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# THE EPIDEMIOLOGY OF APPENDICITIS AND APPENDECTOMY IN THE UNITED STATES

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**To describe the epidemiology of appendicitis and appendectomy in the United States, the authors analyzed National Hospital Discharge Survey data for the years 1979–1984. Approximately 250,000 cases of appendicitis occurred annually in the United States during this period, accounting for an estimated 1 million hospital days per year. The highest incidence of primary positive appendectomy (appendicitis) was found in persons aged 10–19 years (23.3 per 10,000 population per year); males had higher rates of appendicitis than females for all age groups (overall rate ratio, 1.4:1). Racial, geographic, and seasonal differences were also noted. Appendicitis rates were 1.5 times higher for whites than for nonwhites, highest (15.4 per 10,000 population per year) in the west north central region, and 11.3% higher in the summer than in the winter months. The highest rate of incidental appendectomy was found in women aged 35–44 years (43.8 per 10,000 population per year), 12.1 times higher than the rate for men of the same age. Between 1970 and 1984, the incidence of appendicitis decreased by 14.6%; reasons for this decline are unknown. A life table model suggests that the lifetime risk of appendicitis is 8.6% for males and 6.7% for females; the lifetime risk of appendectomy is 12.0% for males and 23.1% for females. Overall, an estimated 36 incidental procedures are performed to prevent one case of appendicitis; for the elderly, the preventive value of an incidental procedure is considerably lower.**

**appendectomy; appendicitis; surgery**

Appendectomy for acute appendicitis is one of the most frequently performed surgical procedures in the United States (1). Much has been written on appendicitis since it was described by Fitz more than 100 years ago (2), but the etiology and epidemiology of this disease remain poorly understood. Acute appendicitis has been attributed to a variety of possible causes, including mechanical obstruction (3, 4), inadequate dietary fiber (5–8), familial susceptibility (9), factors associated with improved socioeconomic conditions (10, 11), and bacterial, viral, and parasitic pathogens (12–15). Few population-based epidemiologic studies of appendicitis have been published, however, and little is known about the demographic characteristics, geographic differences, seasonality, or long-term secular trends of appendicitis in the United States.

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Abbreviations: ICDA-8, *Eighth Revision International Classification of Diseases, Adapted for Use in the United States*; ICD-9-CM, *International Classification of Diseases, Ninth Revision, Clinical Modification*.

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Incidental appendectomies are commonly performed at the time of other abdominal or pelvic surgery to prevent future appendicitis (16). Because the epidemiology of incidental appendectomy for the United States as a whole has not been well characterized, the impact of this surgical practice is difficult to assess. Morbidity from the procedure is generally considered to be negligible (17); however, the preventive value of incidental appendectomy, particularly in the elderly, has been the subject of recent debate (16, 18).

We analyzed 15 years of data from the National Hospital Discharge Survey to describe the epidemiology of appendicitis and incidental appendectomy in the United States. Using a life table model, we estimate the current lifetime risk of appendicitis in the United States and describe the preventive value of incidental appendectomies performed in persons of different ages.

## MATERIALS AND METHODS

Since 1963, the National Center for Health Statistics has conducted the National Hospital Discharge Survey, which provides data on a representative 0.5 percent sample of patients hospitalized in nonfederal acute-care facilities in the United States (1). Each year, approximately 200,000 discharge records are randomly selected for review from a sample of 289–432 hospitals stratified by size (number of beds) and geographic region (19). Stratum-specific weights are applied to derive national estimates. Information obtained from the hospital records includes patient demographic characteristics, diagnoses, surgical procedures performed, discharge status, dates of admission and discharge, hospital characteristics, and region of the country. Up to seven diagnoses and four surgical procedures are coded for each patient, using the *Eighth Revision International Classification of Diseases, Adapted for Use in the United States* (ICDA-8) (20) for the years 1970–1978 and the *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) (21) after 1978. The degree to which discharge diagnoses are confirmed by pathologic or laboratory findings is unknown.

Data tapes were obtained for the years 1970–1984. Primary appendectomy was defined as a nonincidental appendectomy procedure code, either 41.1 (ICDA-8) or 47.0 (ICD-9-CM) (table 1). A primary appendectomy was defined as positive if the patient also had a discharge diagnosis of acute appendicitis with peritonitis (ICDA-8 diagnostic code 540.0 and ICD-9-CM di-

TABLE 1

*Diagnostic and surgical procedure codes for appendicitis and appendectomy, from the* Eighth Revision International Classification of Diseases, Adapted for Use in the United States *(ICDA-8) and the* International Classification of Diseases, Ninth Revision, Clinical Modification *(ICD-9-CM)*

| ICDA-8 (1970–1978) | | ICD-9-CM (1979–1984) | |
|---|---|---|---|
| *Diagnostic codes* | | | |
| 540 | Acute appendicitis | 540 | Acute appendicitis |
| 540.0 | With peritonitis (abscess, perforation, peritonitis, or rupture) | 540.0 | With generalized peritonitis (perforation, peritonitis, or rupture) |
| | | 540.1 | With peritoneal abscess |
| 540.9 | Without mention of peritonitis | 540.9 | Without mention of peritonitis |
| 541 | Appendicitis, unqualified | 541 | Appendicitis, unqualified |
| *Procedure codes* | | | |
| 41 | Operations on appendix | 47 | Operations on appendix |
| 41.1 | Appendectomy | 47.0 | Appendectomy, excludes incidental |
| | | 47.1 | Incidental appendectomy |

agnostic codes 540.0 and 540.1), acute appendicitis without mention of peritonitis (code 540.9), or appendicitis, unqualified (code 541). A patient with a positive primary appendectomy was therefore considered to have acute appendicitis; the terms are used interchangeably in this paper. A primary appendectomy was defined as negative if none of these diagnostic codes for acute appendicitis was recorded. Negative appendectomies, which included the diagnoses of chronic or recurrent appendicitis and appendiceal lymphoid hyperplasia, were considered to represent procedures performed on patients who had been suspected of having appendicitis (since incidental appendectomy was not specified) but were found at the time of surgery not to have acute appendicitis.

An incidental appendectomy was defined as procedure code 47.1 in the ICD-9-CM (table 1); incidental appendectomies were not recorded before 1979. Diagnostic accuracy was defined as the proportion of all primary appendectomies that were positive, and was considered equivalent to the positive predictive value of the surgeon's preoperative diagnosis. The perforation ratio was the percentage of primary positive appendectomies with evidence of perforation, peritonitis, rupture, or abscess (ICDA-8 diagnostic code 540.0 and ICD-9-CM diagnostic codes 540.0 and 540.1). The case-fatality ratio was defined as the percentage of patients with appendectomy who died during hospitalization.

In evaluating temporal trends, we used US resident population estimates for the years 1970–1984 to calculate annual rates of appendicitis and appendectomy (22, 23). For all other analyses, the mean annual incidence for the years 1979–1984 was determined by combining discharges for these years and using the 1980 US Census data for the denominator (24). Regional comparisons were based on the nine geographic divisions of the US Census (22–24).

To determine lifetime and 1-year risk of appendicitis and appendectomy in persons with an intact appendix, we constructed a life table in 5-year age intervals using combined incidence data from 1979 to 1984 (25). In the life table analysis, persons who had had an appendectomy were considered no longer at risk of appendicitis and were excluded from the denominator of successive age groups. Lifetime risk was calculated assuming a life span of 75 years and an incidence of appendicitis and appendectomy that remained constant at 1979–1984 levels.

SAS statistical software was used to analyze the data (26). The Pearson correlation coefficient ($r$) was used to determine the degree of linear correlation between variables. No generally acceptable methods exist for calculating confidence intervals for rates and proportions over multiple years for these data; values are therefore presented as point estimates. However, for each year from 1970 to 1984, the relative standard error for the number of appendectomies and appendicitis cases varied from 5 percent to 9 percent (19).

## Results

In the period 1979–1984, an estimated 3.4 million appendectomies were performed in the United States (561,000 per year), a crude annual incidence of 26 per 10,000 population. Of these, 53 percent were primary appendectomies; 85.3 percent of patients with primary appendectomy (251,000 per year) had a discharge diagnosis of acute appendicitis (primary positive appendectomy). The crude incidence of acute appendicitis was 11 per 10,000 population per year. Forty-seven percent of appendectomies were incidental; the annual rate of incidental appendectomy was 12 per 10,000 population. These national figures were based on a total of 16,457 hospital records with a procedure code of appendectomy.

The case-fatality ratio for both primary positive and primary negative appendectomy was 0.3 percent. The case-fatality ratio for primary positive appendectomy was 4.6 percent in persons aged 65 years or more and 0.2 percent in persons aged less than 65 years.

Between 1979 and 1984, appendicitis accounted for an estimated 1 million hospital days annually. The median length of hospital stay was 4 days for patients with primary appendectomy, 9 days if the appendix was perforated, and 7 days for incidental appendectomy performed at the time of another surgical procedure.

### *Primary positive appendectomy (appendicitis)*

The age-specific incidence of acute appendicitis followed a similar pattern for males and females, but males had higher rates at virtually all ages, with an overall male:female rate ratio of 1.4:1 (figure 1). The incidence was highest in males aged 10–14 years (27.6 per 10,000 population per year) and in females aged 15–19 years (20.5 per 10,000 population per year). In persons aged 45 years or more, appendicitis rates remained relatively constant at approximately six per 10,000 for males and four per 10,000 for females. The median age for both males and females with primary positive appendectomy was 21 years; 69 percent of persons with appendicitis were less than 30 years old.

### *Primary negative appendectomy and diagnostic accuracy*

The incidence of primary negative appendectomy was higher in females than in males, and was highest among women in the childbearing years (figure 1). The rate of negative appendectomy among females aged 15–24 years (4.9 per 10,000 population per year) was 2.5 times higher than that for males of the same age. Overall diagnostic accuracy was lower for females (78.6 percent) than for males (91.2 percent). In females, diagnostic accuracy dropped sharply during the childbearing years; in males, it did not vary appreciably with age (figure 2).

Diagnoses most commonly associated with primary negative appendectomy included mesenteric lymphadenitis, other diseases of the appendix, and gynecologic conditions (table 2).

### *Incidental appendectomy*

The incidence of incidental appendectomy was 6.6 times higher in females than in males (figure 1). In females, 62.7 percent of all appendectomies were incidental, compared with 17.7 percent in males. Women aged 35–44 years had the highest rate of incidental appendectomy, 43.8 per 10,000 population per year, and were 12.1 times more likely to have an incidental appendectomy than were men of the same age. In males, the annual incidence of incidental appendectomy gradually increased with age, to a rate of 7.3 per 10,000 population among men aged 65 years or more. Median age at incidental appendectomy was 34 years for females and 47 years for males. In females, primary surgical procedures most commonly performed at the time of incidental appendectomy were abdominal hysterectomy (45.0 percent), oophorectomy or salpingectomy (37.5 percent), cholecystectomy (18.4 percent), excision of ovarian tissue (7.2 percent), and cesarean section (4.9 percent). In males, the most common primary surgical procedures were cholecystectomy (36.6 percent), total or partial excision of the intestine (11.8 percent), and inguinal hernia repair (4.9 percent).

### *Appendiceal perforation*

A total of 19.2 percent of appendicitis cases (primary positive appendectomies) in males and 17.8 percent in females involved appendiceal perforation, rupture, abscess, or generalized peritonitis. The perforation ratio was lowest among persons aged 20–24 years (9.1 percent) and increased directly with age to 51 percent in persons aged 65 years or more (figure 3); children aged less than 5 years were also at increased risk. In contrast, the age-specific incidence of appendiceal perforation was highest among persons aged 10–14 years (3.5 per 10,000 population per year); a gradual increase in incidence with age was observed for persons over age 35 (figure 3).

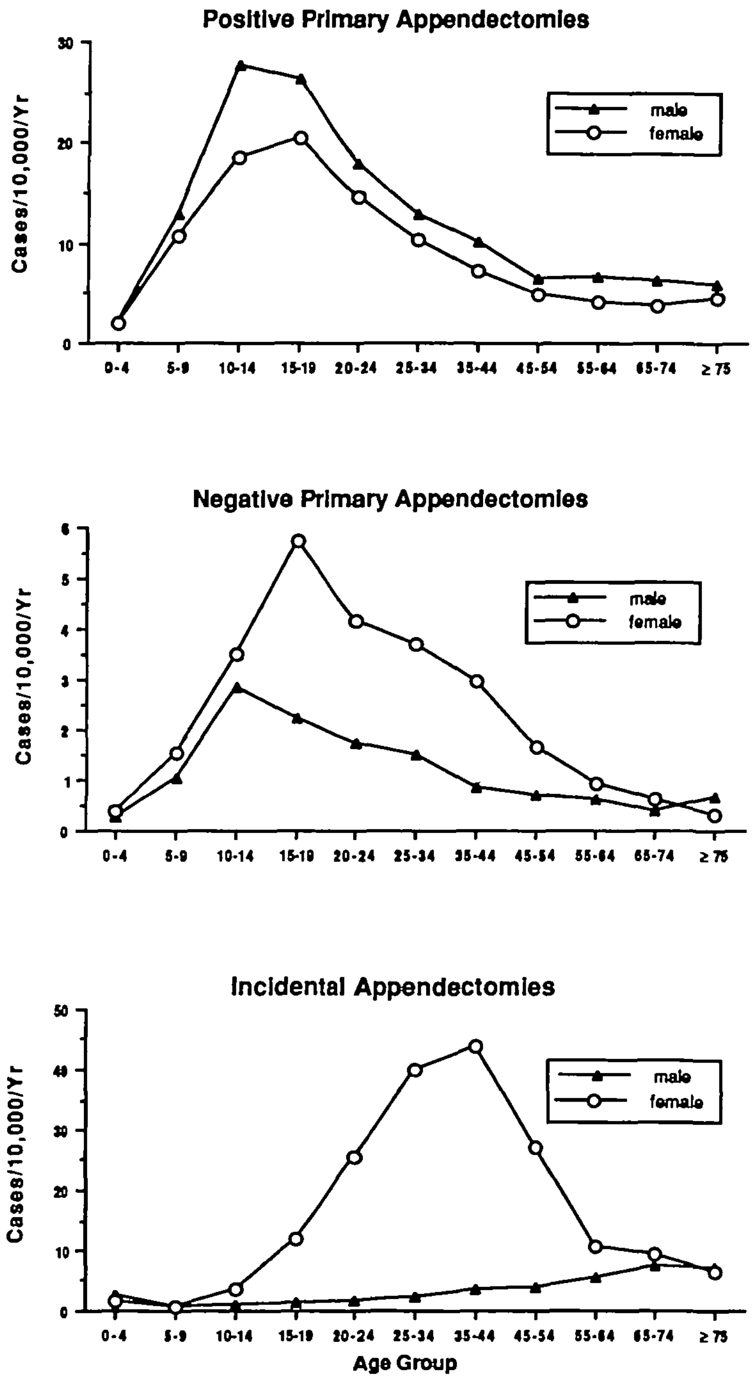


FIGURE 1. Annual incidence of appendectomy (per 10,000 population) in the United States, 1979–1984, by age group, sex, and type of appendectomy.

*Race, region, and season*

Race (white or nonwhite) was recorded for 91 percent of all hospital discharges for appendectomy. The incidences of primary positive, primary negative, and incidental appendectomy were each 1.4–1.6 times higher for whites than for nonwhites, a

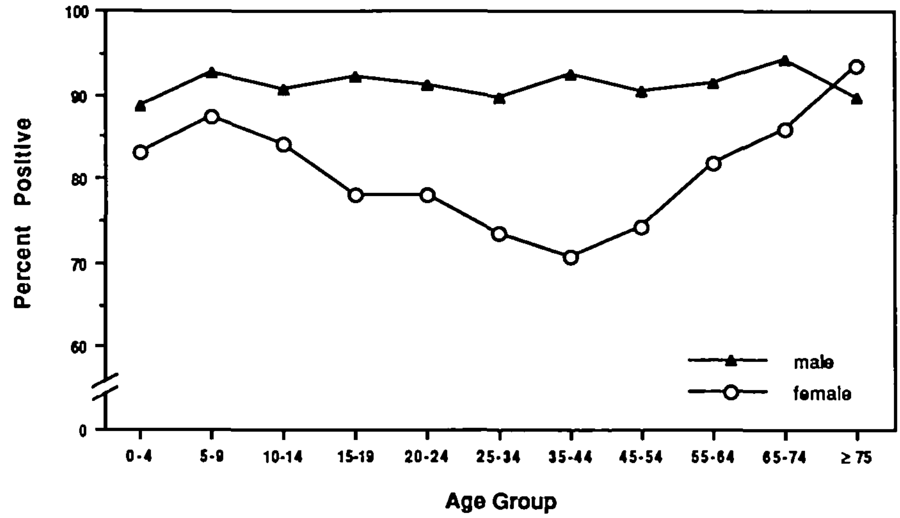


FIGURE 2 Diagnostic accuracy of primary appendectomies performed in the United States, by age group and sex, 1979-1984. Diagnostic accuracy was defined as the proportion of all primary appendectomies with a discharge diagnosis of appendicitis.

TABLE 2

*Discharge diagnoses and surgical procedures most commonly recorded for persons with primary negative appendectomy, National Hospital Discharge Survey, 1979-1984**

| ICD-9-CM code | Diagnosis or procedure | Females | | Males | |
|---|---|---|---|---|---|
| | | % of discharges | National estimate (unweighted no.) | % of discharges | National estimate (unweighted no.) |
| Diagnostic code | | | | | |
| 543.9 | Other diseases of the appendix† | 23.1 | 41,169 (194) | 16.6 | 13,645 (61) |
| 543.0 | Lymphoid hyperplasia of the appendix | 2.5 | 4,485 (25) | 3.3 | 2,693 (16) |
| 542 | Other appendicitis‡ | 18.2 | 32,514 (150) | 15.8 | 12,988 (67) |
| 289.2 | Mesenteric lymphadenitis | 19.4 | 34,629 (172) | 29.0 | 23,825 (117) |
| 789.0 | Abdominal pain | 10.6 | 18,955 (99) | 15.4 | 12,661 (61) |
| 558.9 | Gastroenteritis, noninfectious | 4.8 | 8,503 (44) | 10.8 | 8,840 (40) |
| 574 | Cholelithiasis | 5.1 | 9,161 (42) | 3.9 | 3,182 (12) |
| 620.2 | Ovarian cyst | 8.8 | 15,684 (73) | 0 | 0 (0) |
| 218 | Uterine leiomyoma | 7.5 | 13,311 (56) | 0 | 0 (0) |
| 617 | Endometriosis | 6.6 | 11,811 (52) | 0 | 0 (0) |
| 616.0 | Cervicitis, endocervicitis | 5.0 | 8,839 (35) | 0 | 0 (0) |
| Procedure code | | | | | |
| 65.3-65.6 | Oophorectomy | 14.6 | 26,040 (119) | 0 | 0 (0) |
| 65.2 | Excision or destruction of ovary | 5.3 | 9,420 (43) | 0 | 0 (0) |
| 68.3-68.4 | Abdominal hysterectomy | 14.4 | 25,664 (114) | 0 | 0 (0) |
| 51.2 | Cholecystectomy | 6.9 | 12,359 (54) | 4.5 | 3,728 (15) |
| 54.5 | Lysis of adhesions | 5.0 | 8,879 (43) | 2.3 | 1,918 (9) |
| 54.1 | Laparotomy | 1.7 | 2,990 (16) | 2.9 | 2,395 (10) |
| 54.2 | Diagnostic laparotomy | 2.8 | 4,995 (23) | 0.4 | 309 (2) |

* *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM).
† Colic, concretion, diverticulum, fecalith, fistula, intussusception, mucocele, or stercolith.
‡ Chronic, recurrent, relapsing, or subacute.

difference that persisted when data were stratified by sex, age group, and region. The perforation ratio for nonwhites was 21.8 percent, compared with 18.2 percent for whites. Diagnostic accuracy was 86.1 percent in nonwhites and 85.3 percent in whites.

Regional differences, which persisted when data were stratified by racial group, were also observed. The annual incidence of appendicitis was highest (15.4 per 10,000 population) in the west north central states and lowest (9.4 per 10,000 population) in the middle Atlantic states (table 3). Diagnostic accuracy, which was lowest (81.1 percent) in the west north central states and highest (89.4 percent) in the middle Atlantic states, tended to be inversely related to the incidence of primary appendectomy ($r$ = 0.52) and positively correlated with the perforation ratio ($r$ = 0.37), but these trends were not statistically significant. Regions with the highest rates of primary appendectomy were also highest for incidental appendectomy.

The incidence of primary appendectomy

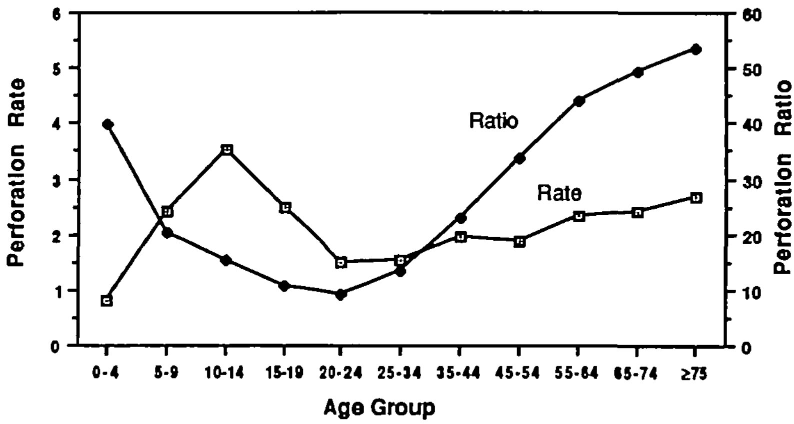


FIGURE 3. Appendicitis perforation rate and perforation ratio in the United States, by age group, 1979–1984. Perforation rate was defined as the mean annual incidence of perforated appendicitis per 10,000 population. Perforation ratio was defined as the percentage of primary positive appendectomies with appendiceal perforation.

TABLE 3

*Diagnostic accuracy, perforation ratio, and incidence of primary appendectomy, acute appendicitis, and incidental appendectomy (per 10,000 population per year), by US Census region, National Hospital Discharge Survey, 1979–1984**

| US Census region | Primary appendectomy rate | Appendicitis rate | Diagnostic accuracy | Perforation ratio | Incidental appendectomy rate |
|---|---|---|---|---|---|
| New England | 14.2 | 12.5 | 87.8 | 18.2 | 11.2 |
| Middle Atlantic | 10.5 | 9.4 | 89.4 | 19.3 | 5.9 |
| East North Central | 11.4 | 9.7 | 85.7 | 18.4 | 12.3 |
| West North Central | 19.1 | 15.4 | 81.1 | 17.7 | 19.1 |
| South Atlantic | 11.6 | 9.5 | 82.2 | 18.8 | 11.7 |
| East South Atlantic | 14.1 | 11.8 | 83.6 | 16.3 | 16.9 |
| West South Central | 14.9 | 12.4 | 83.5 | 18.8 | 18.2 |
| Mountain | 15.5 | 13.4 | 86.6 | 16.3 | 10.6 |
| Pacific | 13.2 | 11.6 | 88.1 | 20.6 | 7.3 |
| Entire United States | 13.0 | 11.1 | 85.3 | 18.6 | 11.8 |

* The numbers of hospital records sampled during this period with a diagnostic or procedure code for primary appendectomy, acute appendicitis, or incidental appendectomy were 8,717, 7,463, and 7,740, respectively.

and appendicitis, but not incidental appendectomy, appeared to increase during the summer months (figure 4). During the months of May through August, the number of cases of appendicitis (adjusted to 31-day months) was 11.3 percent higher than during the winter months of November through February.

*Secular trends, 1970–1984*

Between 1970 and 1984, the overall incidence of primary appendectomy decreased by 22.1 percent; declines were observed in positive (14.6 percent) and negative (52.5 percent) appendectomy rates for both sexes (figure 5). The greatest changes occurred in the younger, higher-risk groups; among persons aged 10–24 years, the primary appendectomy rate decreased 25.5 percent, from 32.6 cases per 10,000 population per year to 24.3 cases per 10,000 population per year. Among nonwhite racial groups, the incidence of primary appendectomy declined slightly, from 9.7 per 10,000 in 1970 to 9.2 per 10,000 in 1984.

Diagnostic accuracy appeared to increase steadily during these 15 years, from 74 percent to 83 percent in females and from 86 percent to 92 percent in males. The perforation ratio also increased, from 15.6 percent in 1970–1972 to 19.5 percent in 1982–1984. A stronger association between the perforation ratio and diagnostic accuracy was noted for males ($r = 0.50$, $p = 0.07$) than for females ($r = 0.31$, $p = 0.29$); both diagnostic accuracy and perforation ratio tended to be higher among males (figure 6).

Between 1979 (when incidental appendectomies were first coded) and 1984, incidental appendectomy rates decreased by 27.7 percent in females and 13.6 percent in males (figure 5). In women, this decline was greatest (33.6 percent) between the ages of 25 and 54 years.

*Life table analysis: risk of appendicitis*

Assuming a constant incidence of appendicitis and appendectomy at 1979–1984 levels, the lifetime risk for a child aged less than 5 years of having his or her appendix surgically removed (primary or incidental appendectomy) was 12.0 percent for males and 23.1 percent for females (table 4). The lifetime risk of appendicitis was 8.6 percent for males and 6.7 percent for females; 2.9 percent of males and 16.0 percent of females could expect to undergo incidental appendectomy.

The risk of appendectomy during the next year of life for those who had not yet had their appendix removed was higher for females than for males (table 5). The highest risk of appendectomy from any cause was found in females aged 35–39 years; six of every 1,000 women in this age group

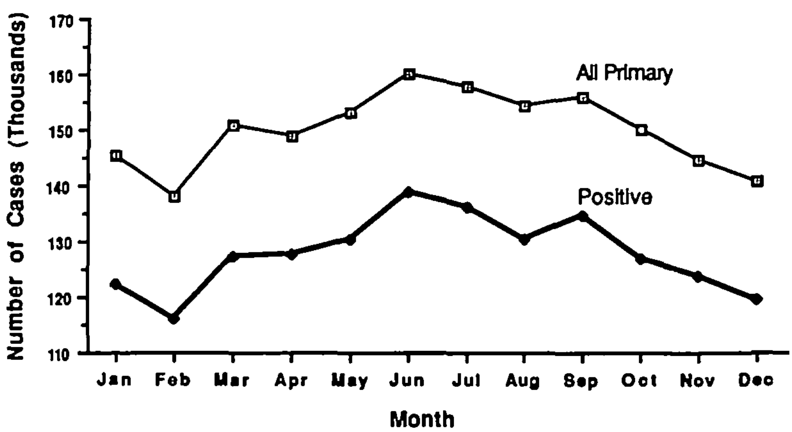


FIGURE 4. Numbers of primary appendectomies (in thousands) in the United States, by month, 1979–1984. Adjusted to 31-day monthly totals; annual data combined.

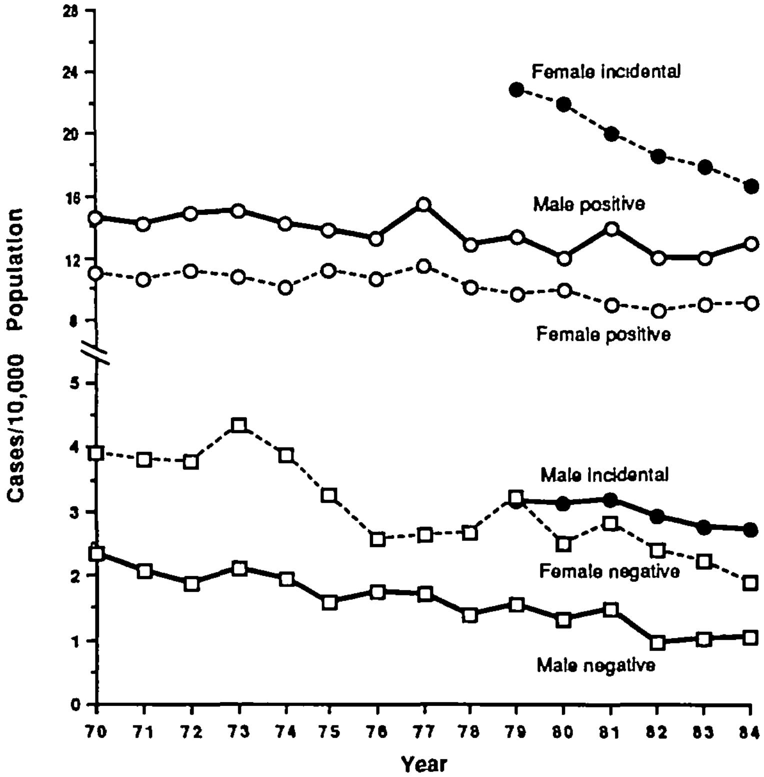


FIGURE 5. Appendicitis and appendectomy trends (per 10,000 population) in the United States, 1970–1984, by year, sex, and type of appendectomy (primary positive, primary negative, and incidental).

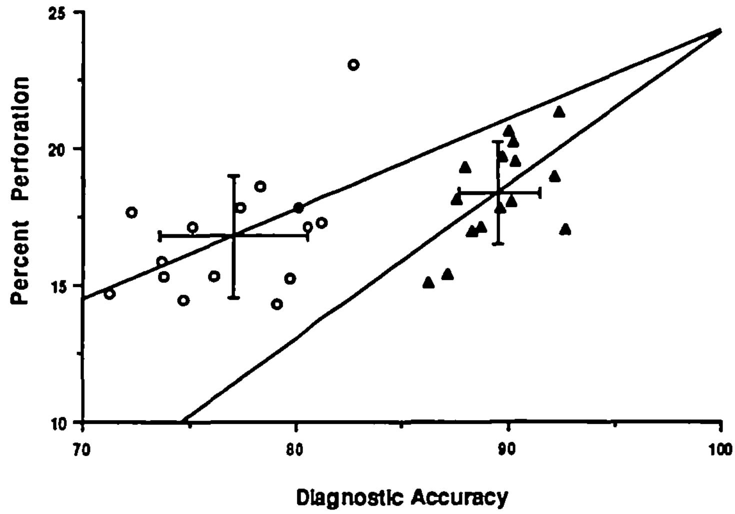


FIGURE 6. Appendicitis perforation ratio and diagnostic accuracy in the United States, by year and sex, 1970–1984. Standard deviations (error bars) and regression lines are shown for males (▲) and females (O). Each point represents data (by sex) for a single year.

would be expected to undergo appendectomy during the next year, and five of these procedures would be incidental appendectomies. In contrast, the highest risk of appendectomy in males was in the 10–14-year age group; three of 1,000 males in this age group would be expected to have an appendectomy during the following year, and few of these (4 percent) would be incidental appendectomies.

TABLE 4

*Cumulative lifetime risk (to age 75 years) for appendectomy per 10,000 population, National Hospital Discharge Survey, 1979–1984*

| Age group (years) | All appendectomies | | Primary appendectomies | | Primary positive appendectomies | | Incidental appendectomies | |
|---|---|---|---|---|---|---|---|---|
| | Males | Females | Males | Females | Males | Females | Males | Females |
| 0–4 | 1,198 | 2,310 | 938 | 843 | 861 | 666 | 287 | 1,602 |
| 5–9 | 1,176 | 2,295 | 927 | 832 | 851 | 657 | 274 | 1,595 |
| 10–14 | 1,111 | 2,245 | 863 | 776 | 792 | 606 | 271 | 1,595 |
| 15–19 | 968 | 2,144 | 722 | 673 | 662 | 518 | 266 | 1,577 |
| 20–24 | 830 | 1,989 | 585 | 547 | 536 | 418 | 260 | 1,526 |
| 25–29 | 728 | 1,803 | 489 | 454 | 447 | 345 | 251 | 1,413 |
| 30–34 | 637 | 1,567 | 408 | 379 | 375 | 290 | 238 | 1,235 |
| 35–39 | 563 | 1,311 | 344 | 310 | 318 | 238 | 227 | 1,033 |
| 40–44 | 482 | 1,028 | 281 | 245 | 259 | 195 | 206 | 802 |
| 45–49 | 416 | 759 | 231 | 198 | 213 | 158 | 189 | 572 |
| 50–54 | 355 | 517 | 187 | 156 | 174 | 127 | 172 | 367 |
| 55–59 | 300 | 369 | 155 | 120 | 144 | 100 | 147 | 251 |
| 60–64 | 232 | 269 | 115 | 89 | 106 | 75 | 118 | 181 |
| 65–69 | 161 | 175 | 77 | 57 | 72 | 48 | 85 | 119 |
| 70–74 | 94 | 86 | 44 | 28 | 43 | 22 | 50 | 58 |

TABLE 5

*Risk of appendectomy in the next year of life (per 100,000 population) for persons who had not yet had their appendix removed, by 5-year age group, National Hospital Discharge Survey, 1979–1984*

| Age group (years) | All appendectomies | | Primary appendectomies | | Primary positive appendectomies | | Incidental appendectomies | |
|---|---|---|---|---|---|---|---|---|
| | Males | Females | Males | Females | Males | Females | Males | Females |
| 0–4 | 51 | 39 | 24 | 24 | 22 | 20 | 27 | 15 |
| 5–9 | 146 | 130 | 139 | 123 | 129 | 108 | 7 | 7 |
| 10–14 | 319 | 258 | 307 | 222 | 279 | 187 | 11 | 36 |
| 15–19 | 304 | 389 | 292 | 267 | 269 | 209 | 12 | 122 |
| 20–24 | 221 | 458 | 204 | 195 | 186 | 152 | 17 | 264 |
| 25–29 | 196 | 567 | 169 | 158 | 150 | 115 | 27 | 409 |
| 30–34 | 156 | 596 | 133 | 142 | 120 | 106 | 23 | 455 |
| 35–39 | 173 | 640 | 131 | 133 | 120 | 89 | 42 | 508 |
| 40–44 | 136 | 589 | 102 | 96 | 95 | 74 | 35 | 493 |
| 45–49 | 127 | 516 | 91 | 87 | 80 | 64 | 36 | 429 |
| 50–54 | 115 | 309 | 65 | 71 | 61 | 54 | 50 | 238 |
| 55–59 | 139 | 206 | 81 | 63 | 76 | 51 | 59 | 143 |
| 60–64 | 144 | 192 | 78 | 65 | 69 | 54 | 66 | 127 |
| 65–69 | 135 | 181 | 65 | 58 | 59 | 53 | 70 | 123 |
| 70–74 | 190 | 172 | 89 | 56 | 86 | 44 | 101 | 116 |
| 75–79 | 192 | 178 | 89 | 72 | 83 | 65 | 104 | 106 |
| 80–84 | 125 | 140 | 67 | 68 | 52 | 65 | 59 | 72 |
| ≥85 | 101 | 99 | 43 | 41 | 40 | 41 | 58 | 57 |

The preventive value of each incidental appendectomy performed in different age groups can be estimated using the life table. For example, 1,000 incidental appendectomies could be expected to prevent 52 cases of appendicitis when performed in women aged 15–19 years, 24 cases when performed in women aged 35–39 years, and eight cases when performed in women aged 60–64 years. Between 1979 and 1984, approximately 260,000 incidental appendectomies were performed annually in persons under 75 years of age. Using the life table model, which is age-adjusted, we can see that these 260,000 procedures prevented an estimated 7,300 future lifetime cases of acute appendicitis; 36 incidental appendectomies were therefore performed for each case of appendicitis averted.

## Discussion

To describe the epidemiology of appendicitis and appendectomy in the United States, we analyzed longitudinal, nationally representative, population-based data from the National Hospital Discharge Survey. Previous studies of appendicitis in this country have been based on hospital case series, for which accurate denominator data were unavailable (27, 28), or on regional or statewide data (16, 29–32).

Our data have several important limitations. The actual number of hospital discharges sampled in any given year was relatively small, and it was often not possible to stratify data by variables of interest. In addition, the discharge records did not specify whether acute appendicitis was a surgical or a pathologic diagnosis. To the extent that the diagnosis was not confirmed, the incidence of acute appendicitis may have been overestimated and the negative appendectomy rate underestimated, since surgical diagnoses are more likely to be positive than those which are pathologically confirmed (33, 34).

It is also possible that some incidental appendectomies were miscoded as nonincidental. For example, 24 percent of primary negative (nonincidental) appendectomies were performed at the time of another major procedure, primarily oophorectomy, abdominal hysterectomy, or cholecystectomy. In these cases, which was the "incidental" procedure? We accepted nonincidental appendectomy codes at face value, assuming that acute appendicitis may have been suspected preoperatively ("rule out appendicitis") and that other pathology had been discovered at the time of surgery. In doing so, we may have overestimated the number of primary negative appendectomies (30) and underestimated diagnostic accuracy. Preoperative diagnoses, which could have helped resolve this issue, were not available. The diagnostic accuracy of 85 percent found in this study, however, is well within the range reported in hospital-based studies where pathologic findings and preoperative diagnoses were available (27).

Our findings using national data generally confirm the observations of others in regional studies and hospital case series. The overall incidence of appendicitis in the United States, 1.1 per 1,000 population per year, is comparable to the rates of 0.96–1.2 per 1,000 reported from Connecticut, South Carolina, and California (16, 30, 31). Although the incidence appears to be declining, appendicitis-related morbidity remains high, and deaths from appendicitis still occur, particularly in the elderly (35, 36).

One of the most striking epidemiologic features of appendicitis is the marked variation in incidence by age and sex. In both males and females, the highest rates were observed in persons aged 10–19 years, a finding consistent with those of several other studies (16, 30, 31, 37–39). In males, however, the peak incidence appeared at ages 10–14 years, compared with ages 15–19 years in females. The incidence of appendicitis was consistently higher in males than in females, even when persons with previous appendectomy were excluded from the denominator. Appendicitis rates 1.2- to 2.3-fold higher for males have also been reported by other investigators (30, 31, 38–

40), but this difference remains unexplained. The elevated rates in males across all age groups suggest that hormonal changes in females may not play as significant an etiologic role as previously hypothesized (41).

In contrast, primary negative appendectomy was more common in females, with the highest rates occurring in women of childbearing age. Accurate diagnosis is particularly difficult in this group, since gynecologic disease often mimics the symptoms of acute appendicitis (42). In addition, early surgical intervention, which has recently been encouraged because of an increased risk of tubal infertility following appendiceal perforation (43), may explain the higher rates of primary negative appendectomy in females.

A slight but consistent increase in appendicitis was noted during the summer months, a pattern found in some previous studies (44–46) but not others (27, 37, 38). The reasons for this seasonal pattern are unknown; speculation has focused on changes in atmospheric pressure (47) and on both increases (38) and decreases (45) in relative humidity. The increase in incidence during the summer months may also reflect an infectious etiology for acute appendicitis, a hypothesis supported by similar summer peaks of other enteric infections (46) and by the association of an acute appendiceal syndrome with *Yersinia* and other enteric pathogens (12–14).

The overall incidence of appendicitis appears to have decreased by 15 percent since 1970; the greatest declines were observed in the populations at highest risk. Declining rates of appendicitis have been reported in the United States and Europe since World War II (48–52), but the reasons for this are unclear. Changes in nutrition and diet (51), increased use of antibiotics (49), improvements in socioeconomic status (50), and changes in patterns of infectious disease and immunity (52) have all been proposed as possible explanations, but no causal associations have been demonstrated. It is also possible that the decrease in the rate of primary positive appendectomy between 1970 and 1984 reflects changing medical or surgical practices rather than an actual decline in the rate of appendicitis. In contrast to this pattern in the United States and Europe, the incidence of acute appendicitis appears to be increasing in developing countries where it has historically been low (5, 38, 53–55). The increase has been attributed to dietary changes (5, 55), improvements in socioeconomic status and hygienic standards (11, 54), and better access to health services (56). Some of these same factors may help explain the relative stability in appendicitis rates among nonwhites in the United States between 1970 and 1984 (a decrease of 4 percent), compared with a 16 percent decline among whites.

Regional variation in the incidence of appendicitis, independent of race or age distribution, was also noted. Geographic variation in appendicitis and appendectomy has been well documented and has been associated with differences in latitude (57), medical and surgical practices (56, 58, 59), appendicitis case definitions (56), and actual risk of disease (60). Whether ethnic or cultural differences contribute to the geographic variation in the United States is unknown, although this possibility is suggested by anecdotal observations. For example, immigrants from Germany, where appendectomy and appendicitis mortality rates are exceptionally high (59), settled primarily in the upper Midwest (61), the region with the highest incidence of acute appendicitis in the United States. Differences in surgical practices may also have played a role, since the regions with the highest rates of appendicitis were generally also highest for negative and incidental appendectomy. The precise relation between surgical practice and the incidence of appendicitis is difficult to determine, however, since both the diagnosis and the cure of acute appendicitis depend on surgery. If some cases of appendicitis do in fact resolve without surgical intervention, as some have suggested (32, 62), then surgical practice could indeed contribute to the observed regional variation.

The classic signs and symptoms of appendicitis do not reliably distinguish between patients who will have positive appendectomies and those who will have negative appendectomies (27). Although improved diagnostic accuracy has been reported with use of computer algorithms (63, 64) and high-resolution ultrasound (65, 66), clinical skill and experience remain the basis for managing patients with suspected appendicitis (67). The challenge to the surgeon is to prevent appendiceal perforation by early operation in cases of true appendicitis, but at the same time make the diagnosis with sufficient specificity to avoid unnecessary negative appendectomies. Because the initial signs and symptoms of appendicitis are not pathognomonic, the prevailing view has been that an acceptably low perforation ratio can be achieved only by surgeons who operate early and therefore perform a certain number of negative appendectomies (68, 69); the optimal negative appendectomy rate has been claimed to be as high as 23 percent (27). Others have argued that a low perforation ratio alone is a poor indicator of the quality of surgical practice (70), especially if it is achieved at the expense of excessively high numbers of negative appendectomies, which can be associated with significant morbidity (71). Indeed, several studies have shown that clinical training (72), intensive in-hospital observation (73), and use of enhanced algorithms for the differential diagnosis of abdominal pain (64) can improve diagnostic accuracy without a concomitant increase in the perforation ratio.

The national data also suggested a correlation between diagnostic accuracy and the perforation ratio when analyzed by region or year; small numbers limited statistical power, however, particularly in the analysis by region. Diagnostic accuracy and the perforation ratio were both higher among men than among women, a finding reported previously (74). Diagnostic accuracy and the total primary appendectomy rate appeared to be inversely related when data were analyzed by region, suggesting that in areas where the clinical "threshold" for operating is lower, diagnostic accuracy is reduced.

Although the incidence of appendiceal perforation did not vary as markedly with age as did the incidence of appendicitis, the two curves tended to be parallel; the peak incidence for both perforation and appendicitis occurred in persons aged 10–14 years. In contrast, the perforation ratio was strongly age-related, being highest in the elderly and the very young. This "J-shaped" pattern has been noted by other investigators (70, 75), and is thought to reflect both the increased diagnostic difficulty and the less timely surgical intervention for persons in these extreme age groups (75–77).

In the life table analysis, we assumed a constant incidence of appendectomy and appendicitis at 1979–1984 levels. Because incidence appears to be declining, the current risk of appendectomy and appendicitis in the United States may have been overestimated. Nonetheless, at rates observed for 1979–1984, one in eight males and one in four females can expect to have their appendix surgically removed during their lifetime; approximately one half of these procedures will be incidental appendectomies. The appropriateness and preventive value of incidental appendectomy, particularly in the elderly, has recently been questioned (16, 18, 78). Although it is generally considered a benign procedure (17), most incidental appendectomies are performed in persons over age 35, which is well past the age of greatest risk for appendicitis, and in females, who are at lower risk than males. Furthermore, it is possible that the additional surgical and hospital costs of incidental appendectomy may be more substantial than is generally assumed (16, 79).

The question of appropriate surgical policy is not whether incidental appendectomy prevents future appendicitis but whether the procedure should be performed in persons at low risk of appendicitis. At least two different ages, 35 years and approximately 60 years, have been proposed as ages at which to restrict incidental appendectomy (18, 78). The life table model suggests that limiting incidental appendectomies to persons under 35 years of age would reduce the total number of incidental procedures in the United States each year by 50 percent (130,000 operations), but it might result in as many as 2,200 additional lifetime cases of appendicitis, including 880 appendiceal perforations. In comparison, limiting incidental appendectomies to persons under 60 years of age would reduce the number of procedures by only 8 percent and result each year in an additional 130 lifetime cases of appendicitis (64 with perforation). To prevent a single lifetime case of acute appendicitis in persons aged 35 and 60 years, 59 and 166 incidental procedures are required, respectively. Although the overall rate of incidental appendectomy declined sharply between 1979 and 1984, little change was noted among the elderly, for whom the procedure has the lowest preventive value. Additional data on the economic and health consequences of incidental appendectomy policy are needed to further refine and guide surgical practice; meanwhile, the indications for this operation in older individuals remain controversial.

Although acute appendicitis is a common condition that has been recognized for more than a century, its etiology is poorly understood. In this study, several previously recognized epidemiologic patterns were confirmed: Persons aged 10–19 years have the highest rates of acute appendicitis; appendicitis is more common during the summer; and the incidence of the disease appears to be higher in males than in females, higher in whites than in nonwhites, and higher in persons living in certain regions of the United States, particularly the upper Midwest. In addition, the rates of appendicitis and appendectomy appear to be decreasing.

Important diagnostic and policy questions remain unanswered. To what extent is it possible, using new technologies, to improve diagnostic accuracy, particularly in women of childbearing age who have the highest rates of primary negative appendectomy? How can the perforation ratio and appendicitis-related mortality best be reduced in the elderly? Under what circumstances should incidental appendectomy be considered inappropriate?

Progress in answering these and other questions has been hampered by a lack of clarity and consensus in defining appendicitis, diagnostic accuracy, negative appendectomy, and incidental appendectomy. We have proposed simple definitions based on ICD codes that could be used in other studies. Further understanding of the etiology and epidemiology of appendicitis in the United States will require carefully designed prospective studies using pathologically confirmed diagnoses and standardized case definitions.

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