abscesses including psoas abscess, liver abscesses, fistulas, and pylephlebitis (portal vein inflammation) can also occur when left untreated.

Perforated appendicitis can be managed either operatively 4 or nonoperatively. Immediate surgery is necessary in patients that appear septic, but this is usually associated with higher complications, including abscesses and enterocutaneous fistulae due to dense adhesions and inflammation.

The management of long-duration, complicated appendicitis is often staged.[38,39] Patients are resuscitated and treated with IV antibiotics.[40,41] Patients with longstanding perforation are better treated with adequate percutaneous image-guided drainage.[42] This strategy is successful in 79% of patients who achieve complete resolution, which occurs more often in lower-grade abscesses, transgluteal drainage, and with CT- (vs. ultrasound-) guided drainage[43] Operative intervention is performed in patients who fail conservative management and in patients with free intraperitoneal perforation.

Interval Appendectomy

The majority of patients with perforated appendicitis (80%) have resolution of their symptoms with drainage and antibiotics. There remains debate about the value of performing an interval appendectomy 6 to 8 weeks after the original inflammatory episode.[44–46] Proponents of this approach cite the incidence of recurrent appendicitis (7.4%–8.8%) and the presence of appendiceal neoplasms detected on the appendectomy (relevant benign lesions 0.7%, malignant lesions 1.3%).[47] Opponents cite the high incidence of no future events after a median follow-up of 34 months in 91% of patients. Currently, shared decision-making is necessary before proceeding with an interval appendectomy.[39]

OPERATIVE INTERVENTION

Preoperative Preparation

Once the decision to proceed with surgical intervention is made, patients can be taken to the operating room rather expeditiously. While resuscitative efforts are important in patients who present with significant dehydration or in a compromised host, the majority of patients can be taken to the operating room within a short interval. Placement of a Foley catheter is optional but not necessary while performing an appendectomy. Preoperative antibiotics must be administered at least 30 to 60 minutes prior to skin incision. The choice of antibiotics include cefoxitin, ampicillin/sulbactam, and cefazolin plus metronidazole for uncomplicated appendicitis. Patients with ß-lactam allergies can be given clindamycin in combination with a fluoroquinolone, gentamicin, or aztreonam. Postoperative antibiotics are usually not necessary.

In patients with perforated appendicitis undergoing operative intervention, preoperative antibiotics are necessary to cover gram-negative bacteria and anaerobes. Monotherapy with piperacillin/tazobactam or combination of cephalosporin with metronidazole are reasonable choices. The duration of postoperative antibiotics is generally less than 4 days once complete source control has been achieved (STOP-IT trial).[48] Patients with incomplete drainage, persistent catheters, complications from surgery, and uncertain resolution of inflammation might need a longer duration of antibiotics.[49]

Operative Technique

Open Appendectomy

An open appendectomy is usually performed under general anesthesia, although regional anesthesia can be used. After wide prep and drape, an incision is usually made on McBurney's point either in an oblique fashion (McBurney's incision) or transverse incision (Rocky-Davis incision). A lower midline laparotomy incision is more appropriate for perforated appendicitis with a phlegmon. A muscle-splitting approach can be utilized to access the peritoneum in patients that are well paralyzed. The bed is positioned in Trendelenburg's with the left side down. The appendix is usually readily identified, but if necessary, it can be found by tracing the anterior taenia (taenia Liberia) of the cecum distally. We generally ligate the mesentery early to allow better exposure. If the base of the appendix is viable, ligating the appendix is acceptable. This can be imbricated with a Z-stitch or purse string configuration, or alternatively the mucosa can be fulgurated. In the event of retraction of the appendiceal artery or unexpected bleeding, the incision can be extended medially (Fowler extension). Skin closure is usually performed in a layered fashion, but in cases with significant abscess or contamination, closure by secondary intention or delayed primary closure has been considered. Recent trials have suggested no difference in surgical site infection rates between primary and delayed primary closure.[50] Placement of surgical drains has not been proven to be beneficial in multiple clinical trials for either complicated or uncomplicated appendicitis.[51,52]

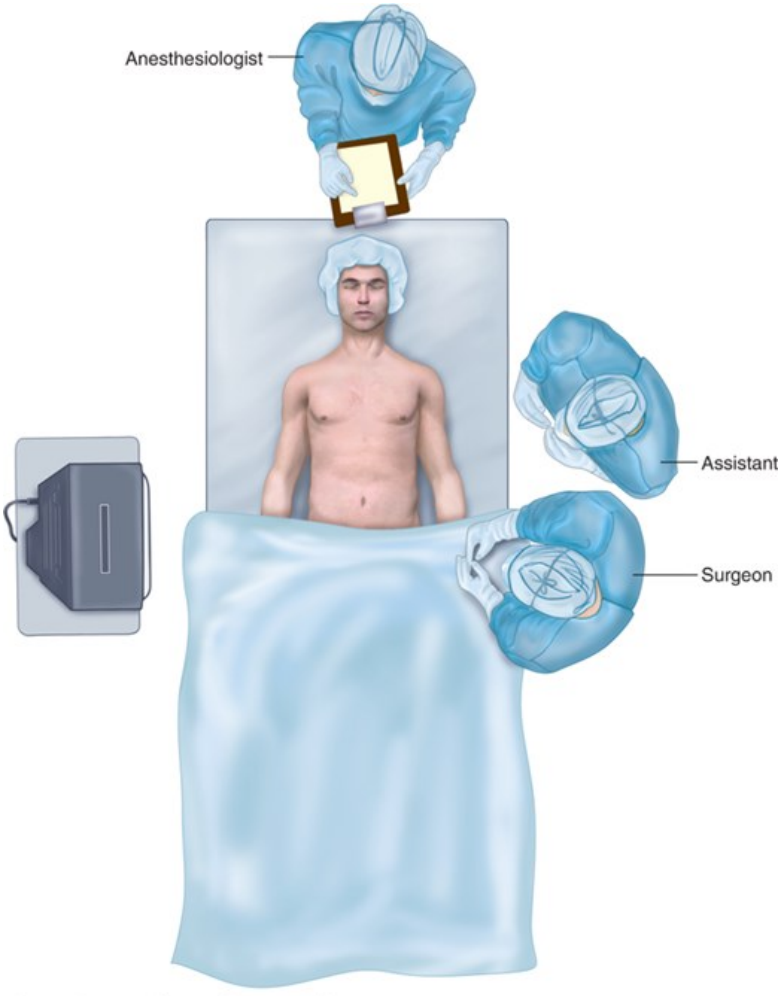
Laparoscopic Appendectomy

Patients undergoing laparoscopic appendectomy are positioned supine with the left arm tucked for better access. Monitors and assistants are positioned appropriately. Access to the peritoneum can be obtained using either the Hasson technique in a periumbilical fashion or with a Verees or

optical trocar in the left upper quadrant 3 cm below the costal margin in the midclavicular line. Five-mm ports are usually placed in the suprapubic and left lower quadrant areas. It is also technically feasible to place the third port in the right upper quadrant. The bed is positioned in Trendelenburg, with the left side down to sweep the bowel away. The appendix is grasped and elevated upwards to identify the window between the mesoappendix and the cecum (Fig. 30-2). Occasionally, it is essential to release the mesenteric attachments of the cecum to mobilize a retrocecal or pelvic appendix to obtain this view. Using a Maryland grasper, the window is created, and the mesoappendix is divided with cautery, clip, or a bipolar energy source. The base of the appendix is divided either with an endoscopic stapler or after placing an endoloop. In the case of a nonviable appendix base, a staple line through the cecum that avoids the ileocecal valve might be sufficient, unless significant inflammation is present. The appendix is retrieved through the midline port in a specimen bag, especially if an appendiceal lesion is suspected. If a periappendiceal phlegmon is encountered or if the operation is being performed for perforated appendicitis, careful sweeping of the bowel with a blunt dissector can release the appendix. It is important to carefully separate adjacent bowel, which can be friable in such settings. Conversion to open surgery should be considered for failure to progress. Typically, once the base of the appendix is identified, it is generally more helpful to divide the stump first. An endoscopic stapler or endoloop can be used for the base, provided the base is viable. Occasionally, an ileocecectomy is necessary when resection of the base of the appendix or cecum is likely to impinge on the ileocecal valve. The mesoappendix is similarly divided with either a stapler with thin leg length staples, a clip, cautery, or energy device.

Figure 30-2.

Operating room setup.



Novel Techniques

Three novel techniques have been investigated in the performance of an appendectomy: single incision appendectomy, natural orifice transluminal endoscopic surgery (NOTES), and robotic appendectomy. Single incision appendectomy has not been shown to 5▶ improve outcomes, including cosmetic outcomes, in prospective randomized studies and has been suggested to have a higher incisional hernia rate.[53] NOTES surgery has been shown to have better cosmetic outcome and less postoperative pain in a meta-analysis of NOTES procedures including appendectomies, although only 40 patients were included in the analysis.[54] The risk of luminal contamination and closure of enteral or vaginal mucosa remain suboptimal; for this reason, there has not been widespread dissemination of this technique.[55] Robotic appendectomy allows flexible motions of intraperitoneal instruments and is therefore superior in ergonomics for the surgeon.[56] However, it is extremely expensive and requires larger ports based on most of the current platforms; thus, this technique is also not utilized widely.

Negative Exploration

Upon performing a laparoscopy or laparotomy for suspected appendicitis, if one finds no evidence of appendicitis, a thorough exploration of the peritoneum must be performed to rule out contributing pathology. A normal appendix is often removed to reduce future diagnostic dilemma.[57] Management of incidentally found common conditions is summarized in Table 30-3.

Table 30-3

Management of Intraoperative Findings Mimicking Appendicitis

Ovarian Torsion	Conservative management with detorsion and oophoropexy
Crohn's terminal ileitis	Appendectomy if base uninflamed
Meckel's diverticulitis	Segmental small bowel resection and primary anastomosis
Appendiceal Mass	Laparoscopic appendectomy/ileocecectomy without capsular disruption or spillage and retrieval in a bag

Incidental Appendectomy

The practice of prophylactic appendectomy has been considered during other operations to prevent the future risk of appendicitis.[6,58] It is routinely performed in children undergoing chemotherapy, compromised hosts with an unclear physical exam, patients with Crohn's disease with a normal cecum, patients traveling to remote places with no urgent care, and in patients undergoing cytoreductive operations for ovarian malignancies.[59] While there is no evidence clearly evaluating long-term 6▶ outcomes of patients undergoing incidental appendectomy with an asymptomatic appendix, the risk of adhesions and future complications after an appendectomy has been suggested to be higher than the risk of future appendicitis and increased economic costs. For these reasons, an incidental appendectomy is currently not advocated.

SPECIAL CIRCUMSTANCES

Appendicitis in Children

Almost 1 in 8 children undergo a workup for the diagnosis of appendicitis.[60,61] Of these, infants and young children are most likely to present with perforated disease (51%–100%), while school-age children have lower rates of perforation.[62,63,64] While most age groups demonstrate the same symptoms previously described in adults, neonates can also present with abdominal distension and lethargy or irritability. The Pediatric Appendicitis Score has components similar to the Alvarado Score and is scored of 10 points, with maximum weight (2 points each) for right lower quadrant tenderness and pain with cough, percussion or hopping. A score of 7 or greater indicates that the patient has a high chance of having appendicitis (78%–96% percent).[65]

In the pediatric population, special considerations must be made to exclude relevant differential diagnoses such as intussusception (currant jelly

stools, abdominal mass), gastroenteritis (often no luekocytosis), malrotation (pain out of proportion), pregnancy (ectopic), mesenteric adenitis, torsion of the omentum, and ovarian or testicular torsion.

With regard to the management of children with appendicitis, early appendicitis is treated preferably with a laparoscopic appendectomy, which has better outcomes than open appendectomies in children.[66,67] For patients with complicated appendicitis, urgent appendectomy is advocated in the setting of no abscess or mass. Laparoscopic appendectomy appears to retain its benefits in this setting as well.[68,69] In the setting of a perforation, antibiotics are continued after surgery for at least 3 days, and preferably 5 days (APSA guidelines).[70,71] Management of perforated appendicitis with abscess is similar to adults, although no adverse effects of an early laparoscopic appendectomy have been seen even in this setting.[39,72,73,74]

Nonoperative management of appendicitis has also been studied in children.[75–77] It may be safe for children with early presentation (less than 48 hours), limited inflammation (WBC less than 18,000/cu.ml), appendicoliths, and no evidence of rupture on imaging.[78] Patients are usually administered IV antibiotics until inflammation reduces and then transitioned to oral antibiotics.[79] This is usually effective in reducing inflammation (88%–92%), but has a recurrence rate of 22% at 1 year and increased resource utilization.[80]

Appendicitis in Older Adults

Older adult patients can have diminished inflammation and thus 7▶ present with perforation or abscess more frequently.[81,82] Such patients are at a higher risk for complications because of their premorbid conditions, and it is more prudent to obtain definitive diagnostic imaging prior to taking patients to the operating room. Laparoscopic appendectomy is safe and might allow patients to reduce pain and their hospital stay.[83]

Appendicitis in Pregnancy

Appendicitis occurs in 1 in 800 to 1 in 1000 pregnancies, mostly in the first and second trimesters. Its incidence is rare in the antepartum state, and it can occur in the postpartum state in geriatric pregnancies (maternal age greater than 35 years).[84] While the majority of the clinical features are similar, patients can also present with heartburn, bowel irregularity, flatulence, or a change in bowel habits. The point of maximum tenderness is usually displaced on physical exam. Ultrasonography is the preferred imaging modality, although nonvisualization can occur. Sensitivity can vary from 67% to 100%, and specificity varies from 93% to 96%.[39] An alternative imaging modality is MRI, with a sensitivity of 94% and specificity of 97%.[85] While CT can be performed in pregnancy, the risk of fetal irradiation leads many practitioners to avoid it unless other modalities are inconclusive.[86] When discussing options with the patient and the patient's family, it is important to note that the risk of fetal loss is up to 36% if appendiceal perforation occurs.[87] Therefore, there remains a lower threshold to operate on such patients, with an acceptable negative exploration rate of as high as 30%. Laparoscopic appendectomies can be safely performed in pregnant patients, although studies suggest a variable but reproducible higher rate of fetal loss (around 7% vs. 3%) than open techniques. Lower intra-abdominal pressures (10–12 mmHg) during insufflation have been suggested to reduce early labor. Nonoperative management has also been proposed for pregnant patients, but treatment failure rates have been reported as high as 25%.

Chronic or Recurrent Appendicitis

Patients with recurrent right lower quadrant abdominal pain not associated with a febrile illness with imaging findings suggestive of an appendicolith or dilated appendix are classified as having chronic appendicitis.[88] Patients often report resolution of symptoms with an appendectomy. In the absence of imaging abnormalities, prophylactic appendectomy is not encouraged.[45]

OUTCOMES AND POSTOPERATIVE COURSE

Appendectomy is a relatively safe procedure with an extremely low mortality rate (less than 1%). The commonest adverse 8▶ events include soft tissue infections, either superficial or deep (including abscesses). Patients with uncomplicated appendicitis do not require further antibiotics after an appendectomy, while patients with perforated appendicitis are treated with 3 to 7 days of antibiotics (4 days from the STOP-IT trial).[89] Patients with wound infections can be managed with simple wound opening and packing, and delayed primary closure has not been shown to be beneficial.[90] In laparoscopic cases, these are usually the periumbilical ports.[91] Patients with deep space abscesses are managed with percutaneous drainage and antibiotics. Fistulas (appendicocutaneous or appendicovesicular) are managed conservatively as the first step. Bowel obstructions and infertility are

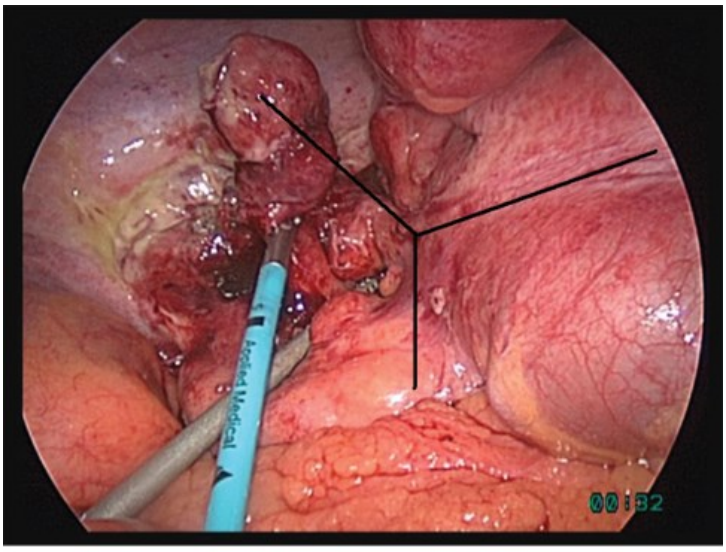
infrequent but reported.

Stump Appendicitis

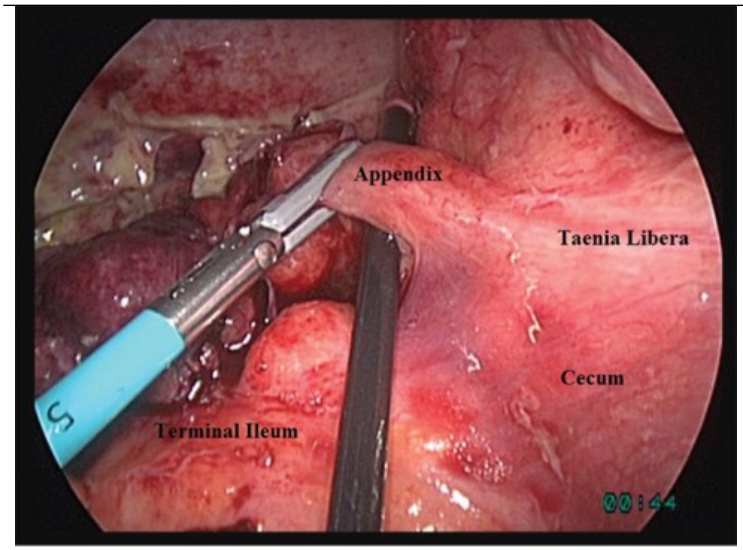
An uncommon complication after surgery is the development of appendicitis in an incompletely excised appendiceal stump (greater than 0.5 cm stump length). Optimal management requires reexcision of the appendiceal base, but diagnosis can be difficult and requires careful assessment of the patient's history, physical exam, and imaging studies.[92] Use of the "appendiceal critical view" (appendix placed at 10 o'clock, taenia coli/libera at 3 o'clock, and terminal ileum at 6 o'clock) and identification of where the taeniae coli merge and disappear is paramount to identifying and ligating the base of the appendix during the initial operation (Fig. 30-3). In patients who have had prior appendectomy, a low index of suspicion is important to prevent delay in diagnosis and complications. Prior appendectomy should not be an absolute criterion in ruling out acute appendicitis.

Figure 30-3.

A and **B.** Appendiceal critical view.



A



B

Source: F.C. Brunicardi, D.K. Andersen, T.R. Billiar, D.L. Dunn, L.S. Kao, J.G. Hunter, J.B. Matthews, R.E. Pollock: Schwartz's Principles of Surgery, 11e

Appendiceal Neoplasms

The incidence of appendiceal neoplasms is estimated at around 1% of all appendectomy specimens, although the true incidence of appendiceal neoplasms is not known.[93] Neoplasms that occur in the appendix are predominantly gastroenteropancreatic neuroendocrine tumors (or GEP-NETs, previously called carcinoids), mucinous neoplasms, or adenocarcinomas.[94–96] Almost one-third of the neoplasms of the appendix present with acute appendicitis, while the others are often incidentally detected or are detected after regional spread of disease.[97]

Gastroenteropancreatic Neuroendocrine Tumors (GEP-NETs or Carcinoid)

Appendiceal carcinoid tumors are submucosal rubbery masses that are detected incidentally on the appendix.[98] Carcinoid tumors of the appendix are relatively indolent but can develop nodal or hepatic metastases.[99] Infrequently, these can be associated with a carcinoid syndrome if there are hepatic metastases (2.9%).[100] Upon incidental findings of a suspected carcinoid, the surgeon must evaluate the nodal basin along the ileocolic pedicle and also examine the liver for any signs of metastases. For lesions that are less than 1 cm (95% of all lesions), a negative margin appendectomy is adequate. For tumors 2 cm or larger, a right hemicolectomy is recommended. For lesions 1 to 2 cm in size, there is no consensus on a completion colectomy. A right colectomy is often performed for mesenteric invasion, enlarged nodes, or positive or unclear margins. Measurement of serum chromogranin A is recommended.

Goblet Cell Carcinomas

These lesions were mistakenly called goblet cell carcinoids, implying a rather indolent biology, while goblet cell carcinomas are adenocarcinoid with both adenocarcinoma and neuroendocrine features.[101,102] Such lesions carry a worse prognosis than carcinoids but slightly better than adenocarcinomas. There is a high risk of peritoneal recurrence in such cases. For incidentally detected lesions, a systematic surveillance of the peritoneum must be performed, and a peritoneal cancer index score must be documented if disease is present.[103] In the absence of metastatic disease, a right hemicolectomy is generally appropriate, although some advocate for a right colectomy only for tumors 2 cm or larger.[104]

Lymphomas

Appendiceal lymphomas are rare (1%–3% of lymphomas, usually non-Hodgkin's) and difficult to diagnose preoperatively (appendiceal diameter can be 2.5 cm or larger).[105,106] Management includes an appendectomy in most cases.

Adenocarcinoma

Primary adenocarcinoma of the appendix is a rare neoplasm with three major histologic subtypes: mucinous adenocarcinoma, colonic adenocarcinoma, and adenocarcinoid. The most common mode of presentation for appendiceal carcinoma is acute appendicitis. Patients also may present with ascites or a palpable mass, or the neoplasm may be discovered during an operative procedure for an unrelated cause. The recommended treatment for all patients with adenocarcinoma of the appendix is a formal right hemicolectomy. Appendiceal adenocarcinomas have a propensity for early perforation, although they are not clearly associated with a worsened prognosis. Overall 5-year survival is 55% and varies with stage and grade. Patients with appendiceal adenocarcinoma are at significant risk for both synchronous and metachronous neoplasms, approximately half of which will originate from the gastrointestinal tract.

Appendiceal Mucoceles and Mucinous Neoplasms of the Appendix

The term *appendiceal mucocele* broadly describes a mucus-filled appendix that could be secondary to neoplastic or nonneoplastic pathologies (mucosal hyperplasia, simple or retention cysts, mucinous cystadenomas, mucinous cystadenocarcinoma). The most common form of presentation is incidental; however, presentation with appendicitis occurs in a third of cases.[107,108] On cross-sectional imaging, a low attenuation, round, well encapsulated cystic mass in the right or quadrant is often encountered, and features such as wall irregularity and soft tissue thickening are suggestive of a neoplastic process. It is important to carefully assess for the presence of ascites, peritoneal disease, and scalloping of the liver surface on imaging upon initial evaluation. A reliable diagnosis cannot be established using imaging alone, and it is recommended that surgical excision without capsular disruption is undertaken.[109] The importance of careful handling of a mucocele and the avoidance of rupture cannot be overemphasized because the intraperitoneal spread of neoplastic cells at subsequent development of pseudomyxoma peritonei are nearly certain in cases of adenocarcinoma.[110,111] When suspecting a mucinous neoplasm of the appendix, it is imperative to systematically examine the peritoneum and document a peritoneal cancer index score if mucin is present. Biopsies to examine the content of epithelial cell, neoplastic cells, and mucin can be helpful.

In cases where a homogeneous cyst without nodularity or signs of dissemination is encountered, laparoscopic excision is acceptable, provided that a stapler is fired across the base of the cecum to avoid a positive margin. The specimen should be placed in a plastic bag and carefully removed through a small incision. In the absence of mesenteric or peritoneal involvement, an appendectomy with concurrent appendiceal lymphadenectomy is sufficient, as the chances of lymph node involvement are quite low. If peritoneal spread is evident upon exploration, it is important to obtain biopsies and document the peritoneal disease burden. An appendectomy is acceptable if the patient has acute appendicitis, but suboptimal debulking is discouraged. In addition, colorectal, ovarian, and endometrial cancers can coexist in the setting of appendiceal mucoceles, and careful examination of intra-abdominal structures is important.

When there is discordance between the primary lesion histology and the peritoneum, the peritoneal histology is usually given priority. For instance, if patients had a neoplasm in the appendix but adenocarcinoma in the peritoneum, the patient would be considered as having adenocarcinoma (AJCC M1b) disease. The recent AJCC 8th edition and the PSOGI 2016 classification consensus has resulted in a therapy-directed classification of mucinous neoplasms of the appendix, summarized in Table 30-4.[112]

Table 30-4

AJCC 8th edition and the PSOGI 2016 classification consensus of mucinous neoplasia of the appendix

LESION	PERITONEAL DISEASE AT DIAGNOSIS	PROGNOSIS	TREATMENT
Low-grade appendiceal mucinous neoplasm (LAMN)	Confined to the appendix	Excellent-curative	Negative margin appendectomy, rarely need ileocecectomy
LAMN	Peri-appendiceal Acellular mucin dissecting through the wall (t4a) or adjacent organs (t4b)	Excellent-low risk of recurrence	Negative margin appendectomy, resection of acellular mucin
LAMN	Peri-appendiceal Epithelial cells dissecting through the wall (t4a) or adjacent organs (t4b)	Excellent-high risk of recurrence	Negative margin appendectomy, peritoneal surveillance with second look laparoscopy vs. HIPEC
LAMN	Distant epithelial cells or acellular mucin (M1a) Low grade mucinous carcinoma peritonei	Excellent-high risk of recurrence	Negative margin appendectomy, omentectomy, HIPEC
High-grade appendiceal mucinous neoplasm (HAMN-rare)	Management is identical to a LAMN with risk stratification as shown above but slightly worse prognosis.		
Mucinous adenocarcinoma	Confined to the appendix	Very Good	Right hemicolectomy
Mucinous adenocarcinoma	Peritoneal Dissemination High grade mucinous carcinoma peritonei with or without signet ring cells	Well Differentiated-Very good Moderately differentiated –Good Poorly differentiated/signet ring cell histology: 10 year survival of 10-20%	Cytoreductive surgery and HIPEC, with systemic chemotherapy for high grade histologies
Adenocarcinoma (non-mucinous, including goblet cell histology)	Management identical to the mucinous histologies, with more extensive use of systemic chemotherapy		
Serrated Adenoma (rare)	Confined to appendix	Excellent-curative	Appendectomy
Adenoma (rare)	Confined to appendix	Excellent-curative	Appendectomy

Data from American College of Surgeons. Amin MB, Edge SB, Greene FL, et al. (Eds.) AJCC Cancer Staging Manual, 8th Ed. Springer New York, 2017 and Carr NJ, Cecil TD, Mohamed F, et al: A Consensus for Classification and Pathologic Reporting of Pseudomyxoma Peritonei and Associated Appendiceal Neoplasia: The Results of the Peritoneal Surface Oncology Group International (PSOGI) Modified Delphi Process, *Am J Surg Pathol.* 2016 Jan;40(1):14-26.

Pseudomyxoma Peritonei Syndrome

Patients with appendiceal mucinous neoplasms develop peritoneal dissemination leading to pseudomyxoma peritonei (PMP) syndrome. This can occur in gastric, ovarian, pancreatic, and colorectal primary tumors as well.[111] Patients with this syndrome can have varied prognosis ranging from curative to palliative. Cytoreductive surgery and hyperthermic intraperitoneal chemotherapy (HIPEC) are considered the standard of care for patients with PMP syndrome from appendiceal primaries.[113–115]

Early detection and management of limited peritoneal disease is favorable and preferred as opposed to extensive intraperitoneal mucin development. The surgical technique involves parietal and visceral peritonectomies, and intraperitoneal administration of heated (42oC [108oF]) chemotherapy (usually mitomycin) in the abdomen. Previously considered a morbid surgery, high volume centers and standardized practices have made the morbidity and mortality similar to any major open GI procedure. This technique can also be performed laparoscopically when the disease is detected early and is low volume.

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