First depicted in anatomic drawings in 1492 by Leonardo da Vinci, the vermiform appendix was described as an anatomic structure in 1521 by Jacopo Berengar da Carpi, a professor of human anatomy at Bologna. Appendicitis became recognized as a surgical disease when the Harvard University pathologist Reginald Heber Fitz read his analysis of 257 cases of perforating inflammation of the appendix and 209 cases of typhilitis or perityphilitis at the 1886 meeting of the Association of American Physicians. In this landmark report, Fitz correctly pointed out that the frequent abscesses in the right iliac fossa were often attributable to perforation of the vermiform appendix, and he referred to the condition as appendicitis. Among his classic observations of the disease was the emphasis on the “vital importance of early recognition” and its “eventual treatment by laparotomy.” It was not until 1894 that Charles McBurney first described the surgical incision that bears his name and the surgical technique that was to become the gold standard for appendectomy.

Although appendectomy has traditionally been done—and largely continues to be done—as an open procedure, there has been increasing interest in laparoscopic appendectomy in the last two decades. At present, however, the only patients for whom laparoscopic appendectomy appears to offer significant advantages are women of childbearing age, obese patients, and patients with an unclear diagnosis [see Figure 1]. Accordingly, the gold standard for surgical treatment of acute appendicitis remains open appendectomy as described by McBurney, although the occasional patient with chronic appendicitis can be electively treated with the laparoscopic approach.

Operative Technique

OPEN APPENDECTOMY

With the patient under general anesthesia and in the supine position, the abdomen is prepared and draped in a sterile fashion so as to expose the right lower quadrant. The skin incision is made in an oblique direction, crossing a line drawn between the anterior superior iliac spine and the umbilicus at nearly a right angle at a point about 2 to 3 cm from the iliac spine. This point, the McBurney point, is approximately one third of the way from the iliac spine to the umbilicus [see Figure 2]. The subcutaneous fat and fascia are incised to expose the external oblique aponeurosis. A slightly shorter incision is made in this aponeurosis; first, a scalpel is used, and then the incision is extended with scissors in the direction of the fibers of the muscle and its tendon in such a way that the fibers are separated but not cut.

The fibers of the internal oblique muscle and the transversus abdominis are separated with a blunt instrument at nearly a right angle to the incision on the external oblique aponeurosis. The parietal peritoneum is lifted up, with care taken not to include the underlying viscera, and is opened in a transverse fashion with a scalpel. This incision is then enlarged transversely with scissors. When greater exposure is required, the lateral edge of the rectus sheath is incised and the rectus abdominis is retracted medially without being divided [see Figure 3].

A foul smell or the presence of pus on entry into the peritoneum is an indication of advanced or perforating appendicitis. The free peritoneal fluid is collected for bacteriologic analysis. The ascending colon or cecum is located, and the appendix is found by following the cecal taeniae distally. The inflamed appendix typically feels firm and turgid. The appendix, together with the cecum, is delivered into the surgical incision and held with a Babcock tissue forceps. If this step proves difficult, the appendix can sometimes be swept into the field with the surgeon’s right index finger as gentle traction is maintained on the cecum with a small, moist gauze pad held in the left hand [see Figure 4]. Care should be taken at this point not to avulse the friable and possibly necrotic appendix. To deliver a retrocecal appendix, it may be necessary to mobilize the ascending colon partially by sharply dividing the peritoneum on its lateral side, starting from the terminal ileum and proceeding toward the hepatic flexure.

The mesoappendix, containing the appendicular artery, is divided between clamps and ligated with 3-0 absorbable sutures [see Figure 5]. The appendix is held up with a Babcock tissue forceps, and its base is gently crushed with a straight mosquito arterial forceps. The mosquito forceps is then opened, moved up the appendix, and closed again. The base of the appendix is doubly ligated with 2-0 absorbable sutures at the point where it was crushed, so that a cuff of about 3 mm is left between the forceps and the tie.

The appendix is divided by running a scalpel along the underside of the forceps. The mucosa of the appendiceal stump is fulgurated with the electrocautery. The stump is not routinely invaginated into the cecum. In those rare cases in which the viability of the appendiceal base is in question, a 2-0 absorbable purse-string suture is placed in the cecum, and the stump is invaginated as the suture is tied. Alternatively, a partial cecectomy is performed using a gastrointestinal anastomosis (GIA) stapler loaded with an intestinal cartridge. If either maneuver is done, palpation for a patent ileocecal valve is indicated. The operative field is then checked for hemostasis, and the ascending colon is returned back to the abdomen. In cases of perforating appendicitis, the right paracolic gutter and pelvis are irrigated and thoroughly aspirated to ensure that any collected pus or particulate material is removed.

The peritoneum is then closed with a continuous 3-0 absorbable suture. The fibers of the transversus abdominis and the internal oblique muscle fall together readily, and their

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closure can be completed with two interrupted 3-0 absorbable ligatures. The external oblique aponeurosis is closed from end to end with a continuous 2-0 absorbable suture. The Scarpa fascia is approximated with interrupted 3-0 absorbable sutures, and the skin is closed with a continuous subcuticular 4-0 absorbable suture and reinforcing tapes (Steri-Strips, 3M, St. Paul, MN).

If the wound has been grossly contaminated, the fascia and muscles are closed as described, but the skin is loosely approximated with Steri-Strips, which can easily be removed postoperatively if surgical site infection develops. An alternative approach is to leave the skin and the subcutaneous tissue open but dressed with sterile nonadherent material and then to perform delayed primary closure with Steri-Strips on postoperative day 4 or 5. A meta-analysis of 27 studies involving 2,532 patients with gangrenous or perforating appendicitis concluded that the risk of surgical site infection was no higher with primary closure than with delayed primary closure.3

**LAPAROSCOPIC APPENDECTOMY**

The patient is under general anesthesia and in the supine position, with both arms tucked along the sides. Decompression with an orogastric tube should be routine, as should placement of a urinary Foley catheter and use of lower extremity sequential compression devices. The abdomen is prepared and draped in a sterile fashion so as to expose the entire abdomen.
The surgeon should stand on the patient’s left side, with the assistant (who operates the camera) near the patient’s left shoulder [see Figure 6]. The monitors are placed on the opposite side of the operating table so that both the surgeon and the assistant can view the procedure at all times.

A three-port approach is routinely used [see Figure 6]. All skin incisions along the midline are made vertically to allow a more cosmetically acceptable conversion to laparotomy should this become necessary. The midline suprapubic port must be large enough to accommodate the laparoscopic stapler or specimen retrieval bag (usually 12 mm); the other two ports can be smaller (e.g., 5 or 10 mm). The left lower quadrant port is placed as far away from the operative field as possible to permit the application of a two-handed dissection technique. The use of a 30° angled scope facilitates operative viewing and dissection.

With the patient pharmacologically relaxed and in the Trendelenburg position, a Veress needle is inserted into the peritoneal cavity at the base of the umbilical ligament. Aspiration and the saline-drop test are performed to ensure that the tip of the needle is correctly positioned. Pneumoperitoneum is established by insufflating CO₂ to an intra-abdominal pressure of 14 mm Hg. The first port is placed at the infraumbilical skin incision, the laparoscope is inserted, and a complete diagnostic laparoscopy is performed. Once the diagnosis of acute appendicitis is confirmed by inspection, the two remaining ports are placed under direct vision. In many cases, however, the diagnosis cannot be confirmed without

Figure 3  Open appendectomy. Depicted is exposure of the abdominal cavity. The external oblique aponeurosis is opened (a). The fibers of the internal oblique muscle are separated bluntly (b). The parietal peritoneum is exposed (c) and opened transversely (d).
first placing the second and third ports and exposing the appendix. If purulent fluid is encountered, it should be carefully aspirated dry without irrigation to ensure that the infected fluid is not disseminated throughout the abdominal cavity.

The patient is tilted toward the left, and the appendix is exposed and traced to its base on the cecum by using an atraumatic retracting forceps. In cases of retrocecal appendix or severe appendiceal inflammation, it is best first to mobilize the cecum medially by taking down the lateral reflection of the peritoneum around the terminal ileum and up the ascending colon with either endoscopic scissors or an ultrasonic scalpel (e.g., the Harmonic Scalpel, Ethicon Endo-Surgery, Inc., Cincinnati, OH). Surrounding structures, such as the iliac and gonadal vessels and the ureter, should be clearly identified to minimize the risk of injury. Dissection of the appendix can then begin.

The tip of the appendix is grasped and retracted anteriorly toward the anterior abdominal wall and slightly toward the pelvis; the mesoappendix is thus exposed in a triangular fashion. A window between the base of the appendix and the blood supply is created with a curved dissecting forceps. The mesoappendix is divided either with hemostatic clips and scissors or with a laparoscopic GIA stapler loaded with a vascular cartridge [see Figure 7]. If a window on the mesoappendix cannot be safely created because of intense inflammation, antegrade dissection of the blood supply is necessary. The ultrasonic scalpel is a handy (albeit expensive) instrument for this purpose. Endoscopic hemostatic clips usually suffice to control the small branches of the appendicular artery during the course of this dissection.

The base of the appendix is then cleared circumferentially of any adipose or connective tissue and is divided with a laparoscopic GIA stapler loaded with an intestinal cartridge [see Figure 8]. To ensure an adequate closure away from the inflamed appendiceal base, a small portion of the cecum may have to be included within the stapler. To ensure proper placement of the stapler and to prevent injury to the right ureter or the adjacent small bowel, the tips of the stapler must be clearly visualized before the instrument is closed. The use of an angled scope and an articulated rotating laparoscopic GIA stapler (e.g., Roticulator, AutoSuture, Norwalk, CT) will facilitate this maneuver. Once closed, the stapler should be rotated to inspect the back side before firing. A noninflamed or minimally inflamed appendix can be ligated with sutures, as described earlier [see Open Appendectomy, above].

Figure 4  Open appendectomy. Depicted is the mobilization of the appendix. The ascending colon is identified (a). The inflamed appendix and the cecum are delivered into the surgical incision; if this is difficult, the appendix can be swept into the field with the right index finger as traction is maintained on the cecum with a gauze pad (b). The appendix may be seen to occupy any of a number of potential locations (c).
The appendix is removed from the abdominal cavity, with care taken to avoid direct contact with the abdominal wall. A mildly inflamed appendix can be delivered through one of the larger ports; a severely inflamed appendix is often too big and hence should be delivered in a specimen retrieval bag to avoid contamination [see Figure 9].

Hemostasis is confirmed, and the cecum is inspected to ensure proper closure of the appendiceal stump. The operative field is irrigated and aspirated dry. The ports are removed under direct vision, the absence of back-bleeding from the port sites is confirmed, and the abdomen is completely decompressed. All fascial defects larger than 5 mm are closed with 0 absorbable sutures. The skin incisions are reapproximated with a subcuticular 4-0 absorbable suture and reinforcing tapes (Steri-Strips).

**Special Considerations**

**The Histologically Normal Appendix**

Acute appendicitis is the most common cause of an acute surgical abdomen in the United States and remains one of the most challenging diagnoses to make in the emergency
Although the use of advanced diagnostic imaging modalities (e.g., ultrasonography and computed tomography) has led to more accurate diagnosis of acute appendicitis in research settings, it has not been shown to reduce the rate of misdiagnosis of acute appendicitis in the general population. Nonetheless, appendectomy relieves symptoms in the vast majority of these patients. When extensive sectioning is done on histologically normal specimens, often a focus of inflammation is found in only a few serial sections. This condition is known as focal appendicitis—so called because the polymorphonuclear infiltration is confined to a single focus, whereas the remaining appendix is devoid of any polymorphonuclear cells. It is not clear that all cases of acute appendicitis arise from this focal inflammation; however, such inflammatory foci may be the earliest recognizable manifestations of appendicitis in some so-called negative appendectomies. Furthermore, a substantial proportion of histologically normal appendices removed from patients with clinical signs and symptoms of acute appendicitis exhibit significantly increased expression of tumor necrosis factor-α and interleukin-2 messenger RNA (a sensitive marker of inflammation in appendicitis) in germinal centers, the submucosa, and the lamina propria. Therefore, when a patient with clinically suspected acute appendicitis is explored and the appendix does not appear to be inflamed and no other pathology is encountered, appendectomy is still recommended.

Laparoscopic appendectomy has not been shown to reduce the incidence of negative exploration in patients with clinically suspected acute appendicitis [see Complications and Outcome Evaluation, Open versus Laparoscopic Appendectomy, below].

APPENDICEAL NEOPLASM

Neoplastic lesions of the appendix are found in as many as 5% of specimens obtained with routine appendectomy for acute appendicitis. Most are benign. Preoperative detection of such conditions is rare, and intraoperative diagnosis is made in fewer than 50% of cases. Appendectomy alone may be curative for appendiceal mucocele, localized pseudomyxoma peritonei, most appendiceal carcinoids, and other benign tumors. Definitive management of an appendiceal mass unexpectedly encountered during exploration for clinically suspected acute appendicitis depends on whether the tumor is carcinoid, its size and location, the presence or absence of metastatic disease, and histologic and immunohistochemical findings [see Figure 10].

Benign neoplasms of the appendix include mucosal hyperplasia or metaplasia, leiomyomas, neuromas, lipomas, angiomatos, and other rare lesions. Appendiceal adenomas tend to be diffuse and to have a predominant villous character. Mucus-producing cystadenomas predispose to appendiceal mucocele, sometimes accompanied by localized pseudomyxoma peritonei. These lesions are rarely symptomatic and are often encountered incidentally during operation; however, they may also be clinically manifested as acute appendicitis, torsion, intussusception, ureteral obstruction, or another acute condition. If the base of the appendix is free of disease, appendectomy alone is sufficient treatment.

Malignant tumors of the appendix primarily consist of carcinoids and adenocarcinomas; all together, they account for 0.5% of all gastrointestinal malignancies. The incidence of malignancy in the appendix is 1.35%. Metastasis to the appendix is rare. Carcinoids are substantially more common than adenocarcinomas in the appendix: as many as 80% of
all appendiceal masses are carcinoid tumors. Overall, carcinoid tumors are found in 0.5% of all appendiceal specimens, and appendiceal carcinoid tumors account for 18.9% of all carcinoid lesions. These tumors are predominantly of neural cellular origin and have a better prognosis than all other intestinal carcinoid tumors, which typically are of mucosal cellular origin. If the tumor is less than 2 cm in diameter, is located within the body or the tip of the appendix, and has not metastasized, appendectomy is the treatment of choice. If the lesion is at the base of the appendix, is larger than 2 cm in diameter, or has metastasized, right hemicolectomy is indicated. In addition, secondary right hemicolectomy is indicated if the tumor is invasive, if mucin production is noted, or if the tumor is found to be of mucosal cellular origin at the final pathologic examination. Patients with metastatic appendiceal carcinoid tumors appear to have a far better prognosis than those with other types of metastatic cancers. Therefore, hepatic debulking for symptomatic control is indicated and justified in cases of liver metastasis.

Primary adenocarcinoma of the appendix is rare, and as yet there is no firm consensus regarding prognosis, treatment of choice, and outcome. Currently, the recommended treatment is right hemicolecotomy: a 1993 study found that this approach resulted in an overall 5-year survival rate of 68% compared with a rate of 20% when appendectomy alone was performed. The prognosis is determined by the degree of tumor differentiation and by the histologic stage. As many as one third of these patients have a second primary neoplasm, which will be located within the gastrointestinal tract about half the time.

Finally, nonepithelial appendiceal tumors, although extremely rare, occur as well. Such lesions include malignant Burkitt lymphomas, smooth muscle tumors, granular cell tumors, ganglioneuromas, and Kaposi sarcoma.

INFLAMMATORY BOWEL DISEASE

The appendix is frequently involved in Crohn disease and ulcerative colitis (25 and 50% of cases, respectively), but isolated Crohn disease of the appendix is rare. When a histologically normal appendix is encountered in a patient with active Crohn disease, appendectomy should be performed because of the high risk of recurrent right lower quadrant pain, fever, and tenderness. Although isolated Crohn disease of the appendix may present as acute appendicitis, it is not clear that this condition will necessarily develop into a more extensive form of Crohn disease. Appendectomy is safe in such cases because fistulas almost never develop after appendectomy in patients with isolated involvement of the appendix.

GYNECOLOGIC CONDITIONS

It is clear that the presentation of right lower quadrant pain in a woman remains a challenge to the treating physician. Frequently, the causes can be identified by means of proper blood work or ultrasonography, but often they can be revealed only through surgical exploration. In such cases, diagnostic
laparoscopy provides an excellent view of the pelvic organs and offers the potential for easy continuation on to laparoscopic treatment. Ovarian cysts found in premenopausal women include unilocular clear fluid cysts (e.g., follicular cysts and corpus luteum cysts), dermoid cysts, and endometrial cysts. They can be removed by making an incision on the ovary and separating the cyst from the ovarian cortex. Dermoid cysts should be removed in toto to prevent chemical peritonitis. Endometrial cysts are best evaporated with the laser: complete removal is very difficult and sometimes impossible. Torsion of the fallopian tube or the ovary can be reversed by gentle detorsion of the organ with atraumatic forceps. If there is no evidence of ischemia, no further therapy is indicated. If there is gangrene with no indication of recovery, resection is indicated. If the organ shows partial recovery within 10 minutes after the pedicle is untwisted, a second-look laparoscopy is indicated in 24 hours. Pelvic inflammatory disease should be treated on an individualized basis in accordance with the degree of inflammation, the patient’s age and desire to have children, and the microbiologic findings.

Complications and Outcome Evaluation

OPEN VERSUS LAPAROSCOPIC APPENDECTOMY

To date, 31 randomized, controlled trials comparing laparoscopic appendectomy with open appendectomy have been published as full articles in English [see Table 1].31-61 These reports involved a total of 4,352 patients, of whom 2,194 underwent laparoscopic appendectomy and 2,158 underwent open appendectomy. The incidence of histologically normal appendix (negative appendectomy rate) was similar in the two groups (14.3% with laparoscopic appendectomy versus 14.8% with open appendectomy). The conversion rate from laparoscopic appendectomy to open appendectomy was 10% (range 0 to 23%). Laparoscopic appendectomy was associated with a lower incidence of postoperative wound infection than open appendectomy was (3.5% versus 6.7%), but it was also associated with a higher incidence of postoperative

Figure 9  Laparoscopic appendectomy. The specimen is delivered either through one of the larger ports (a) or in a specimen retrieval bag (b).

Figure 10  Shown is an algorithm for the management of an appendiceal mass encountered during exploration for clinically suspected acute appendicitis.
**Table 1  Results of 31 Prospective, Randomized Trials Comparing Laparoscopic Appendectomy with Open Appendectomy**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Laparoscopic Appendectomy (n = 2,194)</th>
<th>Open Appendectomy (n = 2,158)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>Range</td>
</tr>
<tr>
<td>Negative appendix</td>
<td>314 (14.3)</td>
<td>7.7–36.0%</td>
</tr>
<tr>
<td>Conversion to open procedure</td>
<td>223 (10.2)</td>
<td>0–23.9%</td>
</tr>
<tr>
<td>Surgical site infection</td>
<td>77 (3.5)</td>
<td>0–18.3%</td>
</tr>
<tr>
<td>Intra-abdominal abscess</td>
<td>55 (2.5)</td>
<td>0–7.4%</td>
</tr>
<tr>
<td>Days in hospital</td>
<td>2.7</td>
<td>1–4.9</td>
</tr>
</tbody>
</table>

NA = not applicable.

In men and children with suspected acute appendicitis, laparoscopic appendectomy has no major advantage over open appendectomy. In women of childbearing age and in equivocal cases, laparoscopy may be valuable as a diagnostic tool, but the practice of not removing a normal-looking appendix during exploration for right lower quadrant pain remains controversial. Laparoscopic appendectomy appears to offer the potential benefit of less postoperative adhesion formation, but the evidence is inconclusive in light of the short follow-up times reported in these trials, and the higher incidence of intra-abdominal abscess formation remains cause for concern. To date, unfortunately, there have been no studies designed specifically to address reduced adhesion formation as a primary end point.

Although laparoscopic appendectomy is being performed with increased frequency, it continues to be used selectively. Laparoscopic appendectomy is at least as safe as the corresponding open procedure, but it is undeniably more time-consuming and more costly. Moreover, it remains questionable whether the benefits of laparoscopic appendectomy—reduced postoperative pain, earlier resumption of oral feeding, shortened hospital stay, quicker return to normal preoperative activities, and lower incidence of surgical site infection—outweigh the higher incidence of postoperative intra-abdominal abscess formation. In clinical settings when the patient is either a woman of childbearing age, is obese, or has an unclear diagnosis and where surgical expertise is available and equipment is affordable, a laparoscopic approach may offer significant advantages over an open procedure. Further randomized clinical studies focusing on the efficacy of laparoscopic appendectomy as a diagnostic tool and on the incidence of postoperative intra-abdominal abscess and adhesion formation are needed, as are additional cost analyses.

**References**


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Figures 2 through 9 Tom Moore

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