Laparoscopic Appendectomy

Initial Experience in a Teaching Program

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From February 1990 to December 1991, 16 laparoscopic procedures were performed for right lower quadrant pain. There were nine men and seven women, aged 16 to 47 years (mean, 27.2 years). All procedures were performed by surgical chief residents with prior experience in laparoscopic cholecystectomy, first-assisted by an attending surgeon. The appendix was visualized and a definitive diagnosis was made in all patients. One patient with acute salpingitis underwent diagnostic laparoscopy only; two patients underwent laparotomy (perforated appendicitis, perforated diverticulitis). A fourth patient had an acute torsion of an ovarian cyst managed laparoscopically. Laparoscopic appendectomy was successfully performed in 12 patients (acute appendicitis, 9; fibrosis or chronic inflammation, 2; normal appendix, 1). Mean operative time for laparoscopic appendectomy was 95.7 minutes, and mean postoperative stay was 2.5 days. The authors conclude that operative time, diagnostic accuracy, and complication rates for laparoscopic appendectomy are acceptable. Within the context of a training program, laparoscopic appendectomy provides an opportunity for surgical residents to expand laparoscopic skills.

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OPERATIVE LAPAROSCOPY WAS introduced into the teaching program of the University of Mississippi Medical Center in February 1990. A 2-day didactic program composed of the basics of laparoscopy, equipment trouble-shooting, and safety considerations followed by laboratory experience in a porcine model preceded clinical exposure for all residents. Diagnostic laparoscopy for right lower quadrant pain preceded the first laparoscopic cholecystectomy, and the first laparoscopic appendectomy was performed several months later. From the beginning, surgical residents were active participants, performing over 95% of procedures with an attending surgeon as first assistant. This report details the experience with the first 16 laparoscopies performed for right lower quadrant pain, including 12 laparoscopic appendectomies, and includes all such cases treated by three attending surgeons (CSC, TJH, FFM) from February 1, 1990 through November 30, 1991 (22 months). It summarizes our total institutional experience to date.

Presented at the 103rd Annual Scientific Session of the Southern Surgical Association, Hot Springs, Virginia, December 1–5, 1991.

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Accepted for publication January 7, 1992.

Methods and Materials

All patients admitted to the gastrointestinal surgery service at the University of Mississippi Medical Center during the study period with right lower quadrant pain were considered for laparoscopic appendectomy (LA). Initially, the procedure was reserved for patients with right lower quadrant pain and equivocal signs and symptoms of appendicitis who had failed a trial of observation. Patients with clear signs of appendicitis were treated by open appendectomy. With experience, these latter patients were managed laparoscopically as well. Patients with generalized peritonitis, significant abdominal distension, or dilated loops of bowel on x-ray were managed by open appendectomy. Pregnancy was considered an absolute contraindication for LA, as was a history of a bleeding diathesis. The nature of the procedure and possible complications were explained to the patients before operation, and consent was obtained for laparoscopic as well as for open appendectomy.

All patients at University of Mississippi Medical Center who undergo laparoscopic procedures, including LA, are entered into a computerized surgical laparoscopic registry. Demographic information, preoperative signs and symptoms, white blood count, temperature, x-ray findings, length of procedure, nature of procedure performed, whether or not conversion to open surgery was required,

surgeon, first assistant, location of appendix (retrocecal *versus* intra-abdominal), pathology, postoperative stay, complications, and follow-up are recorded. In addition, the number of open appendectomies performed on the service during this same time period was recorded.

Surgical Technique for Laparoscopic Appendectomy

The patient was positioned supine, with both arms tucked at the sides. An indwelling urinary catheter and nasogastric tube were placed to decompress the bladder and stomach. The surgeon (chief resident) and camera driver (junior resident or medical student) stood at the patient's left side, the first assistant (attending surgeon) stood to the right. The video monitor was placed at the right side of the table, below the first assistant (Fig. 1).

Laparoscopy was performed by a closed technique. If the findings were consistent with acute appendicitis, or if no other cause was found for the pain, the patient was placed in steep Trendelenberg position. A second trocar (5 mm) was placed in the right lower quadrant, lateral to the rectus sheath (Fig. 2), under direct vision. The first assistant placed an atraumatic or bowel-grasping forceps through this trocar and gently displaced the omentum and cecum with a sweeping motion. Sometimes the appendix became visible at this point; more commonly, it was not.

The third trocar (11 or 12 mm) was placed in the midline and suprapubic. If the patient was small, this trocar was placed to the left of the midline to allow sufficient working distance between trocars and avoid "crossing swords" within the confines of the abdominal cavity (again, the rectus muscle was avoided). This trocar will hereafter be termed the "working trocar," because it is through this port that the surgeon operates. The surgeon placed an atraumatic grasping forceps through the working trocar and grasped the appendix if it was visible. If the

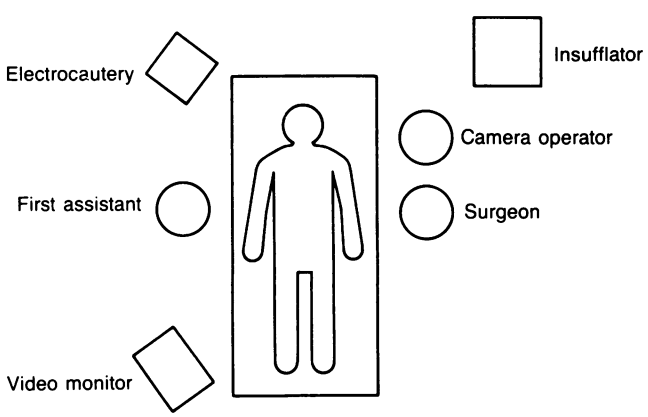

FIG. 1. Position of surgeon, first assistant, camera driver, insufflator, electrocautery, and video equipment.

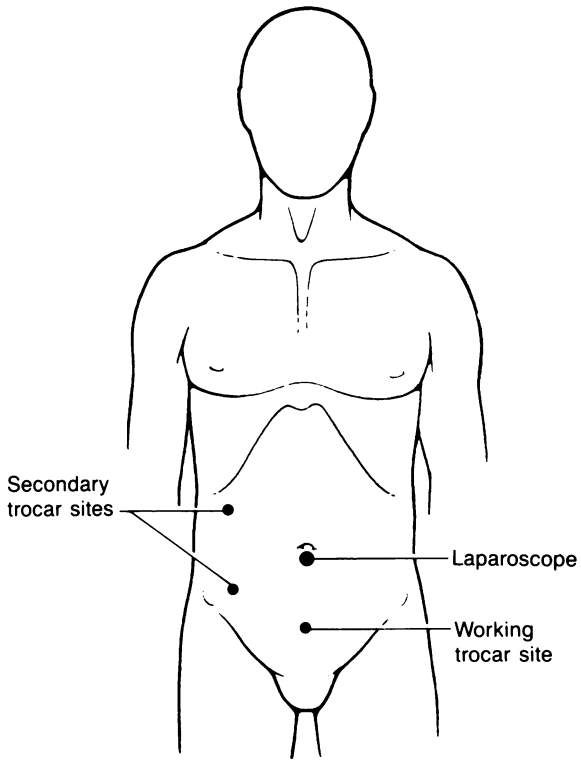

FIG. 2. Placement of trocars for laparoscopic appendectomy.

appendix was not yet visible, the surgeon grasped the cecum and retracted it cephalad.

The fourth (5 mm) trocar was placed in the right upper quadrant, near the anterior axillary line. Placement of this trocar varied, depending on the location of the appendix and the patient's size. The first assistant grasped the cecum with an atraumatic grasping forceps and continued the cephalad retraction begun by the surgeon. The appendix then was grasped by the first assistant (Fig. 3A). If the appendix was so inflamed as to be difficult to grasp, it was encircled with a pre-tied chromic ligature (Endoloop, Ethicon Inc., Somerville, NJ), and the long tail of this ligature was used for retraction (Fig. 3B). The first assistant manipulated the appendix until it and its mesentery were clearly displayed for the surgeon.

The surgeon made a window in the appendiceal mesentery with an alligator-tipped forceps. Clips (EndoClip; US Surgical Corporation, Norwalk, CT) were applied (Fig. 3C) and the mesentery was divided with hook scissors. The mesentery then was divided serially until the base of the appendix was disclosed. The base was carefully inspected to confirm that the juncture of the appendix with the cecum had been defined. The appendix was ligated with two chromic ligatures at the base of the cecum, and a third ligature was placed approximately 1 cm distal (Fig. 3D). The appendix was divided with scissors and removed through the working trocar.

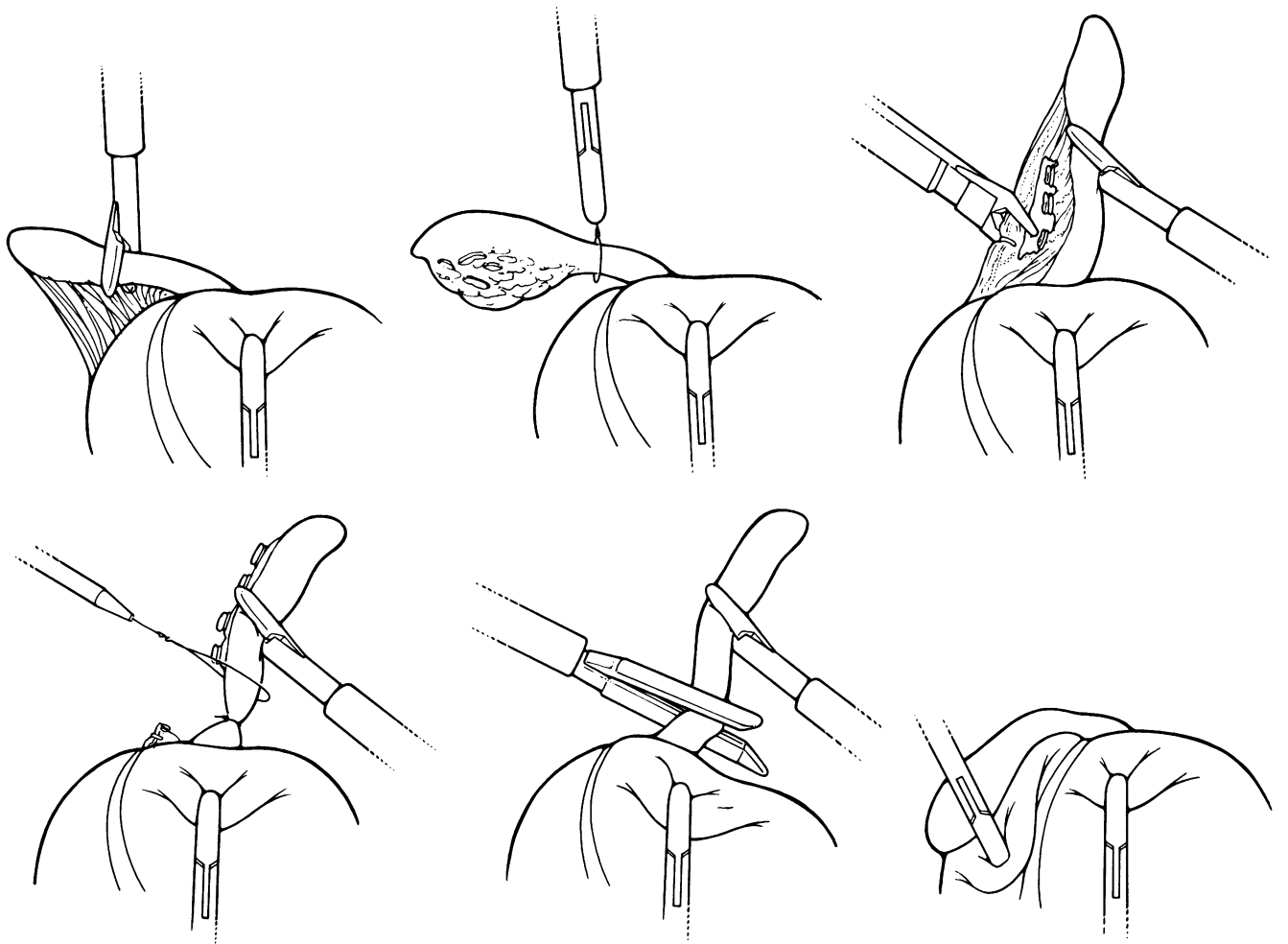

FIG. 3. (A, top left) The appendix is grasped by the first assistant while traction of the cecum cephalad maintains exposure. (B, top center) A very inflamed and rigid or friable appendix may be handled more easily by encircling it with a pre-tied chromic ligature. The first assistant grasps the tail of the ligature rather than the appendix. (C, top right) The mesentery is serially clipped and divided by the surgeon. (D, bottom left) Two pre-tied chromic ligatures are placed at the base of the appendix where it merges with the cecum, and a third ligature is placed approximately 1 cm distally. (E, bottom center) Alternatively, an endoscopic stapler is placed across the base of the appendix after the mesentery has been divided. (F, bottom right) A retrocecal appendix may be exposed by incising the white line and rolling the cecum cephalad and medially.

The stump of the appendix and the appendicular artery then were carefully inspected. If the clip on the appendicular artery seemed insecure, it was secured with an additional chromic ligature. The appendiceal stump was not cauterized nor was an attempt made to invert it.

When the stapling device (Endo-GIA; US Surgical Corporation, Norwalk, CT) was used, a 12-mm port was used for the working trocar. A window was made in the mesentery at the base of the appendix. The stapler was loaded with a 1.0-mm cartridge and fired across the mesentery, securing it with a triple row of staples and dividing it. The stapler was reloaded with a 1.5-mm cartridge and fired across the base of the appendix (Fig. 3E). The appendix was removed through the 12-mm port.

When the appendix was retrocecal, mobilization and exposure was accomplished by sharply incising the white line lateral to the cecum and rolling the cecum medially and cephalad (Fig. 3F).

Monopolar electrocautery was used for hemostasis. The operative site and pelvis were copiously irrigated with saline at the conclusion of the procedure. Neither antibiotics nor heparin were added to the irrigation solution. No drains were used. Trocar sites were inspected for bleeding at the conclusion of the procedure. The fascia of the large (10 to 12 mm) trocar sites was closed with Vicryl (Ethicon); the fascia of the 5-mm trocar sites was left open. The skin was closed with an absorbable subcuticular suture.

All patients received a single dose of a cephalosporin antibiotic (cefoxitin) intravenously on call to surgery and at least two more doses in the immediate postoperative period. Patients in whom purulent-appearing fluid was

TABLE 1. *Laparoscopic Diagnosis, Treatment, and Pathologic Diagnosis*

Laparoscopic Diagnosis	No.	Treatment	Pathologic Diagnosis	No.
Acute salpingitis	1	Antibiotics	—	
Possible appendicitis	3	Laparoscopic appendectomy	Fibrosis	1
			Chronic inflammation	1
			Normal appendix	1
Acute appendicitis	9	Laparoscopic appendectomy	Acute appendicitis	8
			Appendix with fecalith	1
	1	Open appendectomy	Acute appendicitis with perforation	1
Perforated sigmoid diverticulitis	1	Hartmann's procedure	Perforated diverticulitis	1
Torsion of ovarian cyst	1	Laparoscopic cystectomy	Acute torsion of dermoid cyst	1

noted in the abdomen were continued on antibiotics until operative culture results were available. Antibiotics were discontinued when patients were clinically well and had been afebrile for 24 hours. The Foley catheter and nasogastric tube were removed in the recovery room. Antiemetic agents were not routinely used, because of concern that complications might be masked.

Results

Patient Population and Presentation

There were nine men and boys and seven women and girls, with ages ranging from 16 to 47 years (mean, 27.2 years). Patient weights ranged from 46 to 122 kg (mean, 71.8 kg). All patients had right lower quadrant pain of at least 24 hours' duration. Three patients had a history of prior similar attacks that resolved spontaneously. Preoperative temperatures ranged from 37.1 to 39.4 C (mean, 37.9 C) with total white blood cell counts ranging from 6000 to 26,000/mm^3 (mean, 13,400/mm^3). Radiographic findings were nonspecific, and no fecaliths were seen.

Findings at Laparoscopy and Surgical Management

A diagnosis was established at laparoscopy in all 16 patients. The laparoscopic diagnoses, treatment, and pathologic diagnoses are detailed in Table 1. A presumptive diagnosis of possible or definite appendicitis was made at laparoscopy in 13 patients. Laparoscopic appendectomy was successfully achieved in all 12 patients in whom it was attempted; three of these patients had retrocecal appendices and the other nine had the appendix lying intraperitoneally. One patient had a gangrenous, perforated appendix. This patient was an insulin-dependent diabetic and was the fifth patient in the series; the attending surgeon judged that open management would be safer than LA, and did not attempt LA.

Three patients had laparoscopic diagnoses other than acute appendicitis. Two of these patients were managed laparoscopically. One patient had salpingitis with a normal appendix and underwent diagnostic laparoscopy only. A second patient had an acute torsion of a large dermoid cyst of the right ovary. The infarcted, torsed adnexa was divided using the endoscopic stapling device. The working trocar site had to be enlarged to deliver the cyst. The third patient had a normal appendix at laparoscopy, with an abnormal appearing sigmoid colon and free pus in the pelvis. A presumptive diagnosis of colonic perforation, possible diverticulitis, was made. Laparotomy with Hartmann's procedure was performed and subsequent pathologic examination disclosed perforated diverticulitis.

Conversion Rate and Complications

Two of the 16 patients underwent laparotomy (12.5%; perforated appendix, perforated sigmoid diverticulitis). In addition, two patients required extension of a trocar site. One of these patients had persistent muscle bleeding from the right lower quadrant trocar site, visible at laparoscopy. It was treated by exploration of the trocar site and ligation of a muscle bleeder. The second patient had a 10-cm torsed dermoid cyst containing hair and semisolid material. The cyst could not be decompressed sufficiently to deliver it through an existing trocar site. The working trocar site was extended as a minilaparotomy to allow the cyst to be delivered without soilage of the peritoneal cavity. Thus a total of four patients (25%) of the original 16 required either formal laparotomy for management of their pathology, exploration of a trocar site for bleeding, or extension of a trocar site.

Complications occurred in four of 16 (25%) laparoscopic procedures (Table 2). No patients required reoperation. Although one patient developed a small stitch

TABLE 2. *Complications Occurring in 14 Patients Treated Laparoscopically*

Complication	Management and Outcome
Fever, abdominal pain 2 weeks after operation	Computed tomography scan negative for abscess, IV antibiotics × 1 wk, resolved
Trocar site bleeding	Recognized at laparoscopy, trocar site explored, vessel ligated
Unilateral pulmonary edema in recovery room	Positive pressure ventilation (<12 hr), resolved
Stitch abscess at trocar site	Suture removed in clinic, resolved

abscess, there were no significant wound infections and no intra-abdominal abscesses. There were no deaths.

Operative Time

Operative times for the 14 patients treated laparoscopically ranged from 53 to 142 minutes (mean, 96.6 minutes). In the 12 patients who underwent LA, the mean operative time was 95.7 minutes (range, 53 to 142 minutes). The operative times did not appear to decrease with team experience (Fig. 4).

Postoperative Stay and Return to Normal Activities

Mean postoperative stay in the 14 patients treated laparoscopically (12 LA, 1 diagnostic laparoscopy, 1 ovarian cystectomy) was 2.4 days (range, 1 to 4 days). In the 12 patients who underwent LA, the mean stay was 2.5 days (range, 2 to 4 days). At the time of the first postoperative visit, between 1 and 2 weeks after surgery, all patients reported that they had returned to normal activities.

Resident Training

All procedures were performed by chief residents with an attending surgeon as first assistant. A total of six chief residents participated. Each chief resident had performed a mean of eight laparoscopic cholecystectomies (range, 1 to 17) at the time of performance of first LA. Four chief residents each performed one LA, and two chief residents each performed four LAs. As confidence was gained with the technique, the number of patients in whom the laparoscopic approach was selected preferentially increased, as compared with those in whom open appendectomy was chosen at the time of presentation (Fig. 5). During the first year of the study, three laparoscopic and 14 open operations for right lower quadrant pain were performed in the gastrointestinal surgical service at University of Mississippi Medical Center; in contrast, during the second 10 months of the study, there were 11 laparoscopic operations and one open operation done.

Discussion

Laparoscopic appendectomy was first described by Semm, and was initially limited to incidental appendectomy performed at the time of gynecologic laparoscopy or to appendectomy for chronic appendicitis or endometriosis.[1-4] As familiarity developed, the technique was further refined and indications extended to equivocal cases of appendicitis and finally to known appendicitis.[5-19]

The surgical technique is now well developed, and several methods have been described for both antegrade and retrograde appendectomy. The original technique of Semm most closely mimicks the open technique used by most American surgeons.[1,3,14] After careful exposure of the appendix, the appendiceal mesentery is ligated and divided. The appendix is ligated and the stump invaginated by purse string or Z-stitch.[14] Fallopian tube ligation bands and clips have been described as alternative methods to secure the appendiceal stump.[5,10,18] The clip may have some advantage in thickened appendices.[18] Most laparoscopic surgeons, however, have preferred to ligate the base of the appendix with a Roeder knot, generally in the form of a pre-tied, commercially available chromic

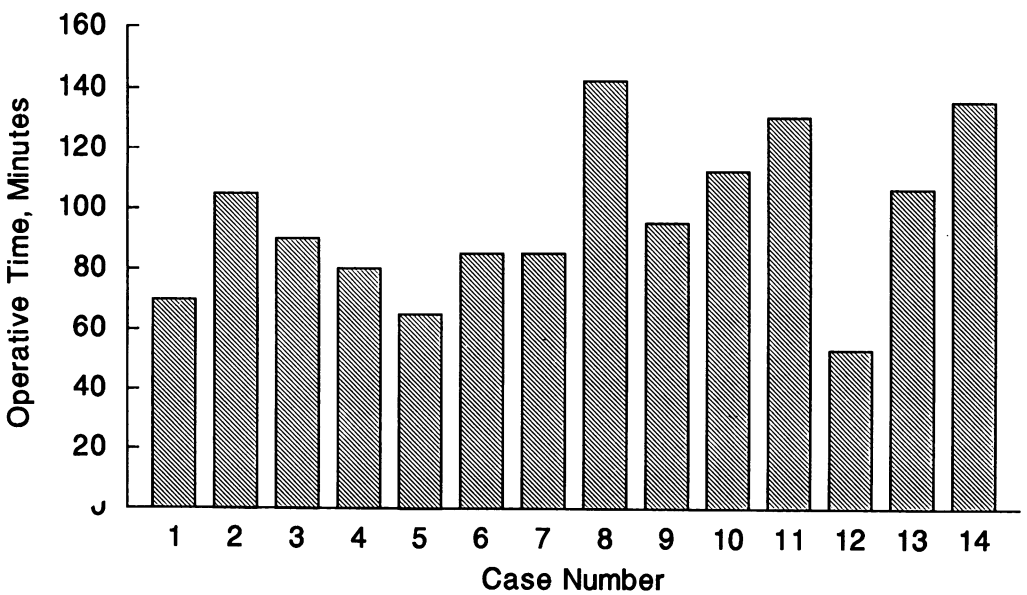

FIG. 4. Operative time for 14 sequential laparoscopic procedures for right lower quadrant pain. Two laparoscopic procedures that were converted to formal laparotomy are not included in the graph.

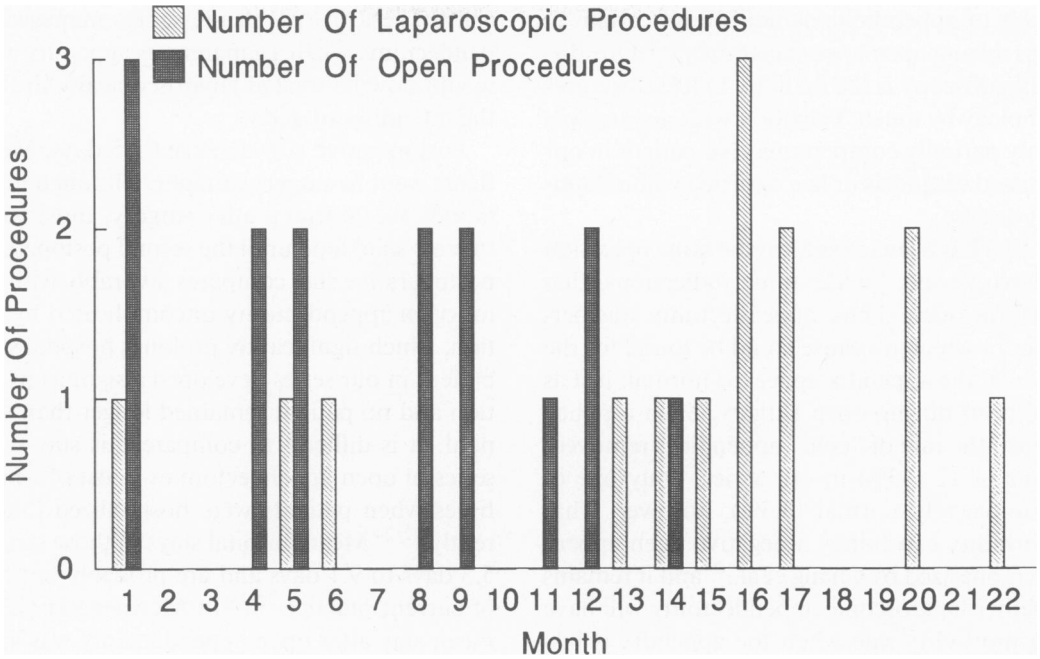

FIG. 5. Laparoscopic and open operations for right lower quadrant pain performed on one teaching service during the study period. Two of the laparoscopic procedures detailed in this report were performed on other teaching services by chief residents under the direction of attending surgeons (CSC, FM) involved in this study. Those two procedures do not appear in this graph.

ligature as we have used.[15,16] Closure using an endoscopic stapling device (Endo-GIA; US Surgical Corporation, Norwalk, CT) has been described and was used in one of our cases.[17] Inversion of the stump can be performed by laparoscopic suturing.[1,3,14] It is generally omitted because comparative studies of stump inversion during open appendectomy have failed to demonstrate any advantage[20] and because suturing is still technically difficult for most laparoscopic surgeons. Although the procedure can be done with three punctures and has been described with two, the use of four punctures allows better control by the attending surgeon.

The negative appendectomy rate in most series of open appendectomies ranges from 20% to 30% in adults.[21-24] It may be higher in the subset of young women of reproductive age, in whom the differential diagnosis of gynecologic pathology can be difficult.[25-27] Berry and Malt,[24] in a detailed review of multiple large published series of appendectomies, showed that the perforation rate increases linearly with diagnostic accuracy. The generally accepted negative appendectomy rate of 20% to 30% for adult patients recognizes this trade-off.[21] Laparoscopy has been advocated as a means of decreasing the negative appendectomy rate in patients, particularly female patients, with equivocal signs of appendicitis.[25-28] An initial series from the pediatric age group of 32 patients with suspected appendicitis demonstrated two false-negative laparoscopies and one false-positive.[25] In an early series, 42 of 46 laparoscopic examinations were successful, but the appendix was visualized directly in only four patients.[28] Indirect signs of appendicitis such as adherence of the omentum to the region of the appendix, cecal inflammation, or the presence of turbid fluid in the pelvis were used as indicators of acute appendicitis.[28]

Operative laparoscopic techniques now in common use were not available then. Because laparoscopy as performed in the United States requires general anesthesia, and because open surgery was required if appendicitis or, indeed, a surgical gynecologic problem was found, this method did not gain widespread popularity. The availability of laparoscopic instruments and techniques for appendectomy, management of ruptured ectopic pregnancies, ovarian cysts, and so on renders this approach more promising. In our series, the appendix was successfully visualized and the pathology identified in all patients. The clear visualization of the upper abdomen, pelvis, and adnexae that is obtained laparoscopically is in contrast to the limited view obtained through the standard McBurney or Rocky-Davis incision. As in laparoscopic cholecystectomy, this advantage is most appreciated in the obese patient. Two of our patients weighed more than 100 kg; one underwent successful LA and the second laparoscopic ovarian cystectomy. In our institution, ruptured ectopic pregnancy is now managed laparoscopically. Two other gynecologic conditions (salpingitis and a torsion of an ovarian cyst) were identified and managed laparoscopically in our series. Laparoscopy allows thorough inspection of all four quadrants of the abdomen. In our series, three patients (18.8%) had other causes for their pain accurately determined at laparoscopy.

The diagnosis of appendicitis is not always certain at laparoscopy, as during open appendectomy.[22–28] One disadvantage of laparoscopy is the inability to feel structures and judge pathology by touch. Palpation with instruments and probes only partially compensates. No patient in our series had a missed diagnosis or has returned with inflammatory bowel disease.

Our philosophy has been to perform the same operation through the laparoscope, for the same indications, that we would perform open. Thus, appendectomy was performed in cases in which no cause could be found for the pain and in which the appendix appeared normal, just as it would have been during open surgery. Such a policy will not diminish the rate of "cold" appendices removed, which was four of 12 (33%) in our series. Only one of these was histologically normal (8.3%), however. That significant morbidity can follow a negative open appendectomy was emphasized by Chang et al.,[29] and it remains to be seen whether laparoscopic appendectomy will have an acceptable morbidity rate when the appendix is histologically normal.

Wound infection remains a significant complication of open appendectomy, averaging 8.5% to 20%.[22–24] In contrast, Pier and Götz reported only three wound infections in a series of 625 LAs.[15] In the only comparative series published to date, the wound infection rate was 11% in open and 4% in laparoscopic appendectomies, and the only wound infection after LA occurred in a patient with a gangrenous appendix who was converted to open appendectomy.[19] When the appendix is withdrawn through the trocar or through an appendix extractor during LA, there is no contact of infected material with the subcutaneous fat. Although one suture abscess occurred, there were no wound infections in our small series. We remain concerned about the possibility of fascial infection, however, and would consider leaving the skin open in the event of fascial contamination.

Operative times did not diminish with experience in our series, despite increasing confidence in the technique as shown by increased use during the second year of the study. In fact, our operative times are higher than those quoted by most authors.[12,15,19] We believe that this was related to the infrequent nature of these procedures (averaging less than one per month over the study period), that most cases were done on the evening or night shift with operating room personnel unfamiliar with equipment and supplies, and the unpredictable nature of the anatomy and findings. Involvement of residents as surgeons and camera drivers and turnover of resident teams, with six chief residents being trained during the study period, may have contributed to longer operative times as well. We regard these factors as inevitable within the training environment.

As confidence was gained with the technique, we performed an increasing number of our cases laparoscopically. The fifth case in the series, managed by open appendectomy when a gangrenous appendix was visualized, would now be treated laparoscopically in the opinion of the attending surgeon.

Postoperative stay averaged 2.5 days. Most of our patients went to surgery at night. Although all started clear liquids the morning after surgery, most were unable to tolerate solid food until the second postoperative day. This postoperative stay compares favorably with that reported for open appendectomy uncomplicated by wound infection, which significantly prolongs hospital stay.[19,22–24] No patient in our series developed a significant wound infection and no patient remained longer than 4 days in hospital. It is difficult to compare this stay with published series of open appendectomies, most of which date from times when patients were hospitalized longer than currently.[22–24] Mean hospital stays in those series range from 5.3 days to 9.1 days and are probably not representative of current practice.[22–24] In McAnena et al.'s series,[19] the mean stay after open appendectomy was 4.8 days, compared with 2.2 days after laparoscopic appendectomy. This latter postoperative stay is quite comparable to our series. All of our patients were back to normal activities at the time of their first postoperative visit, between 1 and 2 weeks after surgery.

One complication in our series, trocar site bleeding, is unique to laparoscopy. It was recognized during surgery in our patient, and simple extension of the trocar site with direct suture of the bleeding vessel controlled the bleeding. Although Leahy has recommended "laparoscopic transillumination" as a method for visualization of the inferior epigastric vessels, most of our patients were too obese for this to be feasible.[10] We believe that this problem can be minimized by placement of trocars lateral to the rectus sheath. The three other complications, a phlegmon, a suture abscess, and unilateral pulmonary edema (possibly drug-related), are not unique to laparoscopy.

The procedure that we use for LA allows a chief resident to perform the critical steps of the operation with full control being maintained by the first assistant. For this reason, one trocar (the working trocar) was used by the surgeon, and two trocars were used by the first assistant. The procedure could easily be modified to allow a two-handed approach by the surgeon. Reserving two trocars for the attending surgeon has facilitated teaching the operation to our chief residents, especially because many of these procedures were done late at night.

The reaction of junior residents to the increasing encroachment on their cases (first cholecystectomy and then appendectomy) has been interesting. By making the first- or second-year resident an integral part of the team (camera driver) from the beginning, resentment has been minimized. In our program, laparoscopic cholecystectomy is starting to be a third- or fourth-year resident case rather than a chief resident case. This has helped to minimize

junior resident anxiety. In addition, LA has been primarily performed on one of three general surgery services, allowing experience with open techniques to be gained on the other two services.

We have noted several pitfalls and difficulties in laparoscopic appendectomy:

1. If the patient is positioned on the operating table with the arms outstretched, it will be difficult for the first assistant and camera operator to stand comfortably. The arms should be tucked at the patient's side.
2. Placement of the trocars too close together will make it difficult for the surgeon and first assistant to work together without interference. This is most likely to be a problem in the small, slender patient.
3. Troublesome bleeding can result if trocars are placed through the rectus muscle or inferior epigastric vessels. Avoid this by placing trocars lateral to the edge of the rectus sheath.
4. If the appendix is extremely mobile, it may be pulled into the upper abdomen by the first assistant. This change of field makes eye–hand coordination difficult for the surgeon and decreases the space available for operating. It also forces the camera operator to move toward the foot of the table, crowding the surgeon. This can be recognized by noting the direction in which the laparoscope is pointing. The laparoscope should point into the right lower quadrant. This is easily corrected by pulling the appendix back down into the lower abdomen.
5. A very long appendix may be difficult to retract because the grasper holding the appendix is pushed up against the underside of the abdominal wall. Such an appendix must be regrasped closer to the base, and the tip allowed to dangle, so that the base of the appendix at the cecum can be accurately identified.

In summary, we believe that laparoscopic appendectomy can be safely performed within the context of a training program. Surgical chief residents who are experienced in the techniques of operative laparoscopy, including laparoscopic cholecystectomy, can perform the procedure with the assistance of an experienced attending surgeon. Diagnostic accuracy is excellent and postoperative complications are acceptable. In particular, wound infection rates may be lower in LA.[15,19] Operative time will probably remain higher than that required for open appendectomy, and postoperative stay, largely determined by length of antibiotic treatment, is comparable.

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Discussion

DR. THOMAS R. GADACZ (Augusta, Georgia): Dr. Ochsner, Dr. Jones, it is a pleasure to discuss Dr. Scott-Conner's paper on laparoscopic appendectomy, and I appreciate a copy of the manuscript. We have had experience with this procedure, but I would like to limit my comments to her paper.

I have two technical and a few general questions. You used four cannulas for the procedure. How important was the right axillary cannula and did it help with exposure? The second technical question is the