REVIEW ARTICLE

ANNALS OF SURGERY
Vol. 225, No. 3, 252–261

Appendectomy

A Contemporary Appraisal

Douglas A. Hale, M.D., F.A.C.S., Mark Molloy, M.D., F.A.C.S., Richard H. Pearl, M.D., F.A.C.S., David C. Schutt, M.D., and David P. Jaques, M.D., F.A.C.S.

From the Quality Assurance Office, Assistant Secretary of Defense (Health Affairs), Washington, D.C.

Objective

The authors present an accurate and comprehensive snapshot of appendicitis and the practice of appendectomy in the 1990s.

Methods

Appendectomies were performed on 4950 patients in 147 Department of Defense hospitals worldwide over a 12-month period ending January 31, 1993.

Results

The median age was 23 years (range, 6 months to 82 years) with 64% males and 36% females. The patients were assigned a diagnosis of normal appendix in 632 (13%) cases, acute appendicitis in 3286 (66%) cases, and perforated appendicitis in 1032 (21%) cases. There were no differences in perforation and normal appendix rates between those operations performed in teaching hospitals *versus* community hospitals or between high-volume hospitals (≥100 appendectomies/year) *versus* low-volume hospitals. Both a preoperative temperature ≥ 100.5 and a preoperative leukocyte count ≥ 10,000 were incapable of discriminating between patients with appendicitis and those with a normal appendix. Multivariate analysis showed a significantly increased risk of perforation associated with age younger than or equal to 8 years (38% *vs.* 18%) and age older than or equal to 45 years (49% *vs.* 18%). Females had a significantly higher rate of normal appendices (19% *vs.* 9%) and a lower rate of perforation (18% *vs.* 23%). The complication rates to include reoperation and intraabdominal sepsis were markedly increased in those patients with perforation. There were four deaths in this series (0.08%).

Conclusions

Despite a marked decline in associated mortality over the past 50 years, rates of perforation and negative appendectomy remain unchanged because they are influenced strongly by factors untouched by the intervening technologic advances.

It has been nearly 110 years since Reginald Heber Fitz was able to consolidate a fragmented surgical philosophy regarding the pathophysiology and treatment of appendicitis with his now famous paper, yet appendicitis continues to be a paradox.[1] Although considered one of the most elemental of general surgical disease processes, its presentation regularly confounds the diagnostic acumen of even the most experienced of surgeons. Investigation of this quandary traditionally has been accomplished through comprehensive reviews of appendectomy that typically have been based on retrospective analyses of approximately 1000 cases.[2-8] Factors limiting the use and general applicability of these studies include long accrual periods, restricted social and geographic population bases, and the fact that most are single institution studies representing a rather limited variety of surgical management techniques.

Herein we present a 12-month review of appendectomies performed in the 147 Department of Defense hospitals located throughout the world. Our goals are twofold: 1) to present an accurate and comprehensive snapshot of appendicitis and the practice of appendectomy in the 1990s and 2) to identify those factors most responsible for the lack of improvement in diagnostic accuracy of acute appendicitis.

MATERIALS AND METHODS

This study was conducted as part of a program of external civilian peer review and continuous quality improvement of medical care rendered in Department of Defense hospitals. The medical records of all patients undergoing nonincidental appendectomy over a 12-month period ending in January 1993 were collected for analysis. These operations were performed in 147 Department of Defense hospitals worldwide. The hospitals included tertiary referral medical centers and community hospitals. The hospitals range in size from a few dozen beds to nearly 1000 beds. The level of experience of the surgeons performing the cases spans the entire spectrum from recent residency graduates to surgeons with more than 20 years of experience. The population served by this system consists of some 9 million dependents, retirees, and active-duty members.

Cases were identified through review of discharge diagnoses and hospital operative logs. Records were retrieved in 97% of cases. The medical records were reviewed by professional medical chart abstracters who entered data for each patient into a 121-field database specifically designed to collect data pertinent to issues surrounding the practice of appendectomy. Readmissions within 45 days of the date of appendectomy were scrutinized to identify major complications. In addition, centralized outpatient medical records of the patients undergoing appendectomy were reviewed to identify minor complications not requiring admission.

Criterion indicating possible instances where care or its documentation could be improved was established. Records meeting these preset criteria (including all cases of perforation and complications) then were reviewed by surgeons in civilian practice for relevance, consistency, and a determination of whether the community standard of care was met. Records containing unclear data were reanalyzed after communication with the attending surgeon involved.

Data were collected in the form of categoric and continuous variables as well as narrative text. Variables were analyzed with chi square analysis, analysis of variance, and multiple logistic regression as appropriate. Descriptive statistics are used throughout.

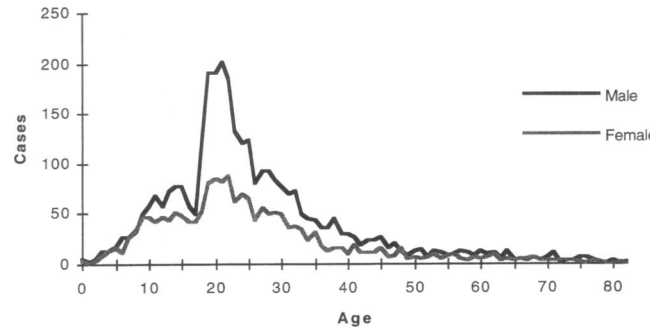

Figure 1. Distribution of patient ages by gender.

RESULTS

General Demographics

A total of 4950 nonincidental appendectomies were performed over this period. The mean age at the time of surgery was 25.5 ± 13.3 years (range, 6 months–82 years, Fig. 1). Of patients undergoing appendectomy, 3184 were male (64.4%) and 1762 were female (35.6%). These demographics are consistent with those of other reported series (Table 1). Whites comprised 80.4% of the sample, blacks 12.2%, Hispanics 4.0%, Asian–Pacific islanders 3.3%, and Native Americans 0.1%. Fifty-four percent of the procedures were performed on active-duty members

Address reprint requests to Douglas A. Hale, M.D., Division of Organ Transplantation, New England Deaconess Hospital, One Deaconess Road, Boston, MA 02215.

Accepted for publication March 20, 1996.

The opinions expressed in this article are those of the authors and do not reflect the opinions of the United States Army or the Department of Defense.

Table 1. COMPARISON WITH PREVIOUS STUDIES

Author	N	Time Frame	% Male	Mean Age (yr)	Normal Rate (%)	Perforating Rate (%)
Babcock[2]	1662	1936–1955	NA	NA	NA	25
Mittelpunkt[3]	1000	1960–1964	67	43	NA	24
Lewis[4]	1000	1963–1973	64	NA	20	21
Silberman[5]	1013	1976–1978	NA	NA	15	19
Pieper[6]	1018	1972–1976	49	22	32	20
Maxwell[7]	844	1985–1987	77	24	13	18
Andersson[8]	3029	1984–1989	49	21	31	16
Hale (current study)	4950	1992–1993	64	26	13	24

NA = not applicable.

or military retirees, 18% were performed on their spouses, and 28% were performed on their children.

Diagnosis

For purposes of analysis, the patients were divided into three diagnostic groups: 1) normal appendix, 2) acute appendicitis (no perforation), and 3) perforated appendicitis.

A pathologic diagnosis of normal appendix was returned in 653 cases (13.2%). In 506 of these cases, the clinically based postoperative diagnosis taken from the operative report also indicated a normal appendix. The operative diagnosis rendered in 126 cases was appendicitis with a host of adjectives (*i.e.,* minimal, early, mild, slight), indicating a less-than-overwhelming confidence in its accuracy. In the remaining cases, clinical conditions were encountered in lieu of acute appendicitis and were most likely responsible for the clinical findings leading to the diagnosis of acute appendicitis. These conditions included right ovarian cyst (n = 8), *Enterobius vermicularis* infestation (n = 8), colon cancer (n = 4), salpingitis (n = 2), Meckel's diverticulitis (n = 2), torsed appendix epiploicae (n = 2), cecal volvulus (n = 1), and presence of a straight pin in the lumen of the appendix (n = 1). Ten patients with a normal appendix had appendicolithiasis noted in their pathology reports.

An operative diagnosis of acute appendicitis was confirmed pathologically in 3265 cases (66.0%). The presence of an obstructing appendicolithiasis was documented in the operative report or path report in 254 instances (7.8%). Sixteen patients had tumors either causing the obstruction leading to appendicitis or noted incidentally at the time of appendectomy. These included 12 appendiceal carcinoids, 2 appendiceal adenocarcinomas, and 2 cecal adenocarcinomas.

An operative diagnosis of perforated appendicitis was confirmed pathologically in 1032 cases (20.8%). The presence of an obstructing appendicolithiasis was documented in the operative report or path report in 126 instances (12.2%). Five tumors were identified at the time of surgery, including four appendiceal carcinoids and one cecal adenocarcinoma.

Age

Age had a significant effect on the risk of an individual with appendicitis having a perforated appendix at the time of surgery. The perforation rate (*i.e.,* number of perforated cases/total number of cases of appendicitis) increased at both ends of the age spectrum (Fig. 2). The overall risk of perforation for individuals having appendicitis in the younger than or equal to 8 years and older than or equal to 45 years age ranges is 48% *versus* only 20% in those individuals between the ages of 8 and 45 ($p < 0.001$, Table 2).

The negative appendectomy rate (*i.e.,* number of negative appendectomies/total number of cases) in patients younger than 5 years old or older than 45 years old were 22% and 4%, respectively. The rate of negative appendec-

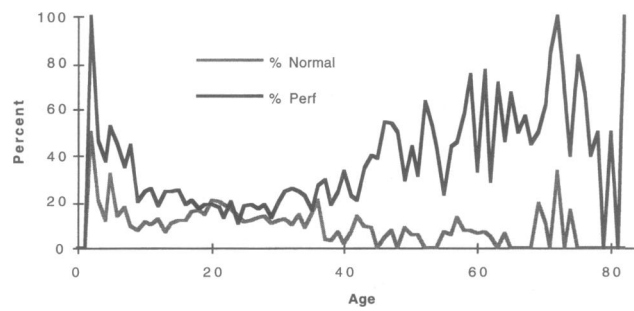

Figure 2. Distribution of patient ages by perforation rate and normal appendix rate.

Table 2. RESULTS OF LOGISTIC REGRESSION ANALYSIS COMPARING ACUTE WITH PERFORATED APPENDICITIS

Factor	R^2 (%)	T Ratio	p
Temperature >100.5 F	7.7	17.1	≤0.0001
Age ≥ 65 yr	1.3	8.1	≤0.0001
Age ≤ 8 yr	0.5	4.6	≤0.0001
WBC >10 × $10^3/\mu L$	0.4	3.9	0.0001
Gender	0.1	2.4	0.0159

WBC = white blood cell.

tomy for patients between the ages of 5 and 45 was 13%. Both of these differences were significant on multivariate analysis ($p < 0.05$, Table 3).

Gender

Appendectomies were performed on 3186 males and 1764 females. Figure 3 illustrates the distribution of diagnosis (normal, acute, perforated) by gender. Males were somewhat more prone to perforation than were females, 25% *versus* 22% ($p = 0.016$, Table 2). Conversely, the rate of normal appendices being found at the time of surgery was elevated significantly in females, 20% *versus* 9.4% ($p < 0.001$, Table 3).

Although there was no significant overall difference in the age distribution of males and females in this study ($p = 0.17$, t test), there was a slight increase in the proportion of men in the 18- to 25-year range (Fig. 4). This most likely reflects the influence of the active-duty population.

Table 3. RESULTS OF LOGISTIC REGRESSION ANALYSIS COMPARING APPENDICITIS (ACUTE AND PERFORATED) WITH NEGATIVE APPENDECTOMY

Factor	R^2 (%)	T Ratio	p
WBC > 10 × $10^3/\mu L$	6.9	−18.2	≤0.0001
Gender	1.6	−9.3	≤0.0001
Age ≥ 65 yr	0.2	−2.45	0.0144
Age ≤ 8 yr	0.1	2.42	0.0154
Temperature > 100.5 F	<0.1	−1.04	0.2986

WBC = white blood cell.

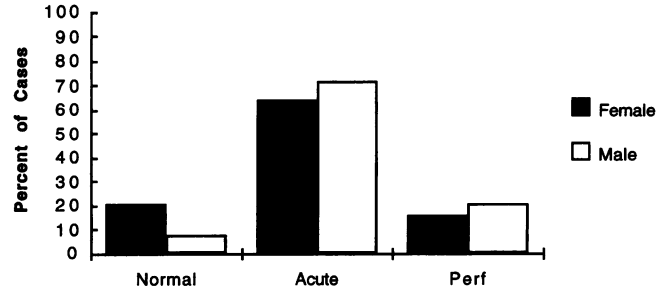

Figure 3. Distribution of diagnosis by gender.

Race

Race had little influence on the rates of normal appendices and perforation (Fig. 5). The rate of perforation in Native American–Eskimo patients was over 70% with no patients having a normal appendix at the time of surgery. Appropriate caution should be exercised in attempting to draw conclusions regarding this finding, however, because the number of Native American–Eskimo patients included in this study is very small (n = 7).

Leukocyte Count

An elevated leukocyte count was defined as greater than 10,000 cells/μL. Preoperative values were defined as having been drawn on the day of surgery either in the evaluating clinic, emergency department, or on the surgical ward. Patients with appendicitis (acute and perforated) had an elevated preoperative leukocyte count in 90% of cases (Fig. 4). Patients with a normal appendix had an elevated preoperative leukocyte count in 60% of cases, thus rendering this parameter of little use in discriminating between these populations despite its significance on multivariate analysis (Table 3).

Temperature

An elevated temperature was defined as greater than 100.5 F. Preoperative temperatures were defined as hav-

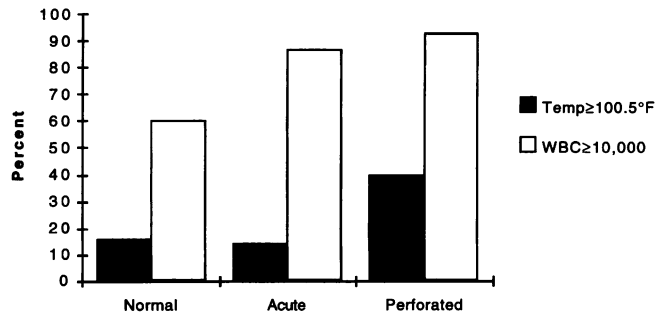

Figure 4. Percentage of patients in each diagnostic group with temperature ≥ 100.5 F and percentage of patients in each diagnostic group with leukocyte count ≥ 10,000.

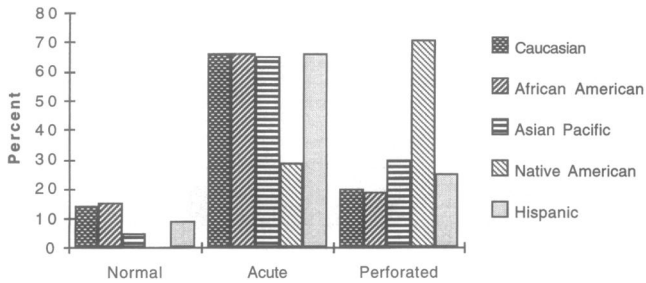

Figure 5. Distribution of diagnosis by race.

ing been recorded in the evaluating clinic, emergency department, or on the surgical ward on the day of surgery. There was no difference in the percentage of patients with acute appendicitis presenting with elevated temperatures when compared to patients with normal appendices (both approximately 15%). The percentage of individuals with perforated appendicitis presenting with an elevated temperature was higher, but was still only 40% (Fig. 4). Although this factor achieves statistical significance on multivariate analysis, its relatively low incidence in all three diagnostic groups imparts little in the way of diagnostic value (Table 2).

Hospital Type and Volume

Thirty percent (n = 1472) of the appendectomies were performed in teaching centers. There were no differences in rates of perforation or normal appendices between these and community hospitals. Twenty-four percent (n = 1167) of cases were done in hospitals having volumes of more than 100 appendectomies per year. There was no difference in the rates of perforation or normal appendices between these hospitals and those performing fewer (Fig. 6).

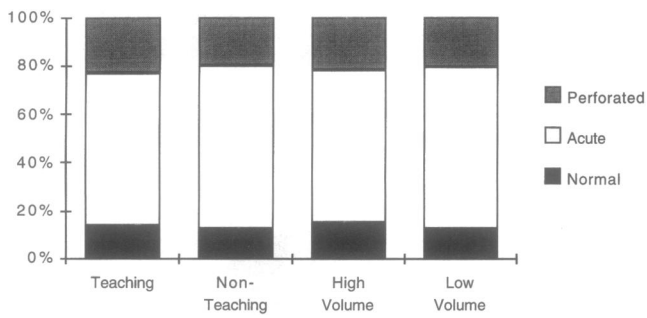

Figure 6. Distribution of diagnoses in medical centers (teaching), community hospitals (nonteaching), hospitals performing 100 or more appendectomies per year (mean time to failure ≥ 100), and hospitals performing less than 100 appendectomies per year (mean time to failure < 100).

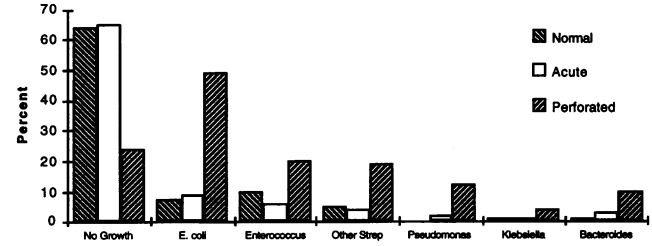

Figure 7. Distribution of organisms isolated from peritoneal cultures stratified by diagnosis.

Bacteriology

Intraoperative cultures of peritoneal fluid were obtained in 2522 cases (51%). A diagnosis of normal appendix was made in 184 of these cases, 1499 were diagnosed as acute appendicitis, and the remaining 839 were obtained in cases of perforated appendicitis. No growth was obtained in 64% of normal cases, 65% of acute appendicitis cases, and 24% of perforated appendicitis cases. The most commonly isolated organism was *Escherichia coli* followed by Enterococcus and other Streptococcus species. Less commonly encountered organisms included Pseudomonas, Klebsiella, and Bacteroides species (Fig. 7).

Antibiotics

Perioperative (prophylactic) antibiotics were administered to 4650 (94%) patients. Second-generation cephalosporins were administered most often (60%), followed by aminoglycoside-based combinations (15%), beta-lactamase inhibitors (12%), third-generation cephalosporins (4%), and other miscellaneous antibiotics (8%). The postoperative antibiotic therapy of patients with perforation consisted of aminoglycoside-based combination (43%), second-generation cephalosporin (33%), beta-lactamase inhibitor (13%), third-generation cephalosporin (4%), and other miscellaneous antibiotics (8%).

Length of Stay

The mean length of hospitalization for all patients was 4.3 days. The mean length of stay for patients with normal appendices and acute appendicitis was 3.8 and 3.4 days, respectively. Patients with perforated appendicitis had a significantly longer hospital mean stay of 7.2 days ($p < 0.001$, analysis of variance).

Pregnancy

Thirty-nine women were operated on while pregnant and 2 women were operated on 2 days postpartum. Preg-

nant women were assigned a diagnosis of perforated appendicitis in 2 instances, acute appendicitis in 25 instances, and normal appendix in 12 instances. One of the postpartum patients had a normal appendix and a broad-ligament hematoma accounting for her symptoms, whereas another patient had histologically confirmed acute appendicitis.

Preterm contractions occurred during the immediate perioperative period in 3 of the 25 patients with acute appendicitis. In all instances, they were arrested by appropriate medical intervention. One of the two patients with perforated appendicitis presented with preterm contractions, which were arrested successfully. The other patient with perforated appendicitis, although having no immediate perioperative contractions, was readmitted to the hospital on the eighth postoperative day with a spontaneous abortion. Three of the 12 patients with normal appendices had preterm contractions as part of their initial presentation, all successfully managed medically. The mean gestation of patients experiencing preterm contractions was 25.1 ± 8.0 weeks. This was not significantly different from the gestation of the remainder of the pregnant patients (20.0 ± 9.0). Similarly, the mean age of patients experiencing preterm contractions was 25.1 ± 6.0 years. Again, this was not significantly different from the age of the remainder of the pregnant patients (24.4 ± 5.0).

Laparoscopy

Laparoscopic appendectomies were attempted in 174 cases. Twelve cases required conversion to an open procedure secondary to difficult dissection, whereas 1 case was converted secondary to a right common iliac artery laceration made by a trocar. Laparoscopic procedures were distributed evenly between medical centers (n = 75, 5% of total medical center cases) and community hospitals (n = 87, 2% of total community hospital cases). One hundred seventeen (72%) of the laparoscopic appendectomies were performed in patients between the ages of 18 and 45, whereas 33 (21%) were performed in patients 18 years of age or younger and 12 (7%) were performed in patients older than 45 years of age. Five percent (n = 84) of all appendectomies performed on women were laparoscopic, whereas 2% (n = 78) of the procedures in men were laparoscopic.

Successfully completed laparoscopic appendectomies took approximately 50% longer to perform than did open appendectomies (Table 4). There was no significant decrease in the length of hospitalization associated with the use of laparoscopy (Table 5).

Morbidity

A total of 259 complications were recorded for an overall complication rate of 5.2%. There was no difference in the overall rates of complications between the normal appendix group and the acute appendicitis group (4% *vs.* 3%, respectively), whereas the complication rate associated with perforated appendicitis was 12%. The distribution of these complications by diagnosis is listed in Table 6.

The most common complication was wound infection (n = 124, 2.5%). The distribution of wound infections was not significantly affected by gender or age. The risk of a wound infection increased markedly with perforated appendicitis (6.4%) compared to the rate associated with normal appendices (1.8%) and acute appendicitis (1.4%), respectively. Intraoperative cultures were obtained in 88 (71%) of the patients in whom a wound infection developed subsequently. The spectrum of organisms identified from these cultures (no growth 23%, *Escherichia coli* 28%, *Bacteroides fragilis* 10%, Pseudomonas 7%) mirrored that obtained from patients who had no wound infection. There was no difference in the pattern of antibiotic usage in this subgroup of patients compared to the population at large. Two patients undergoing successful laparoscopic appendectomy had wound infections (1.2%). One of these patients had acute appendicitis, and the other had perforated appendicitis.

Urinary tract disorders (retention and infection) accounted for 25% (n = 64) of all complications. Urinary retention was slightly more common in patients with perforated appendicitis (1.8% *vs.* 0.8%, $p < 0.05$) and in males (1.3% *vs.* 0.6%, $p < 0.05$). Otherwise, the distribution of these complications was not affected significantly by diagnosis, age, or gender.

Eleven postoperative pneumonias were documented. The incidence of postoperative pneumonia was affected significantly by age (mean age, 45 ± 7 years, $p < 0.05$) and more than half of these complications were associated with the presence of perforation ($p < 0.05$). Gender had no influence on the rate of this complication.

Twenty-two small bowel obstructions were diagnosed within 45 days of appendectomy. Age and gender did not significantly influence the occurrence of this complication. However, it occurred nearly four times more commonly in patients with perforated appendicitis than in those with normal appendices or acute appendicitis (1.2% *vs.* 0.3%, $p < 0.05$). Fifteen cases of obstruction resolved with conservative measures alone, and 7 required laparotomy and lysis of adhesions.

Nineteen postoperative intraperitoneal abscesses were diagnosed. Patients with a diagnosis of perforated appendicitis were more than twice as likely to experience this complication as were patients with acute appendicitis (0.8% *vs.* 0.3%, $p < 0.05$). No patient with an original diagnosis of normal appendix had an intraperitoneal abscess develop. Ten abscesses were managed by open

Table 4. COMPARISON OF LAPAROSCOPIC AND OPEN PROCEDURE OPERATIVE TIME

	Normal	Acute	Perforated
Laparoscopic	86.6 ± 51 (37–280)	81.9 ± 27 (30–173)	88.5 ± 28 (35–130)
Open	57.4 ± 28 (9–265)	55.7 ± 30.9 (10–675)	68.8 ± 32 (10–265)

Values are given as minutes [mean ± standard deviation (range in parentheses)].

drainage, two were managed with transrectal drainage, and one was drained percutaneously with computed tomographic guidance. In two instances, the abscesses were managed successfully with antibiotics alone. It could not be determined how the remaining four abscesses were treated. This complication was distributed evenly across gender and age range.

Five enterocutaneous fistulas occurred after surgery. All patients had an original diagnosis of perforated appendicitis. Four fistulas were cecal in origin, and one originated from the small bowel. Two cecal fistulas required operative closure, and the remaining three closed with conservative management.

Four cases of pseudomembranous enterocolitis were documented after surgery. One occurred in a patient with an original diagnosis of normal appendix, and the remaining three cases occurred in patients with perforated appendicitis. No patient received antibiotics for more than 4 days. Two patients had been on an aminoglycoside-based regimen, one received Unasyn (Pfizer, New York, NY) exclusively, and the last received cefoxitin exclusively.

Miscellaneous complications encountered included a pulmonary embolus (n = 1), acute renal failure (n = 1), myocardial infarction (n = 1), deep venous thrombosis (n = 1), and a common iliac artery laceration secondary to laparoscopic trocar insertion. Finally, an emergent cricothyroidotomy was performed on induction of anesthesia for an appendectomy when the anesthesiologist was unable to maintain the patient's airway.

In summary, 27 patients required reoperation within 45 days of their appendectomy. None of these patients had a diagnosis of normal appendix at their original operation. The indications for reoperative surgery by original diagnosis are listed in Table 7. The retained objects included a sponge discovered on a postoperative x-ray and a drain that broke while being removed. The patient operated on for hemorrhage went to the operating room on the day of the original appendectomy for control of a mesenteric bleeder.

Mortality

Four deaths occurred in this series. One patient had a normal appendix, one had acute appendicitis, and two had perforated appendicitis.

The patient with a pathologically normal appendix was a 72-year-old female inpatient recuperating from an antrectomy with Billroth II reconstruction for perforated gastric ulcer. Evidence of intra-abdominal sepsis led to an exploratory laparotomy to rule out appendicitis or other source. The patient was noted to have a breakdown of the gastrojejunostomy and a "mildly inflamed" appendix. This patient ultimately died of sepsis.

The patient with acute appendicitis was a 49-year-old black male who presented in septic shock with an acute abdomen. Exploratory laparotomy showed acute nonperforated appendicitis and multiple hepatic abscesses. The patient died of sepsis on postoperative day 1.

The first patient with perforated appendicitis was taken back to the operating room for systemic sepsis and a diagnosis of cecal fistula. On induction of anesthesia for this re-exploration and placement of a cecostomy tube, the patient aspirated gastric contents. The patient ultimately died of adult respiratory distress syndrome and sepsis.

Table 5. COMPARISON OF LAPAROSCOPIC AND OPEN PROCEDURE HOSPITAL STAY

	Normal	Acute	Perforated
Laparoscopic	2.8 ± 1.5 (1–7)	3.0 ± 2.8 (1–19)	5.8 ± 4.1 (1–17)
Open	3.8 ± 5.7 (1–124)	3.5 ± 3.5 (1–108)	7.3 ± 4.2 (1–36)

Values are given as days [mean ± standard deviation (range in parentheses)].

Table 6. ITEMIZED COMPLICATION RATES STRATIFIED BY DIAGNOSIS

Complication	Normal (N = 653)	Acute (N = 3265)	Perforated (N = 1032)	Total (N = 4950)
Wound infection	12 (1.8)	46 (1.4)	66 (6.4)	124 (2.5)
UTI	4 (0.6)	5 (0.2)	3 (0.3)	12 (0.2)
Urinary retention	5 (0.8)	28 (0.9)	19 (1.8)	52 (1.0)
Pneumonia	2 (0.3)	3 (0.1)	6 (0.6)	11 (0.2)
Bowel obstruction	2 (0.3)	8 (0.2)	12 (1.2)	22 (0.4)
Abscess	NA	11 (0.3)	8 (0.8)	19 (0.4)
Intestinal fistula	NA	NA	5 (0.5)	5 (0.1)
C. dif colitis	1 (0.2)	NA	3 (0.3)	4 (0.1)
PE	NA	NA	1 (0.1)	1 (0.02)
ARF	NA	NA	1 (0.1)	1 (0.02)
MI	NA	NA	1 (0.1)	1 (0.02)
DVT	NA	NA	1 (0.1)	1 (0.02)
Cricothyroidotomy	NA	1 (0.03)	NA	1 (0.02)
Vascular injury	1 (0.2)	NA	NA	1 (0.02)
Death	1 (0.2)	1 (0.03)	2 (0.2)	4 (0.1)
Total	27 (4.0)	103 (3.0)	128 (12)	259 (5.2)

UTI = urinary tract infection; C. dif = clostridium difficile; PE = pulmonary embolism; ARF = acute renal failure; MI = myocardial infarction; DVT = deep vein thrombosis; NA = not applicable.
Values in parentheses are percentages.

The final patient with perforated appendicitis was a 35-year-old black male who underwent an appendectomy after 24 hours of observation in the hospital. The patient was recovering uneventfully when he died of a pulmonary embolus on postoperative day 3.

DISCUSSION

The more things change, the more they stay the same. This apt phrase pertains to the diagnosis and treatment of appendicitis as much as to any other phenomena. Perforation rates of 20% to 30% have been reported consistently over the past 70 years despite the technologic advances over this interval.[9–11] Recent evidence indicating that perforation precedes surgical evaluation in the majority of cases indicates that reduction of perforation rates will have to be addressed through encouraging earlier evaluation and greater access to care.[12,13] We can take some solace, however, from the observation that modern surgical therapy has been responsible for reducing the mortality of appendicitis from 26% overall to well less than 1% over the same period.[11] The mortality rate of 0.08% that we report is testament to the benefits of advancing technology in managing a persistent rate of perforation and its attendant complications.

Perforation continues to disproportionately affect those individuals at the extremes of age. This is most likely due to delays in presentation and diagnosis related to an

Table 7. INDICATIONS FOR REOPERATION STRATIFIED BY DIAGNOSIS

Indication	Normal (N = 653)	Acute (N = 3265)	Perforated (N = 1032)	Total (N = 4950)
Bowel obstruction	0 (0.0)	3 (0.1)	4 (0.4)	7 (0.1)
Intestinal fistula	0 (0.0)	0 (0.0)	2 (0.2)	2 (0.04)
Abscess	0 (0.0)	6 (0.2)	6 (0.6)	12 (0.2)
Retained objects	0 (0.0)	2 (0.1)	0 (0.0)	2 (0.04)
Dehiscence	0 (0.0)	1 (0.03)	1 (0.1)	2 (0.04)
Cholecystitis	0 (0.0)	1 (0.1)	0 (0.0)	1 (0.02)
Hemorrhage	0 (0.0)	1 (0.1)	0 (0.0)	1 (0.02)
Total	0 (0.0)	14 (0.5)	13 (1.3)	27 (0.5)

Values in parentheses are percentages.

inability to communicate in the younger population. In the older population, a combination of delayed presentation, confounding medical conditions and a decreased index of suspicion may contribute to this observation. This study confirms a slight increase in the perforation rate associated with male gender, which has been described many times previously.[8,14] Our study confirms the increased risk of postoperative complications in those patients with perforation. This applies not only to infectious complications (*e.g.*, abscess, wound infection) but to noninfectious complications as well (*e.g.*, urinary retention, small bowel obstruction). Additionally, perforation increased the risk of the patient requiring a second laparotomy by 260%. Clearly, the most effective means of controlling the human and economic costs associated with appendicitis appears to lie in the identification and correction of those factors most responsible for perforation.

Negative appendectomy rates also have been relatively stable over the years, and although all patients are affected to one extent or another, women of reproductive age and children younger than 5 years of age are especially vulnerable.[15,16] The culprit here is the fact that there currently is no test or objective physical finding that can rule out the presence of appendicitis with acceptable accuracy. Our study points out the limitations of the two most commonly used parameters, namely leukocyte count and temperature in this regard. Improvements in the rate of negative appendectomy await development of more specific radiologic or laboratory studies.

Diagnostic accuracy and complication rates were equivalent for tertiary referral centers, remote community hospitals, high-volume hospitals, and low-volume hospitals. It seems clear that the presence of a competent health care team and access to care is more important than any available advanced technology in obtaining satisfactory results.

We present one of the larger series of appendectomies performed in pregnant women reported over the past few decades. A few facts seem clear based on our data and a review of the literature. The removal of a normal or nonperforated acutely inflamed appendix appears to pose little risk to either mother or fetus and perforation increases the probability of fetal demise.[17–20] Additionally, premature labor in the perioperative period typically responds to standard tocolytic therapy.

This study was conducted during the early phase of the adoption of laparoscopic techniques for appendectomy. As would be expected, operative times were longer and hospital stay was not affected significantly. This is not surprising considering that length of hospitalization has been dictated predominately by the severity of the underlying disease process and the need for antibiotic therapy more than the minimal physiologic insult associated with open appendectomy. Despite its introductory status, laparoscopic appendectomy was not associated with any increase in the rate of complications. Widespread adoption of this technique appears to be warranted once documentation of greater patient comfort and a more expeditious return to normal activity is shown.[21–23]

In conclusion, rates of perforation and negative appendectomy have been relatively stagnant over the past 50 years despite the dramatic advances in technology that have occurred over the same period. In the case of negative appendectomy, this is a reflection of the fact that these technologic advances have not produced a clinically useful objective test possessing a high degree of sensitivity, specificity, and accuracy. Significantly lower rates of perforation will not occur until potential patients have the inclination and opportunity to seek earlier evaluation and intervention.

References

1. Fitz RH. Perforating inflammation of the vermiform appendix with special reference to its early diagnosis and treatment. Am J Med Sci 1886; 92:321–346.
2. Babcock JR, McKinley WM. Acute appendicitis: an analysis of 1662 consecutive cases. Ann Surg 1959; 150:131–141.
3. Mittelpunkt A, Nora PF. Current features in the treatment of acute appendicitis: an analysis of 1:00Q consecutive cases. Surgery 1966; 60:971–975.
4. Lewis FR, Holeroft JVV, Boey J, et al. Appendicitis: a critical review of diagnosis and treatment in 1:000 cases. Arch Surg 1975; 110:677–684.
5. Silberman VA. Appendectomy in a large metropolitan hospital. Retrospective analysis of 1:013 cases. Am J Surg 1981; 142:616–618.
6. Pieper R, Kager L, Nasman P. Acute appendicitis: a clinical study of 1018 cases of emergency appendectomy. Acta Chir Scand 1982; 148:51–62.
7. Maxwell JM, Ragland JJ. Appendicitis. Improvements in diagnosis and treatment. Am Surg 1991; 57:282–285.
8. Andersson RE, Ilugander A, Thulin AJ. Diagnostic accuracy and perforation rate in appendicitis: association with age and sex of the patient and with appendectomy rate. Eur J Surg 1992; 158:37–41.
9. Barnes BA, Behringer GE, Wheelock FC, et al. Surgical sepsis: analysis of factors associated with sepsis following appendectomy (1937–1959). Ann Surg 1962; 156:703–712.
10. Rogers H, Faxon HH. A statistical study of six hundred and seventy one cases of appendiceal peritonitis. N Engl J Med 1942; 226:707–717.
11. Berry JJ, Malt RA. Appendicitis near its centenary. Ann Surg 1984; 200:567–575.
12. Temple CL, Huchcroft SA, Temple WJ. The natural history of appendicitis in adults. Ann Surg 1995; 221:278–281.
13. Hale DA, Molloy M, Pearl RH, et al. Appendectomy: improving care through quality improvement. Arch Surg 1997; in press.
14. Arnbjornsson E. Some factors affecting perforation in acute appendicitis. Ann Chir Gynaecol 1983; 72:50–52.
15. Jones PF. The influence of age and gender on normal appendectomy rates. Aust N Z J Surg 1988; 58:919–920.
16. Agafonoff S, Hawke I, Khadra M, et al. The influence of age and

gender on normal appendectomy rates. Aust N Z J Surg 1987; 57:843–846.
17. Mahmoodian S. Appendicitis complicating pregnancy. South Med J 1992; 85:19–24.
18. Doberneck RC. Appendectomy during pregnancy. Am Surg 1985; 51:265–268.
19. Bailey LE, Finley RKJ, Miller SF, et al. Acute appendicitis during pregnancy. Am Surg 1986; 52:218–221.
20. Horowitz MD, Gomez GA, Santiesteban R, et al. Acute appendicitis during pregnancy. Diagnosis and management. Arch Surg 1985; 120:1362–1367.
21. Vallina VL, Velasco JM, McCulloch CS. Laparoscopic versus conventional appendectomy. Ann Surg 1993; 218:685–692.
22. Attwood SE, Hill AD, Murphy PG, et al. A prospective randomized trial of laparoscopic versus open appendectomy. Surgery 1992; 112:497–501.
23. Erazee RC, Roberts JW, Symmonds RE, et al. A prospective randomized trial comparing open versus laparoscopic appendectomy. Ann Surg 1994; 219:725–731.