Appendectomy

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INTRODUCTION

For over a century, appendectomy was the only therapy for appendicitis, and it continues to be the dominant treatment for appendicitis around the world [1]. In this topic, we discuss the indications, approaches (open versus laparoscopic), and techniques of appendectomy.

The general approach to and other aspects of the management of appendicitis in adult patients are discussed elsewhere. (See "Management of acute appendicitis in adults".)

INDICATIONS

Appendectomy is indicated for appendicitis and appendiceal neoplasms.

Appendicitis — Appendectomy is most commonly performed to treat appendicitis in one of four clinical scenarios:

- Emergency appendectomy is required for patients with free perforation of the appendicitis, with diffuse peritonitis, or who are septic or hemodynamically unstable as a result of perforated appendicitis. (See "Management of acute appendicitis in adults", section on 'Unstable patients or patients with free perforation'.)

- Upfront appendectomy may be performed for nonperforated appendicitis or perforated appendicitis associated with a small but well-contained abscess or a larger abscess not accessible to percutaneous drainage. It may also be performed in the presence of a right

lower quadrant phlegmon if the surgeon judges the risk of requiring an ileocecal resection is low. (See "Management of acute appendicitis in adults", section on 'Stable patients'.)

- Rescue appendectomy is required for patients who fail to respond to nonoperative management with intravenous antibiotics with or without percutaneous drainage, regardless of initial imaging findings (nonperforated or perforated). (See "Management of acute appendicitis in adults", section on 'Nonoperative management' and "Management of acute appendicitis in adults", section on 'Stable patients'.)

- Interval appendectomy is recommended for patients with perforated appendicitis managed nonoperatively primarily to exclude an appendiceal neoplasm [2]. The prevalence of appendiceal neoplasm is an order of magnitude higher in this population (10 to 29 percent [3-5]) than in routine appendectomy specimens (0.9 to 1.4 percent [5-7]), especially in adults over 40 [4,8]). (See "Management of acute appendicitis in adults", section on 'Interval appendectomy'.)

Appendiceal neoplasm — Appendectomy is typically the initial procedure performed to remove an appendiceal neoplasm usually diagnosed incidentally during radiologic or endoscopic evaluation for unrelated complaints. Additional surgery (eg, right hemicolectomy) may be required depending on the histology and margin status of the appendectomy specimen. (See "Appendiceal mucinous lesions" and "Epithelial tumors of the appendix", section on 'Adenocarcinoma' and "Well-differentiated neuroendocrine tumors of the appendix".)

SURGICAL APPROACHES

Both open and laparoscopic approaches to appendectomy are appropriate for all patients. Although laparoscopic appendectomy has gained widespread acceptance, there are both benefits and limitations to the laparoscopic approach. As a result, the operative approach in patients with suspected appendicitis is best decided by the surgeon based on personal experience, institutional capabilities, and individual patient factors such as the confidence in the diagnosis; history of prior surgery; patient's age, sex, and body habitus; and severity of disease.

Evidence from comparative studies — In general, patients treated with a laparoscopic appendectomy have fewer wound infections, less pain, and a shorter duration of hospital stay but more intra-abdominal abscesses and a longer operating time.

Open and laparoscopic appendectomy have been compared in over 70 randomized trials and analyzed in many systematic reviews and meta-analyses [9-13]. A 2015 systematic review of nine

moderate- to high-quality meta-analyses (each analyzed 8 to 67 randomized trials) concluded that [14]:

- The laparoscopic approach was superior for:
  - A lower rate of wound infections (all nine meta-analyses; odds ratio [OR] 0.3 to 0.52)
  - Less pain on postoperative day 1 (two out of three meta-analyses; by 0.7 to 0.8 points on a 10 point visual analog scale [VAS])
  - Shorter duration of hospital stay (seven out of eight meta-analyses; by 0.16 to 1.13 days)
- The open approach was superior for:
  - A lower rate of intra-abdominal abscesses (three out of six meta-analyses; OR 1.56 to 2.29)
  - A shorter operative time (eight meta-analyses; by 7.6 to 18.3 minutes)

A separate systematic review and pooled analysis also found laparoscopic appendectomy to be associated with fewer short-term (pooled OR 0.43, 95% CI 0.3-0.63) and long-term adhesive bowel obstructions (OR 0.33, 95% CI 0.19-0.56) [15].

Conditions favoring laparoscopy — Evidence suggests that laparoscopy may be the preferred approach in these following settings:

- **An uncertain diagnosis** – The laparoscopic approach provides an advantage in patients in whom the diagnosis is uncertain since it permits inspection of other abdominal organs. This benefit may be greater for women of childbearing age, who traditionally have had higher negative appendectomy rates and in whom laparoscopy may reveal other causes of pelvic pathology [6,16]. In a study of 181 women who underwent laparoscopy for suspected acute appendicitis, 86 (48 percent) were diagnosed with a gynecologic disorder as the etiology of the symptoms [16].
- **Obesity** – Laparoscopic appendectomy is beneficial in patients with obesity since exposure of the right lower quadrant during open appendectomy may require larger, morbidity-prone incisions [17-19]. In a meta-analysis of five studies of patients with a body mass index of >30 kg/m^2, laparoscopic appendectomy, as compared with open surgery, was associated with fewer postoperative complications, including wound infections and intra-

abdominal abscesses, short operative time and hospital stay, and lower hospital charges [20].

Perforated appendicitis — In contemporary practice, both open and laparoscopic approaches to appendectomy are performed for perforated appendicitis. We suggest that surgeons choose the technique with which they are more experienced and prepare to convert to open surgery if unexpected findings occur during laparoscopic exploration.

In the early days of laparoscopic appendectomy, it was contraindicated in perforated appendicitis due to the severity of inflammation and complexity of anatomy. In a study of 235,473 patients with suspected acute appendicitis undergoing a laparoscopic or open appendectomy between 2000 and 2005 from the United States Nationwide Inpatient Sample, the proportion of patients with uncomplicated appendicitis was significantly higher in the laparoscopic group (76 versus 69 percent) [9]. For patients with complicated appendicitis, defined as an appendiceal perforation or abscess, the laparoscopic approach was significantly associated with a shorter mean hospital stay (3.5 versus 4.2 days), higher rates of intraoperative complications (OR 1.61, 95% CI 1.33-1.94), and higher hospital costs (9 percent) compared with patients undergoing an open appendectomy.

As surgeons gained more experience with the technique, laparoscopic appendectomy became feasible for patients with perforated appendicitis undergoing immediate surgery [21]. A 2017 systematic review and meta-analysis of two trials and 14 retrospective studies of perforated appendicitis showed that, compared with open surgery, laparoscopic appendectomy reduced the risk of surgical site infection, length of hospital stay, and time to oral intake without increasing the rate of intra-abdominal abscess. The operating time was slightly longer with laparoscopic appendectomy, but only by 14 minutes [22].

SURGICAL TECHNIQUES

Open technique — Open appendectomy was described by McBurney in 1891 [23]. Since then, the technique has remained largely unchanged.

- **Anesthesia** – Open appendectomy in adults can be performed under general or regional (spinal) anesthesia.
- **Incision** – The patient should be reexamined after the induction of general anesthesia as this allows deep palpation of the abdomen. If a mass representing the inflamed appendix can be palpated, the incision can be located over the mass. If no appendiceal mass is detected, the incision should be centered over McBurney's point, one-third of the distance

from the anterior superior iliac spine to the umbilicus. A curvilinear incision in a skin fold allows for an excellent cosmetic result.

It is important not to make the incision too medial or too lateral. An incision placed too medially opens onto the anterior rectus sheath, rather than the desired oblique muscles, while an incision placed too laterally may be lateral to the abdominal cavity. The incision can be oriented transversely or obliquely (perpendicular to the line connecting the anterior superior iliac spine to the umbilicus) (figure 1). Some surgeons prefer a transverse incision because it can be more easily extended to increased exposure if needed.

- **Mobilization and resection** – The dissection begins through the subcutaneous tissue to the external oblique fascia, which is sharply incised lateral to the rectus sheath. Using a muscle-splitting technique, the external oblique is bluntly separated in the direction of the muscle fibers; the internal oblique and transversus abdominis muscles are bluntly separated in a similar fashion. The peritoneum is sharply entered, avoiding injury to the underlying intestine.

  The surgeon can often locate the appendix by sweeping a finger laterally to medially in the right paracolic gutter. Thin adhesions between the appendix and surrounding structures may generally be freed with blunt dissection; occasionally, sharp dissection is required for more dense adhesions. If the appendix cannot be identified through palpation, it can be located by following the teniae coli to its origin at the cecal base.

  Once identified and freed from adhesions, the appendix is delivered through the incision. The mesoappendix may be grasped with a Babcock clamp, taking care not to tear the appendiceal wall and cause spillage of enteric contents. The appendiceal artery, which runs in the mesoappendix, is divided between hemostats and tied with 3-0 absorbable sutures.

  A nonabsorbable purse-string suture is placed in the cecal wall around the appendix. After crushing the appendiceal base with a Kelly clamp, the appendix is doubly tied with 2-0 absorbable sutures. The appendix is excised with a scalpel, and the remaining stump is cauterized to prevent a mucocele. The appendiceal stump is typically inverted into the cecum while the purse-string suture is tightened, although the usefulness of stump inversion is debatable [24-30]. The surgical bed is then irrigated with saline.

- **Closure** – The incision is closed in layers with running 2-0 absorbable suture, beginning with the peritoneum, followed by the transversus abdominis, internal oblique, and external oblique. Irrigation is performed at each layer. To improve analgesia and limit

postoperative narcotic requirements, the external oblique fascia may be injected with local anesthetic. Scarpa's fascia is closed with interrupted 3-0 absorbable suture, followed by a subcuticular closure or staples for the skin. In nonperforated appendicitis, the skin may be closed primarily with a low likelihood of wound infection.

Laparoscopic technique — Laparoscopic appendectomy was first described by Semm in 1983 [31]. Although open appendectomy preceded it by almost 100 years, laparoscopic appendectomy has overtaken its open counterpart in popularity [9-11,32].

- **Anesthesia** – Laparoscopic appendectomy is typically performed under general anesthesia.

- **Patient preparation** – In the laparoscopic approach, an orogastric tube is typically placed to decompress the stomach. The bladder can be decompressed either with a Foley catheter or by having the patient void immediately prior to entering the operating room.

- **Patient positioning** – The patient is positioned supine on the operating room table with the left arm tucked. The video monitor is placed to the patient's right side because once pneumoperitoneum is established, both the surgeon and assistant stand on the patient's left.

- **Port placement** – Various port placements have been advocated for laparoscopic appendectomy. These methods share the principle of triangulation of instrument ports to ensure adequate visualization and exposure of the appendix. In one method, pneumoperitoneum is obtained through a 12 mm periumbilical port, through which the laparoscope is inserted and exploratory laparoscopy performed. The other two ports are placed under direct vision: a 5 mm port in the left lower quadrant and a 5 mm suprapubic port in the midline (figure 2). If a 5 mm laparoscope is used, it can be placed through the left lower quadrant trocar, and the umbilical 12 mm trocar can be used for a stapler. Most staplers require a 12 mm port.

  When the appendix is located in the retrocecal position, good triangulation of instruments can also be achieved with a 12 mm port placed in the upper midline. This port allows instruments or the laparoscope to be positioned for access to the gutter between the right colon and the abdominal wall. If the risk for open conversion is high, all midline incisions should be oriented vertically so they can easily be incorporated into a lower midline incision.

  An alternative abdominal access method to conventional laparoscopy is single-incision laparoscopy, in which all instruments and the laparoscope are inserted through a multi-

channel portal placed at the umbilicus [33,34]. In a meta-analysis of 11 randomized trials comparing single-incision with conventional laparoscopic appendectomy, single-incision laparoscopic appendectomy was associated with a shorter length of stay and a quicker return to activities but a longer operative time and a higher conversion rate [35].

- **Mobilization** – Once the diseased appendix is identified, any adhesions to surrounding structures can be lysed with a combination of blunt and sharp dissection. If a retrocecal appendix is encountered, division of the lateral peritoneal attachments of the cecum to the abdominal wall often improves visualization. Care must be taken to avoid underlying retroperitoneal structures, specifically the right ureter and iliac vessels.

- **Mesoappendix dissection** – The appendix or mesoappendix can be gently grasped with a Babcock clamp and retracted anteriorly. The appendiceal artery, or mesoappendix containing it, can be divided sharply between hemostatic clips, with a laparoscopic gastrointestinal anastomosis (GIA) stapler, monopolar cautery, or one of the advanced vessel ligation devices (eg, ultrasonic scalpel or LigaSure). The various technologies differ in operating time and cost but not in patient-important outcomes such as complication rate and length of stay [36]. Thus, surgeons may choose a technique based on their personal experience, the condition of the appendix, and available resources.

- **Appendix transection** – The appendix is cleared to its attachment with the cecum, and the appendiceal base is divided using a laparoscopic GIA stapler, taking care not to leave a significant stump [37]. It is sometimes necessary to include part of the cecum within the stapler to ensure that the staples are placed in healthy, uninfected tissue. Alternatively, the appendix can be divided sharply between endoloops. Using endoloops to close the appendiceal stump takes more time but costs less than using a laparoscopic GIA stapler; otherwise, the length of stay and complication rate (including that of intra-abdominal abscess) do not differ [38,39]. Thus, each surgeon may choose the method of appendiceal stump closure based on their personal preference, the condition of the appendix, and available resources. Other methods of appendiceal stump closure have been described (eg, suture knot, clip, LigaSure) but are less commonly used due to limited data [40]. The appendiceal stump is typically not inverted after laparoscopic appendectomy.

- **Closure** – The appendix is then removed through the umbilical port in a specimen bag to prevent wound infection. The operative field is inspected for hemostasis and irrigated with saline if needed, and then the fascial defect and skin incisions are closed.

Technical variances for perforation — For perforated appendicitis, operative techniques are similar to those used for nonperforated appendicitis described above, with the following

exceptions:

- **Incision** – In an open appendectomy for perforation, a larger incision may be required to provide adequate exposure for drainage of abscesses, enteric contents, and purulent material. In some instances, a lower midline incision is preferable to a right lower quadrant incision (eg, free perforation or generalized peritonitis).

- **Irrigation** – In both open and laparoscopic approaches to perforated appendicitis, the goal is to remove any infected material and drain all abscess cavities at the time of appendectomy. Copious irrigation was traditionally used to reduce the likelihood of postoperative abscess formation, although most [41-44], but not all [45], contemporary studies failed to demonstrate a benefit. For perforated appendicitis with intra-abdominal or pelvic contamination, we suggest first clearing the purulent collection with suction. Peritoneal irrigation can then be applied judiciously, with frequent, repeated suctioning of the irrigant. The goal is to dilute and remove infected material without spreading the infection to the rest of the abdomen.

- **Drains** – Peritoneal drains are not necessary after an appendectomy for perforated appendicitis [46,47]. A 2021 Cochrane systematic review of six trials found the effect of abdominal drainage on the prevention of intraperitoneal abscess or wound infection after open appendectomy to be uncertain for patients with complicated appendicitis due to low or very low quality of the evidence [48].

- **Closure** – Skin closure techniques include primary closure, loose partial closure, and closure with secondary intention. Because of wound infection rates ranging from 30 to 50 percent with primary closure of grossly contaminated wounds, many advocate delayed primary or secondary closure [49,50]. However, two meta-analyses showed that, compared with primary closure, delayed closure increased the length of hospital stay by 1.6 days without decreasing the wound infection rate [51,52]. A cost-utility analysis of contaminated appendectomy wounds also showed primary closure to be the most cost-effective method of wound management [53].

  For patients with a contaminated wound due to perforated appendicitis, we suggest against delayed wound closure. Our preferred technique of skin closure after an open appendectomy is interrupted permanent sutures or staples every 2 cm with loose wound packing in between. Removal of the packing in 48 hours often leaves an excellent cosmetic result with an acceptable incidence of wound infection. If heavy fecal contamination is present, the skin is often left open to close secondarily. Wounds are typically closed after a laparoscopic appendectomy for perforated appendicitis.

UNEXPECTED FINDINGS

Despite preoperative imaging studies such as computed tomography, unexpected findings may still occur both intraoperatively and at the time when the final pathology is reported.

Normal appendix — The diagnosis of appendicitis can be uncertain. In some historical studies, more than 15 percent of patients with suspected appendicitis had a normal appendix at laparotomy, with higher percentages in infants, older adults, and young women [6,54]. However, the use of imaging studies and laparoscopy has reduced the negative appendectomy rate [55]. The contemporary negative appendectomy rate varies from 6 percent in the United States (routine use of preoperative imaging) and Switzerland (routine use of laparoscopy) to 21 percent in the United Kingdom (selective use of imaging and laparoscopy) [55-57].

If an uninflamed appendix is encountered at appendectomy, it is important to search for other causes of the patient's symptoms, including terminal ileitis; cecal or sigmoid diverticulitis; a perforating colon carcinoma; Meckel's diverticulitis; mesenteric adenitis; or uterine, fallopian, or ovarian pathology in a female.

Even if the appendix appears normal, early intramural or serosal inflammatory changes can sometimes be found in subsequent microscopic evaluation [58,59]. Accordingly, the normal-appearing appendix should be removed. Moreover, if right lower quadrant pain recurs, appendicitis can be excluded from the differential diagnosis [60].

Chronic appendicitis — Chronic appendicitis refers to the pathologic finding of chronic inflammation or fibrosis of the appendix in a subset of patients undergoing appendectomy [61,62]. These patients are clinically characterized by prolonged (>7 days) right lower quadrant pain that may be intermittent and a normal white blood cell count. Most patients have resolution of pain with appendectomy. Chronic appendicitis may be present in 14 to 30 percent of adults undergoing appendectomy [61,62] but is much rarer in children.

Appendiceal neoplasms — Neoplasms of the appendix are rare, occurring in fewer than 1 percent of routine appendectomies. Patients may present with symptoms of appendicitis, a palpable mass, intussusception, urologic symptoms, or an incidentally discovered mass on abdominal imaging or at laparotomy for another purpose.

It is not uncommon for patients with an appendiceal neoplasm to have acute appendicitis as well [5,63,64]. Typically, the diagnosis is not appreciated until surgery or pathologic evaluation of the appendectomy specimen. The most common appendiceal tumors include carcinoid tumors, adenocarcinoma, and mucinous neoplasms [65]. At the five-year follow-up of the

Appendicitis Acuta (APPAC) trial, cancer was diagnosed in four of 272 patients who underwent initial appendectomy, compared with none of the 260 patients who had been assigned to receive antibiotics [66]. Among 697 patients who underwent appendectomy in the Comparison of Outcomes of Antibiotic Drugs and Appendectomy (CODA) trial, nine appendiceal neoplasms were identified (eight carcinomas and one mucinous neoplasm); patient age ranged from 21 to 74 years [67].

- **Appendiceal neuroendocrine (carcinoid) tumor** – Simple appendectomy is sufficient in most cases of appendiceal carcinoid, while right hemicolectomy is indicated for tumors >2 cm or if the adjacent mesenteric nodes are involved. Management of carcinoid tumors is discussed elsewhere in detail. (See "Well-differentiated neuroendocrine tumors of the appendix", section on 'Terminology and classification'.)

- **Appendiceal adenocarcinoma** – The standard treatment is right hemicolectomy, and reoperation is recommended if the diagnosis is made on pathologic evaluation of an appendectomy specimen. This is discussed in detail elsewhere. (See "Epithelial tumors of the appendix", section on 'Adenocarcinoma' and "Well-differentiated neuroendocrine tumors of the appendix".)

- **Appendiceal mucocele** – Sometimes referred to as mucoceles, mucinous neoplasms of the appendix include a spectrum of diseases including retention cysts, serrated polyps of the appendix, low-grade appendiceal mucinous neoplasm (LAMN), high-grade appendiceal mucinous neoplasm (HAMN), mucinous adenocarcinoma of the appendix (MACA), and pseudomyxoma peritonei [68]. If there is any preoperative suspicion of an appendiceal tumor, care must be taken to avoid spillage of mucin-secreting cells throughout the abdomen. These tumors are discussed in detail elsewhere. (See "Appendiceal mucinous lesions".)

POSTOPERATIVE CARE

After either open or laparoscopic appendectomy for nonperforated appendicitis, patients may be started on a clear liquid diet and advanced as tolerated to a regular diet. Antibiotics are not required postoperatively. Most patients are discharged within 24 to 48 hours of surgery. Same-day discharge is feasible, most commonly following a laparoscopic appendectomy [69,70].

Three to 7 percent of patients with perforated appendicitis can develop an ileus or early bowel obstruction after surgery [71,72]. Thus, diet should only be advanced as the clinical situation warrants. Patients may be discharged once they tolerate a regular diet, usually in five to seven

days. Three to five days of intravenous antibiotics are recommended for perforated appendicitis after appendectomy [73]. (See "Antimicrobial approach to intra-abdominal infections in adults", section on 'Duration of therapy'.)

COMPLICATIONS

Overall complication rates of 8.2 to 31.4 percent, wound infection rates of 3.3 to 10.3 percent, and pelvic abscess rates of 9.4 percent have been reported following appendectomy [73].

The most common complication following appendectomy is surgical site infection, either a simple wound infection or an intra-abdominal abscess. Both typically occur in patients with perforated appendicitis and are very rare in those with simple appendicitis. Thorough irrigation and broad-spectrum antibiotics are used to minimize the incidence of postoperative infections. Delayed primary closure of the wound has not decreased the rate of wound infection compared with primary closure. (See 'Technical variances for perforation' above.)

Compared with open appendectomy, laparoscopic appendectomy has been associated with a lower risk of incisional infection (odds ratio [OR] 0.37, 95% CI 0.32-0.43) but a high risk of organ space (intra-abdominal or pelvic) infection (OR 1.44, 95% CI 1.21-1.73) [74]. (See 'Evidence from comparative studies' above.)

SOCIETY GUIDELINE LINKS

Links to society and government-sponsored guidelines from selected countries and regions around the world are provided separately. (See "Society guideline links: Appendicitis in adults".)

INFORMATION FOR PATIENTS

UpToDate offers two types of patient education materials, "The Basics" and "Beyond the Basics." The Basics patient education pieces are written in plain language, at the 5^{th} to 6^{th} grade reading level, and they answer the four or five key questions a patient might have about a given condition. These articles are best for patients who want a general overview and who prefer short, easy-to-read materials. Beyond the Basics patient education pieces are longer, more sophisticated, and more detailed. These articles are written at the 10^{th} to 12^{th} grade reading level and are best for patients who want in-depth information and are comfortable with some medical jargon.

Here are the patient education articles that are relevant to this topic. We encourage you to print or e-mail these topics to your patients. (You can also locate patient education articles on a variety of subjects by searching on "patient info" and the keyword(s) of interest.)

- Basics topics (see "Patient education: Appendicitis in adults (The Basics)")

SUMMARY AND RECOMMENDATIONS

- **Indications** – Appendectomy is typically performed for appendicitis or appendiceal neoplasms. (See 'Indications' above.)
- **Surgical approaches** – Both open and laparoscopic approaches to appendectomy are appropriate for all patients and for both nonperforated and perforated appendicitis; the choice is by patient factors and surgeon preference. In general, patients treated with a laparoscopic appendectomy have fewer wound infections, less pain, and a shorter duration of hospital stay but more intra-abdominal abscesses and a longer operating time. (See 'Surgical approaches' above.)
- **Surgical techniques** – The standard open and laparoscopic appendectomy techniques and variances for perforation are presented. (See 'Surgical techniques' above.)
- **Unexpected findings** – A normal-appearing appendix should be removed, which should prompt a search for other potential causes of the patient's symptoms. Chronic appendicitis and appendiceal neoplasms are typically diagnosed pathologically after appendectomy. (See 'Unexpected findings' above.)
- **Postoperative care** – Following appendectomy for nonperforated appendicitis, patients are typically discharged home the same day or in 24 to 48 hours. Patients with perforated appendicitis may develop an ileus after appendectomy, which may prolong their hospital stay. (See 'Postoperative care' above.)
- **Complications** – The most common complication following appendectomy is surgical site infection, either a simple wound infection or an intra-abdominal abscess. Both typically occur in patients with perforated appendicitis and are very rare in those with simple appendicitis. (See 'Complications' above.)

REFERENCES

1. Sartelli M, Baiocchi GL, Di Saverio S, et al. Prospective Observational Study on acute Appendicitis Worldwide (POSAW). World J Emerg Surg 2018; 13:19.
2. Kristo G, Itani KMF. Settling the Controversy-Appendectomy as the Criterion for Appendicitis Diagnosis. JAMA Surg 2019; 154:207.
3. Carpenter SG, Chapital AB, Merritt MV, Johnson DJ. Increased risk of neoplasm in appendicitis treated with interval appendectomy: single-institution experience and literature review. Am Surg 2012; 78:339.
4. Wright GP, Mater ME, Carroll JT, et al. Is there truly an oncologic indication for interval appendectomy? Am J Surg 2015; 209:442.
5. Teixeira FJR Jr, Couto Netto SDD, Akaishi EH, et al. Acute appendicitis, inflammatory appendiceal mass and the risk of a hidden malignant tumor: a systematic review of the literature. World J Emerg Surg 2017; 12:12.
6. Marudanayagam R, Williams GT, Rees BI. Review of the pathological results of 2660 appendicectomy specimens. J Gastroenterol 2006; 41:745.
7. Andersson RE, Petzold MG. Nonsurgical treatment of appendiceal abscess or phlegmon: a systematic review and meta-analysis. Ann Surg 2007; 246:741.
8. Mällinen J, Rautio T, Grönroos J, et al. Risk of Appendiceal Neoplasm in Periappendicular Abscess in Patients Treated With Interval Appendectomy vs Follow-up With Magnetic Resonance Imaging: 1-Year Outcomes of the Peri-Appendicitis Acuta Randomized Clinical Trial. JAMA Surg 2019; 154:200.
9. Sporn E, Petroski GF, Mancini GJ, et al. Laparoscopic appendectomy--is it worth the cost? Trend analysis in the US from 2000 to 2005. J Am Coll Surg 2009; 208:179.
10. Nguyen NT, Zainabadi K, Mavandadi S, et al. Trends in utilization and outcomes of laparoscopic versus open appendectomy. Am J Surg 2004; 188:813.
11. Brügger L, Rosella L, Candinas D, Güller U. Improving outcomes after laparoscopic appendectomy: a population-based, 12-year trend analysis of 7446 patients. Ann Surg 2011; 253:309.
12. Jaschinski T, Mosch CG, Eikermann M, et al. Laparoscopic versus open surgery for suspected appendicitis. Cochrane Database Syst Rev 2018; 11:CD001546.
13. Andersson RE. Short-term complications and long-term morbidity of laparoscopic and open appendicectomy in a national cohort. Br J Surg 2014; 101:1135.
14. Jaschinski T, Mosch C, Eikermann M, Neugebauer EA. Laparoscopic versus open appendectomy in patients with suspected appendicitis: a systematic review of meta-analyses of randomised controlled trials. BMC Gastroenterol 2015; 15:48.

15. Markar SR, Penna M, Harris A. Laparoscopic approach to appendectomy reduces the incidence of short- and long-term post-operative bowel obstruction: systematic review and pooled analysis. J Gastrointest Surg 2014; 18:1683.
16. Moberg AC, Ahlberg G, Leijonmarck CE, et al. Diagnostic laparoscopy in 1043 patients with suspected acute appendicitis. Eur J Surg 1998; 164:833.
17. Enochsson L, Hellberg A, Rudberg C, et al. Laparoscopic vs open appendectomy in overweight patients. Surg Endosc 2001; 15:387.
18. Golub R, Siddiqui F, Pohl D. Laparoscopic versus open appendectomy: a metaanalysis. J Am Coll Surg 1998; 186:545.
19. Mason RJ, Moazzez A, Moroney JR, Katkhouda N. Laparoscopic vs open appendectomy in obese patients: outcomes using the American College of Surgeons National Surgical Quality Improvement Program database. J Am Coll Surg 2012; 215:88.
20. Ciarrocchi A, Amicucci G. Laparoscopic versus open appendectomy in obese patients: A meta-analysis of prospective and retrospective studies. J Minim Access Surg 2014; 10:4.
21. Lin HF, Lai HS, Lai IR. Laparoscopic treatment of perforated appendicitis. World J Gastroenterol 2014; 20:14338.
22. Yu MC, Feng YJ, Wang W, et al. Is laparoscopic appendectomy feasible for complicated appendicitis ?A systematic review and meta-analysis. Int J Surg 2017; 40:187.
23. McBurney C. II. The Indications for Early Laparotomy in Appendicitis. Ann Surg 1891; 13:233.
24. Arnbjörnsson E. Invagination of the appendiceal stump for the reduction of peritoneal bacterial contamination. Curr Surg 1985; 42:184.
25. Watters DA, Walker MA, Abernethy BC. The appendix stump: should it be invaginated? Ann R Coll Surg Engl 1984; 66:92.
26. Engström L, Fenyö G. Appendicectomy: assessment of stump invagination versus simple ligation: a prospective, randomized trial. Br J Surg 1985; 72:971.
27. Street D, Bodai BI, Owens LJ, et al. Simple ligation vs stump inversion in appendectomy. Arch Surg 1988; 123:689.
28. Poole GV. Management of the difficult appendiceal stump: how I do it. Am Surg 1993; 59:624.
29. Lavonius MI, Liesjärvi S, Niskanen RO, et al. Simple ligation vs stump inversion in appendicectomy. Ann Chir Gynaecol 1996; 85:222.
30. van der Graaf Y, Obertop H. [Simple ligation better than invagination of the appendix

stump; a prospective randomized study]. Ned Tijdschr Geneeskd 1992; 136:1525.

31. Semm K. Endoscopic appendectomy. Endoscopy 1983; 15:59.
32. Faiz O, Clark J, Brown T, et al. Traditional and laparoscopic appendectomy in adults: outcomes in English NHS hospitals between 1996 and 2006. Ann Surg 2008; 248:800.
33. Frutos MD, Abrisqueta J, Lujan J, et al. Randomized prospective study to compare laparoscopic appendectomy versus umbilical single-incision appendectomy. Ann Surg 2013; 257:413.
34. Kim JH, Kim HY, Park SK, et al. Single-incision Laparoscopic Appendectomy Versus Conventional Laparoscopic Appendectomy: Experiences From 1208 Cases of Single-incision Laparoscopic Appendectomy. Experiences From 1208 Cases of Single-incision Laparoscopic Appendectomy. Ann Surg 2015; 262:1054.
35. Deng L, Xiong J, Xia Q. Single-incision versus conventional three-incision laparoscopic appendectomy: A meta-analysis of randomized controlled trials. J Evid Based Med 2017; 10:196.
36. Lee JS, Hong TH. Comparison of various methods of mesoappendix dissection in laparoscopic appendectomy. J Laparoendosc Adv Surg Tech A 2014; 24:28.
37. Mangi AA, Berger DL. Stump appendicitis. Am Surg 2000; 66:739.
38. Sajid MS, Rimple J, Cheek E, Baig MK. Use of endo-GIA versus endo-loop for securing the appendicular stump in laparoscopic appendicectomy: a systematic review. Surg Laparosc Endosc Percutan Tech 2009; 19:11.
39. Mannu GS, Sudul MK, Bettencourt-Silva JH, et al. Closure methods of the appendix stump for complications during laparoscopic appendectomy. Cochrane Database Syst Rev 2017; 11:CD006437.
40. Mayir B, Ensari CÖ, Bilecik T, et al. Methods for closure of appendix stump during laparoscopic appendectomy procedure. Ulus Cerrahi Derg 2015; 31:229.
41. Moore CB, Smith RS, Herbertson R, Toevs C. Does use of intraoperative irrigation with open or laparoscopic appendectomy reduce post-operative intra-abdominal abscess? Am Surg 2011; 77:78.
42. St Peter SD, Adibe OO, Iqbal CW, et al. Irrigation versus suction alone during laparoscopic appendectomy for perforated appendicitis: a prospective randomized trial. Ann Surg 2012; 256:581.
43. Gemici E, Bozkurt MA, Sürek A, et al. Laparoscopic Lavage Versus Aspiration Alone in Perforated Acute Appendicitis: A Prospective Randomized Controlled Study. Surg Laparosc Endosc Percutan Tech 2020; 30:14.

44. Burini G, Cianci MC, Coccetta M, et al. Aspiration versus peritoneal lavage in appendicitis: a meta-analysis. World J Emerg Surg 2021; 16:44.
45. Sun F, Wang H, Zhang F, et al. Copious Irrigation Versus Suction Alone During Laparoscopic Appendectomy for Complicated Appendicitis in Adults. J Invest Surg 2018; 31:342.
46. Greenall MJ, Evans M, Pollock AV. Should you drain a perforated appendix? Br J Surg 1978; 65:880.
47. Petrowsky H, Demartines N, Rousson V, Clavien PA. Evidence-based value of prophylactic drainage in gastrointestinal surgery: a systematic review and meta-analyses. Ann Surg 2004; 240:1074.
48. Li Z, Li Z, Zhao L, et al. Abdominal drainage to prevent intra-peritoneal abscess after appendectomy for complicated appendicitis. Cochrane Database Syst Rev 2021; 8:CD010168.
49. Lemieur TP, Rodriguez JL, Jacobs DM, et al. Wound management in perforated appendicitis. Am Surg 1999; 65:439.
50. Cohn SM, Giannotti G, Ong AW, et al. Prospective randomized trial of two wound management strategies for dirty abdominal wounds. Ann Surg 2001; 233:409.
51. Bhangu A, Singh P, Lundy J, Bowley DM. Systemic review and meta-analysis of randomized clinical trials comparing primary vs delayed primary skin closure in contaminated and dirty abdominal incisions. JAMA Surg 2013; 148:779.
52. Siribumrungwong B, Noorit P, Wilasrusmee C, Thakkinstian A. A systematic review and meta-analysis of randomised controlled trials of delayed primary wound closure in contaminated abdominal wounds. World J Emerg Surg 2014; 9:49.
53. Brasel KJ, Borgstrom DC, Weigelt JA. Cost-utility analysis of contaminated appendectomy wounds. J Am Coll Surg 1997; 184:23.
54. Flum DR, Morris A, Koepsell T, Dellinger EP. Has misdiagnosis of appendicitis decreased over time? A population-based analysis. JAMA 2001; 286:1748.
55. SCOAP Collaborative, Cuschieri J, Florence M, et al. Negative appendectomy and imaging accuracy in the Washington State Surgical Care and Outcomes Assessment Program. Ann Surg 2008; 248:557.
56. National Surgical Research Collaborative. Multicentre observational study of performance variation in provision and outcome of emergency appendicectomy. Br J Surg 2013; 100:1240.
57. Güller U, Rosella L, McCall J, et al. Negative appendicectomy and perforation rates in patients undergoing laparoscopic surgery for suspected appendicitis. Br J Surg 2011;

98:589.

58. Phillips AW, Jones AE, Sargen K. Should the macroscopically normal appendix be removed during laparoscopy for acute right iliac fossa pain when no other explanatory pathology is found? Surg Laparosc Endosc Percutan Tech 2009; 19:392.
59. Strong S, Blencowe N, Bhangu A, National Surgical Research Collaborative. How good are surgeons at identifying appendicitis? Results from a multi-centre cohort study. Int J Surg 2015; 15:107.
60. Grimes C, Chin D, Bailey C, et al. Appendiceal faecaliths are associated with right iliac fossa pain. Ann R Coll Surg Engl 2010; 92:61.
61. Mussack T, Schmidbauer S, Nerlich A, et al. [Chronic appendicitis as an independent clinical entity]. Chirurg 2002; 73:710.
62. Leardi S, Delmonaco S, Ventura T, et al. [Recurrent abdominal pain and "chronic appendicitis"]. Minerva Chir 2000; 55:39.
63. Olsen J, Skovdal J, Qvist N, Bisgaard T. Treatment of appendiceal mass--a qualitative systematic review. Dan Med J 2014; 61:A4881.
64. Tannoury J, Abboud B. Treatment options of inflammatory appendiceal masses in adults. World J Gastroenterol 2013; 19:3942.
65. Charfi S, Sellami A, Affes A, et al. Histopathological findings in appendectomy specimens: a study of 24,697 cases. Int J Colorectal Dis 2014; 29:1009.
66. Salminen P, Tuominen R, Paajanen H, et al. Five-Year Follow-up of Antibiotic Therapy for Uncomplicated Acute Appendicitis in the APPAC Randomized Clinical Trial. JAMA 2018; 320:1259.
67. CODA Collaborative, Flum DR, Davidson GH, et al. A Randomized Trial Comparing Antibiotics with Appendectomy for Appendicitis. N Engl J Med 2020; 383:1907.
68. Rymer B, Forsythe RO, Husada G. Mucocoele and mucinous tumours of the appendix: A review of the literature. Int J Surg 2015; 18:132.
69. Frazee RC, Abernathy SW, Isbell CL, et al. Outpatient Laparoscopic Appendectomy: Is It Time to End the Discussion? J Am Coll Surg 2016; 222:473.
70. Frazee RC, Abernathy SW, Davis M, et al. Outpatient laparoscopic appendectomy should be the standard of care for uncomplicated appendicitis. J Trauma Acute Care Surg 2014; 76:79.
71. Low ZX, Bonney GK, So JBY, et al. Laparoscopic versus open appendectomy in pediatric patients with complicated appendicitis: a meta-analysis. Surg Endosc 2019; 33:4066.
72. Quah GS, Eslick GD, Cox MR. Laparoscopic appendicectomy is superior to open surgery for complicated appendicitis. Surg Endosc 2019; 33:2072.

73. Bhangu A, Søreide K, Di Saverio S, et al. Acute appendicitis: modern understanding of pathogenesis, diagnosis, and management. Lancet 2015; 386:1278.

74. Fleming FJ, Kim MJ, Messing S, et al. Balancing the risk of postoperative surgical infections: a multivariate analysis of factors associated with laparoscopic appendectomy from the NSQIP database. Ann Surg 2010; 252:895.

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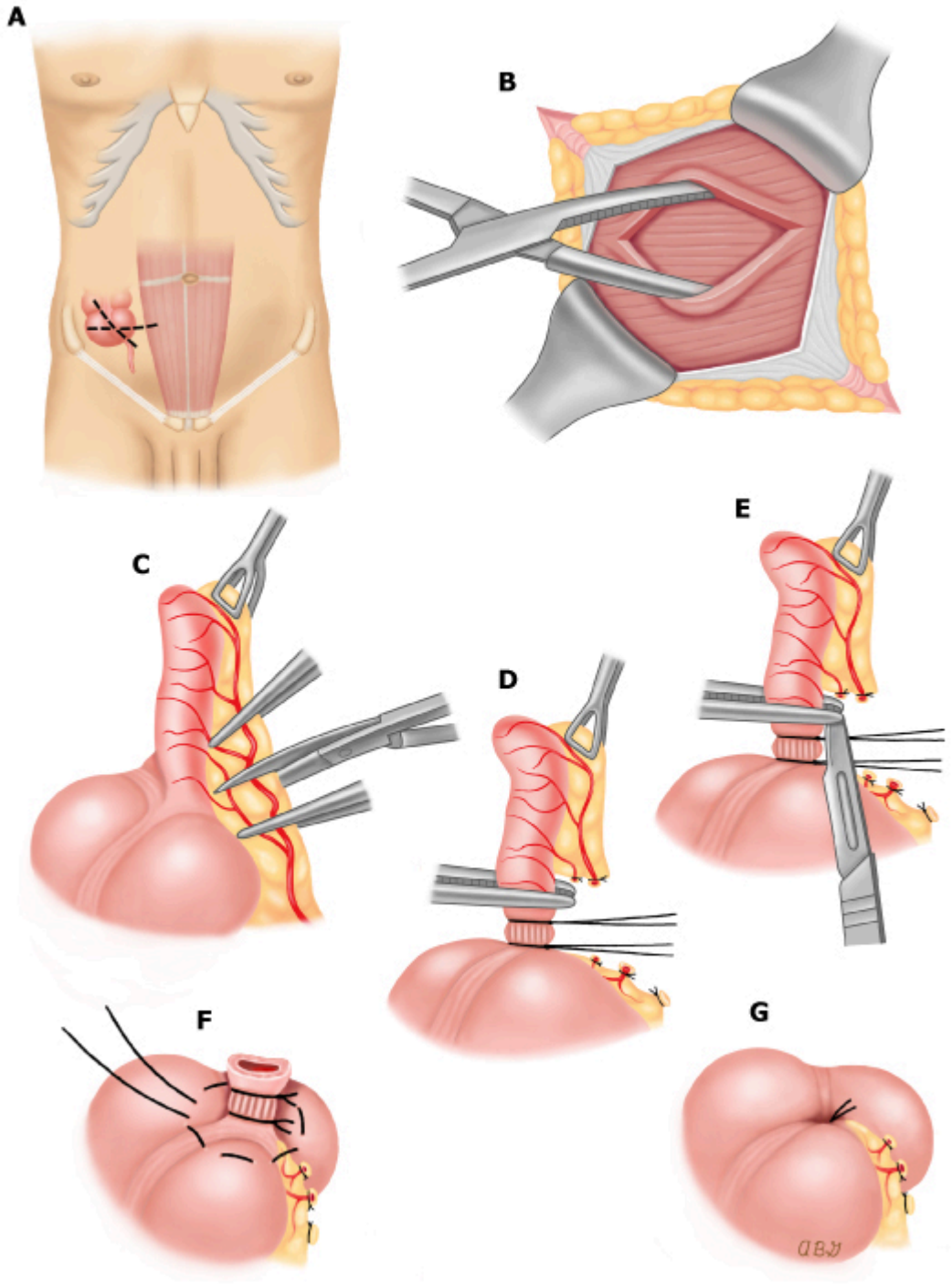
GRAPHICS

Open appendectomy



Graphic 53185 Version 1.0

Laparoscopic appendectomy

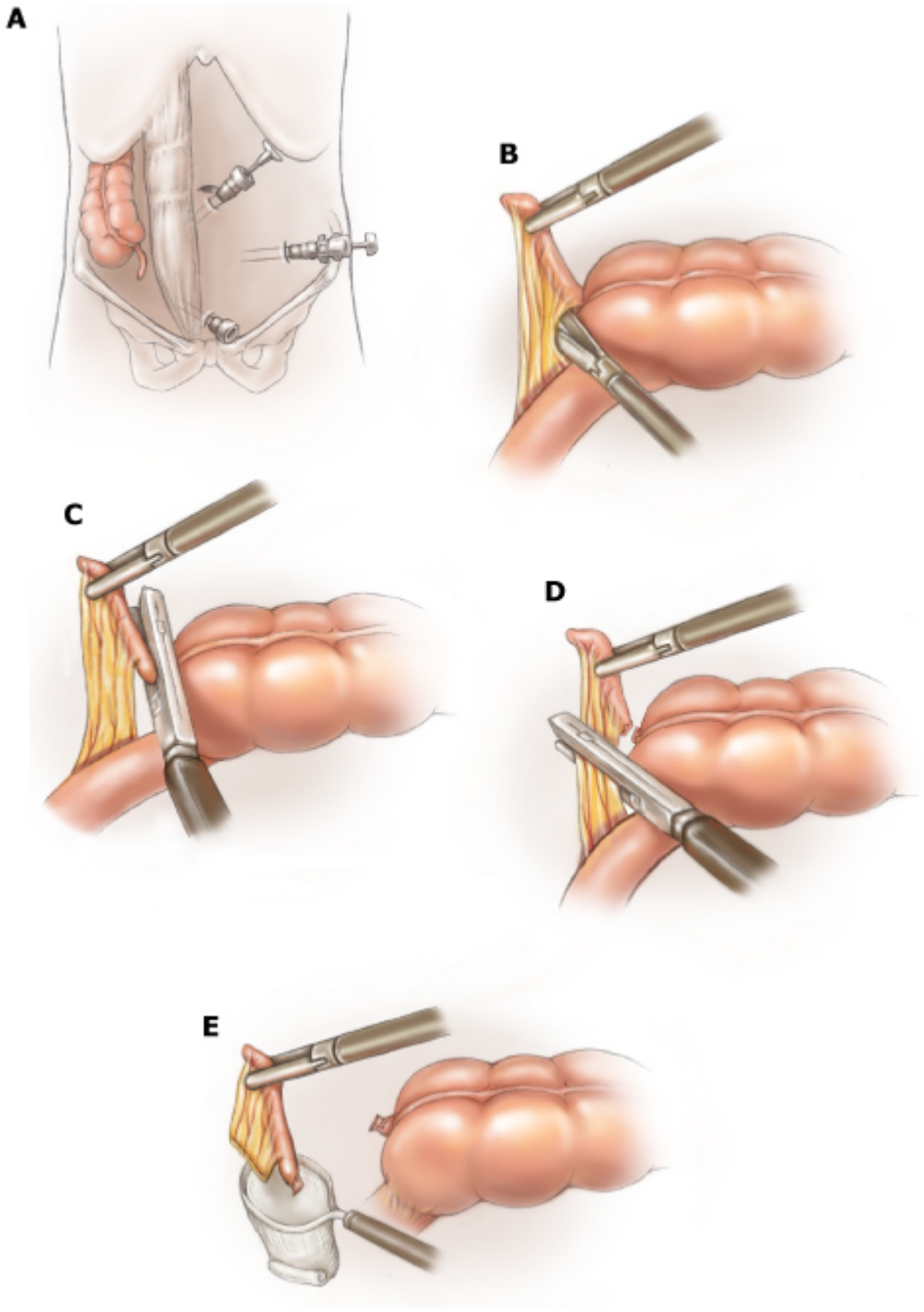


Illustration by Jenny Wang.

Graphic 78264 Version 5.0

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