J Gastrointest Surg (2011) 15:1223–1231
DOI 10.1007/s11605-011-1486-x

ORIGINAL ARTICLE

Characteristics of Perforated Appendicitis: Effect of Delay Is Confounded by Age and Gender

Toms Augustin · Burt Cagir · Thomas J. VanderMeer

Received: 12 December 2010 / Accepted: 8 March 2011 / Published online: 10 May 2011

Abstract
Introduction The effect of age and gender on time to perforation in acute appendicitis has not been well characterized. This study examined the relationship between duration of disease and appendiceal perforation in different subgroups of age and gender.
Methods This study is a retrospective analysis of 380 patients who underwent an appendectomy from January 2000 to June 2005 at a rural teaching hospital.
Results Factors associated with perforated appendicitis included age, symptom duration, CT scan, and distance from the hospital. Factors associated with increased patient time included age, temperature >101.5 F, and referral from an outside institution. Factors associated with shorter system time included right lower quadrant tenderness, classic or severe presentation, and leading diagnosis of acute appendicitis. Preoperative CT scan increased system time by approximately 3 h. Analyzing symptom duration and time to perforation, males have a higher prevalence of perforated appendicitis compared to females with similar duration of symptoms. In patients older than 55 years of age, 29% had perforated appendicitis at 36 h of symptoms and 67% at 36 to 48 h of symptoms. In a multivariate regression analysis, age greater than 55 years (odds ratio (OR) 3.0, *P* value 0.007), fever (OR 4.3, *P* 0.007), and symptom duration more than 24 h (OR 4.1, P 0.001) were significant predictors of perforated appendicitis.
Conclusions There is an early risk of perforated appendicitis even within the first 36 h of symptoms. This risk appears to be higher in males and patients older than 55 years, a quarter of whom are perforated within the first 36 h of symptom duration. Additionally, perforation in acute appendicitis may be more of a continuous phenomena worsening exponentially with duration of symptoms rather than a threshold phenomenon.

Keywords Timing · Operation · Appendectomy · Acute appendicitis · Perforated appendicitis · Delays · Waiting time

Introduction

The delay associated with the treatment of acute appendicitis can be broadly divided into patient-related delay and system-related delay. Patient delay in the form of late presentation to the hospital probably constitutes majority of the delay in the treatment of acute appendicitis.[1–7]

Recent studies in pediatric populations suggest that postponing appendectomy until daytime hours with fluids and antibiotic treatment is safe.[8–10] Similar analyses in adults have yielded mixed results with proponents of both initial nonoperative treatment[2, 11] as well as urgent appendectomy on diagnosis.[12] This decision, however, is best based on knowledge of the natural history of acute appendicitis. Published data from urban centers suggests that the risk of perforated appendicitis increases after 36 h of untreated symptoms.[13] However, there is evidence that this progression to perforated appendicitis varies with age and gender. For example, a significant proportion of elderly patients present with perforation or abscess formation.[14, 15] At present, it is not known whether this is due to late

The abstract was presented as an oral presentation at the 5th Annual Academic Surgical Congress of the Association for Academic Surgery held at the Marriott Rivercenter Hotel in San Antonio, TX, USA from February 3–5, 2010.

T. Augustin (✉) · B. Cagir · T. J. VanderMeer
Department of Surgery, Guthrie-Robert Packer Hospital,
One Guthrie Square,
Sayre, PA 18840, USA
e-mail: taugustin@gmail.com

presentation of older adults to the hospital or an aggressive course of acute appendicitis. The effect of gender is less clear but may exist especially due to greater diagnostic delays in females.[16] Finally, whether rural versus urban residence, based on underlying differences in demographics, socio-economic status, and access to health care, influences progression of acute appendicitis has not been studied.[16]

With these issues in mind, this study looked at the factors associated with perforated appendicitis as well as patient delay and system delay in a rural population undergoing appendectomy. To further clarify the effect of age and gender on the progression of acute appendicitis to perforation, we did further analyses with the hypothesis that the rate of progression of acute appendicitis to perforation is different in subgroups of age and gender with older adults having a more rapid progression.

Material and Methods

This study is a retrospective analysis of all patients who underwent appendectomy at the Guthrie-Robert Packer Hospital (RPH) in Sayre, PA from January 2000 to June 2005. Robert Packer is a tertiary community teaching hospital with 240 beds that serves rural areas stretching over a 100-mile radius. The vast majority of patients undergoing appendectomies at this hospital are admitted through the emergency room (ER) where they are first seen by the ER physicians. Surgical consults are then obtained as deemed appropriate by the ER physician.

Initially, we identified all patients who underwent appendectomy at this institution during the above period. On a case by case basis, we then excluded patients who had an incidental or interval appendectomy. Of the 492 patients who underwent appendectomies during this time period, 45 patients were thus excluded. In order to obtain comparability to published studies of acute appendicitis, we then excluded all patients who had undergone a negative appendectomy.[13] There were 60 negative appendectomies during this period for a negative appendectomy rate of 13%. Seven patients with incomplete medical records were also excluded.

Patient Variables

Data were then collected on the remaining 380 patients. Chart review was done to collect information on patient demographics including age, gender, race, insurance, distance from the hospital based on the zip code of residence, relevant clinical history including comorbidities (diabetes mellitus, coronary artery disease, congestive cardiac failure, hypertension, or renal insufficiency or failure), radiological studies including CT scans, and pathology results. Age was analyzed both as a continuous and a categorical variable (<15, 15–45, 45–55, and >55 years). Since more than 97% of the patients in our population are Caucasians, the effect of race was not analyzed further. Patients for whom physicians noted appendicitis or acute abdomen with appendicitis as the leading diagnoses were considered to have a clinical impression of appendicitis. All other diagnoses were considered uncertain. Patients with five or more of the following clinical features were considered to have a classic presentation of appendicitis: (1) history of right lower quadrant pain; (2) anorexia; (3) nausea; (4) a temperature greater than 101.5 F; (5) right lower quadrant tenderness, guarding, or rebound tenderness; and (6) a white blood cell count (WBC) greater than 12,000/dL. Data on admission heart rate and dysuria were also collected. Patients with a classic presentation of appendicitis along with generalized abdominal tenderness were considered to have severe disease.

CT scan results were interpreted based on the final radiology report. CT scans at this institution are interpreted by an attending radiologist from 8 AM to 9 PM and by a consultant radiology service at night. All the consultant radiology reports are reinterpreted by an attending radiologist the next day for accuracy and quality assurance. In cases of ambiguity about reports, results were coded in consultation with an in-house attending radiologist. We categorized the findings on CT scan into normal appendix, acute appendicitis, and acute appendicitis with perforation. These were based on an internal consensus about the definitions to be used due to lack of a standard scale and the low sensitivity and specificity of CT scans for the diagnosis of perforated appendicitis.[17] Presence of periappendiceal fluid with or without extraluminal gas and/or loculated fluid collection with or without fluid level on the CT scan was used to classify perforated appendicitis.

All specimens were examined by an attending pathologist. The rate of perforated appendicitis was calculated based on all the appendectomies. A patient was defined to have perforated appendicitis if a perforation was noted by the pathologist, or if intraoperatively, the surgeon noted perforated appendicitis along with an abscess. There was a high correlation between the surgeon and the pathologist for the diagnosis of perforated appendicitis by the above definition (tetrachoric correlation coefficient 0.81, P value <0.0005).

Delay

The time between a patient's first notice of symptoms of fever, anorexia, nausea or vomiting, or abdominal pain and the time of registration in the ER were defined as "patient time". This was recorded in hours when the exact time of start of symptoms was available. When the exact time was not available, the nearest 12 h time was recorded. For example, "early morning" was approximated to 0600,

"evening" was approximated to 1800, and so on. Commonly, patients also noted the duration of symptoms in terms of half day increments. For example, the term "one day" was used by about 20% of patients to describe duration of symptoms. This was recorded as 24 h for the analyses. No particular age group or gender was noted to use such descriptive terms more often than other groups. The time from ER to the operating room was defined as "system time" and was coded in hours. ER arrival time was available from the ER registration sheet. For patients who had been referred for abdominal pain from outside facilities, system time was calculated with respect to the examination leading to the appendectomy. Time of surgery was available from the operating room documentation.

We also defined the "symptom duration" to perforation from the first start of symptoms. For this, we adjudicated the time of perforation for all patients. As there is no practical method to ascertain the exact time of perforation, we defined it to be the time of surgery for patients who did not have a preoperative CT scan suggesting perforated appendicitis. For patients who had evidence of perforated appendicitis on the preoperative CT scan which was confirmed operatively or postoperatively, the time of the CT scan was used as the time of perforation. There were 15 patients who had a preoperative CT scan suggesting perforated appendicitis and evidence for the same operatively or postoperatively. Symptom duration was analyzed as a categorical variable (<12 h, 12 to 24 h, 1 to 1 1/2 days, 1 1/2 to 2 days, 2 to 4 days, 4 to 8 days and >8 days). The data for calculation of symptom duration was not available for 31 patients (8% of the total population, 12 patients with perforated appendicitis).

Statistical Analysis

Statistical analysis was performed using STATA (Version 10, College Station, TX, USA). Bivariate associations were evaluated using chi-square tests for pairs of normally distributed ordinal variables. Many of the variables were not normally distributed. We used the Wilcoxon rank-sum test and Kruskal–Wallis equality-of-populations rank test to examine differences in central tendency for these variables. The Wilcoxon rank-sum test and Kruskal–Wallis equality-of-populations rank test are nonparametric tests that can be used to compare medians in populations that are comparably but not necessarily normally distributed.[18–20] The P value for trend was calculated using a logistic regression model with perforated appendicitis as the outcome variable and time periods of symptom duration as the independent variable. A P value less than 0.05 would indicate a significantly increased risk of perforated appendicitis with increasing symptom duration. Logistic regression was also used to assess the risk of perforated appendicitis while controlling for other independent variables. The study was approved by the Institutional Review Board at the Robert Packer Hospital.

Results

Clinical Characteristics and Perforation

There were 380 patients who underwent an appendectomy for acute appendicitis. Eighty-one (21%) patients were found to have perforated appendicitis. Median age for the overall population was 30 years. Patients with perforated appendicitis were significantly older that the group with no perforation. There was no difference in gender distribution between the two groups. On physical exam, patients with perforated appendicitis were noted to have a significantly increased prevalence of right lower quadrant tenderness and dysuria compared to the nonperforated group. There was no difference in abdominal pain, nausea or vomiting, diarrhea, anorexia, or mean heart rate, temperature, or WBC count between the two groups. Patients found to have perforated appendicitis underwent CT scans significantly more often than patients who were found not to have a perforation. Seventeen patients (28%) with perforated appendicitis were noted to have evidence for the same on CT scan. Patients with perforated appendicitis had a significantly longer patient time (60 vs. 33 h, $P<0.005$). The mean duration of symptoms prior to ER presentation for the entire population was 38.5 h. There was no significant difference in system time between the two groups. Patients with perforated appendicitis were noted to live farther from the hospital compared to the nonperforated group. Although statistically significant, this result is unlikely to be a clinically significant difference. There was no significant difference in place of first examination or insurance status between the two groups. As expected, the length of stay was significantly longer for patients with perforated appendicitis (Table 1).

Factors Associated with Patient Time

Patients older than 45 years of age were noted to have a significantly longer patient time. There was no significant difference based on gender, insurance status, anorexia, nausea or vomiting, or peri-umbilical pain. Patients with temperature more than 101.5 F on presentation had a significantly longer patient time probably reflecting advanced disease on presentation. Distance from the hospital did not influence patient time. Patients who were first examined outside of the RPH ER were noted to have a significantly longer patient time. Additionally, patients who underwent CT scans on admission were also noted to have a significantly longer patient time, suggesting that patients

Table 1 Patients' characteristics based on the presence or absence of rupture

Variable	Overall *N*	Nonperforated appendicitis	Perforated appendicitis	*P* value
N (%[a])	380	299 (79)	81 (21)	
Mean age (median; range[b])[c,d]	34 (30; 6–79)	31 (26; 7–79)	44 (50; 3–81)	<0.005
Women, *N* (%)[e]	149 (39)	121 (40)	28 (35)	0.34
Clinical exam, *N* (%)[e]				
Abdominal pain	377 (99)	297 (99.3)	80 (98.7)	0.61
RLQ tenderness	194 (51)	146 (49)	48 (59)	0.03
Nausea/vomiting	262 (69)	202 (68)	56 (69)	0.97
Diarrhea	38 (10)	26 (9)	12 (15)	0.10
Anorexia	241 (63)	190 (63)	51 (63)	0.39
Dysuria	14 (4)	8 (3)	6 (7)	0.04
Median heart rate (range)[e]	88 (48–144)	87 (47–144)	90 (60–145)	0.15
Mean temperature (range)[e]	98.8 (95.1–104.4)	98.8 (95.7–104.4)	99.2 (95.1–104)	0.06
Mean WBC count (range)[e]	14.5 (3–36)	14.6 (4.9–28.1)	14.5 (3–25.3)	0.45
CT scan, *N* (%)[e]				
Performed	221 (58)	161 (54)	60 (74)	<0.005
Perforated appendicitis	26 (11)	9 (5.5)	17 (28)	<0.005
Mean delay in hours (median; range)[c,d]				
Patient time	38.5 (24; 2–336)	33.2 (24; 2–336)	60 (48; 1.5–336)	<0.005
System time	9.8 (6.5; 0.7–92)	10 (6.5; 0.4–113)	8.9 (6.5; 0.8–76)	0.82
Mean distance from hospital in miles (median; range)[c,d]	21 (19.5; 1–86)	20 (19; 1–86)	24 (21.5; 1–89)	0.04
First examined, *N* (%)[e]				
RPH ER	257 (68)	208 (70)	49 (60)	
Outside RPH ER	117 (31)	88 (29)	29 (36)	0.21
Medicaid or self pay, *N* (%)[e]	84 (22)	68 (23)	16 (20)	0.92
Mean length of stay (median; range)[c,d]	2.9 (2; 0–15)	2 (1; 0–10)	6 (5; 0–27)	<0.005

All patients with negative appendectomies have been excluded

RLQ right lower quadrant, *RPH* Robert Packer Hospital, *ER* emergency room

[a] Percentages are a percent of the column total for whom the condition was recorded. The percentages may not add up to 100 due to patients with missing information

[b] Range is the 1st to the 99th percentile

[c] Based on Wilcoxon rank-sum test

[d] Median and mean values are reported for variables that are not normally distributed

[e] Based on chi-square

with longer duration of symptoms may preferentially undergo CT scans at this institution (Table 2).

Factors Associated with System Time

Clinical characteristics associated with significantly shorter system time included right lower quadrant tenderness, classic or severe presentation of acute appendicitis, and leading diagnosis of acute appendicitis. Duration of symptoms more than 36 h, age, gender, insurance, heart rate, or temperature did not significantly influence the system time. Patients first examined in the RPH ER had a significantly longer system time, probably reflecting the need for further workup compared to patients referred from outside institutions. Patients undergoing preoperative CT scan had significantly longer system time by 2.6 h compared to those who did not (Table 3).

Effect of Age, Gender, and Delay on Symptom Duration

Figure 1 shows the rate of perforation in the overall population at various intervals of symptom duration. In the overall population, percent perforated steadily increased from 7% at less than 12 h to 42% at 2–4 days. Thus, of the total 211 patients with a symptom duration of 36 h or less 9% were noted to have perforated appendicitis. Figure 2 compares the perforation rates based on gender. Males had a shorter symptom duration to perforation compared to

Table 2 Time from start of symptoms to registration in the RPH ER: patient time

Characteristics	Number	Mean patient time (median; 1st–99th percentile)	*P* value
Age (years)			
≤15	70	35 (24; 2–336)	
15–45	177	34.5 (24; 2–336)	
45–55	51	48.6 (36; 3–168)	
>55	51	47 (24; 1.5–336)	0.006
Gender			
Male	215	38 (24; 2–168)	
Female	134	39.4 (24; 3–336)	0.57
Insurance			
Medicaid or self pay	84	40 (24; 1–336)	
Other insurance	265	33.2 (24; 2–336)	0.34
Temperature (°F)			
≤101.5	307	36.4 (24; 2–336)	
>101.5	21	49.6 (36; 12–168)	0.009
Anorexia			
No	53	50.3 (24; 1–336)	
Yes	227	34.8 (24; 2–168)	0.38
Nausea or vomiting			
No	106	41.5 (24; 1.5–336)	
Yes	243	37.2 (24; 3–336)	0.87
Peri-umbilical and RLQ pain			
No	235	42.8 (24; 2–336)	
Yes	105	28.5 (24; 3–144)	0.31
Distance from the hospital			
Less than 20 miles	184	37 (24; 1.5–336)	
More than or equal to 20 miles	165	39.8 (24; 3–336)	0.25
Location of first examination			
RPH ER	239	30.2 (24; 2–168)	
Outside RPH ER	108	56.9 (24; 4–336)	<0.005
CT performed			
No	147	32.2 (24; 2–336)	
Yes	202	43.1 (24; 2–168)	0.05

**P* values are based on the Kruskal–Wallis equality-of-populations rank test for age and Wilcoxon rank-sum test for the other variables

females. Eleven percent of males present with perforated appendicitis in the first 36 h of symptoms as opposed to 6% of females; 31% of males and 19% of females presenting between 36 to 48 h were noted to have perforated appendicitis. Figure 3 compares patients less than or equal to 55 years to patients aged more than 55 years. For the patients aged more than 55 years, we combined the less than 12-h and 12- to 24-h time intervals due to the small number of patients in these groups. We also combined the 4- to 8-day and the more than 8-day time intervals for the above reason. Twenty-nine percent (7 out of 24) of patients aged older than 55 years have perforated appendicitis within 36 h of symptoms as opposed to 7% (13 out of 188) of patients aged 55 years or less. After 36 h, there is a steady increase in the percent perforated in the less than 55 age group and a dramatic increase in percent perforated in the more than 55-year age group. Seventy-one percent of patients older than 55 years with symptoms for 36 to 48 h had perforated appendicitis. Figure 4 compares the perforation rates between males and females in the less than 55-year-old age group. Again, males perforate sooner than females, with 8.5% of males (10 out of 117) having perforated appendicitis within 36 h of the start of symptoms as opposed to 4% of females (3 out of 71). These trends were noted to be significant in all the groups except the 55 years and older. We think that the nonsignificant *P* value for the 55-year and older group may be due to both the higher rate of perforation on presentation as well as the small number of patients in each interval of symptom duration. In all time periods of symptom duration, we noted a gradual increase in the percent of perforated appendicitis rather than a threshold effect. In a multivariate logistic regression model, age more than 55 years (odds ratio 3.0, *P* value 0.007), elevated temperature >101.5 F (odds ratio 4.3, *P* value 0.007), and symptom duration more than

Table 3 Time from registration in the ER to surgery: system time

Characteristic	Number	Mean system time (median; range)	*P* value*
Age (years)			
≤15	71	8.5 (6.6; 0.65–29.9)	
15–45	180	9.9 (6.2; 0.35–126.9)	
45–55	52	9 (6.7; 0.9–75.7)	
>60	52	8.9 (6.8; 0.8–113)	0.68
Gender			
Male	218	9.2 (6.2; 0.7–46)	
Female	137	10.7 (6.8; 0.7–113)	0.16
Insurance			
Medicaid or self pay	84	8.7 (6.3; 0.3–127)	
Other insurance	271	10.2 (6.6; 0.7–92)	0.22
Heart rate			
<100	231	9 (6.5; 0.7–40)	
≥100	96	12 (6.7; 0.9–127)	0.22
Temperature (°F)			
>101.5	21	7.8 (6.6; 1–26)	
≤101.5	308	9.3 (6.5; 0.7–64)	0.65
Right lower quadrant tenderness			
No	167	12.2 (6.8; 0.4–127)	
Yes	182	7.6 (6; 0.7–39)	0.01
Classic presentation			
No	228	10.4 (6.7; 0.7–76)	
Yes	127	8.8 (6.0; 0.7–127)	0.01
Symptoms more than 36 h			
No	247	8.7 (6.6; 0.6–35)	
Yes	102	10.3 (6.4; 0.8–76)	0.59
Severe presentation			
No	107	8.7 (5.4; 0.7–127)	
Yes	19	9.7 (9.8; 1.4–23)	0.01
Leading diagnosis a/c appendicitis			
No	43	15.7 (12.5; 0.8–137)	
Yes	306	9.1 (6.3; 0.7–64)	<0.005
Location of first examination			
RPH ER	239	10 (7.2; 1.5–64)	
Outside RPH ER	112	9.5 (3.9; 0.4–113)	<0.005
CT performed			
No	149	8.3 (4.5; 0.4–113)	
Yes	206	10.9 (8.0; 0.8–76)	<0.005

**P* values are based on the Kruskal–Wallis equality-of-populations rank test for age and Wilcoxon rank-sum test for the other variables

24 h (odds ratio 4.1, *P* value 0.001) were significant predictors of perforated appendicitis (adjusted for age, gender, heart rate >100, temperature >101.5 F, admission CT scan, insurance, distance, and symptom duration).

Discussion

In an analysis of patients undergoing appendectomy for acute appendicitis in a rural population, we found that (1) CT scans significantly contribute to system delays in the treatment of acute appendicitis. (2) Delay in presentation, age more than 55 years, and elevated temperature (>101.5 F) on admission are predictors of perforated appendicitis. (3) There is an early risk of perforation even within the first 36 h of start of symptoms which may be higher in males than females. Additionally, patients older than 55 years of age have a 29% prevalence of perforated appendicitis in the first 36 h from start of symptoms. (4) Rather than a threshold effect, we noted a gradual increase in the percent of perforated appendicitis in all time periods of symptom duration.

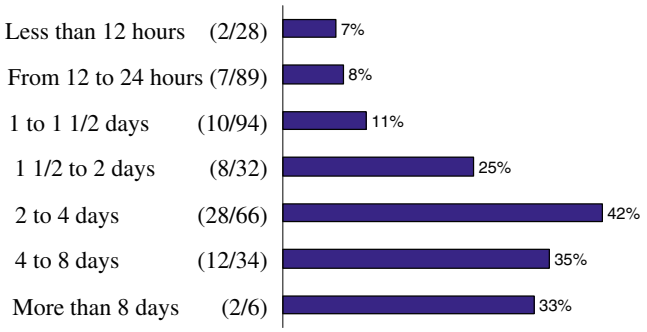

Fig. 1 Graph showing symptom duration (*X* axis) and percentage perforated (*Y* axis). The *numbers in parentheses* are the total number of patients with perforated appendicitis over the total number of patients undergoing appendectomy in that respective time interval

Previous authors have suggested that the risk of perforated appendicitis is relatively small in the first 36 h of symptom onset.[13, 21] Bickell et al. also noted that the risk of perforation increases by 5% for each ensuing 12-h period after 36 h. Our study found an increasing incidence of perforated appendicitis starting at even less than 12 h of duration of symptoms. We explored the reasons for this discrepancy. The rate of perforated appendicitis in our study is higher compared to the above study but is comparable to studies from other US centers.[12] Our adjudication of symptom duration was different from the studies in the past. For patients with perforated appendicitis on whom a preoperative CT scan demonstrated the same, we used time of CT scan to indicate time of perforation.[12, 13] To address possible selection bias due to different quantification of symptom duration for patients with CT scans, we analyzed the symptom duration in all 15 patients where perforation was noted on the preoperative CT scan. We next compared this time to the usual definition of symptom duration based on the time of surgery. All but one patient were noted to have the same classification of time period of symptom duration. So our adjudication of symptom duration probably does not explain our results. The median age of our population is higher than the study by Bickell et al. Another influential study by Ditillo et al. found that there was an increasing incidence of "G3 pathology" (perforated appendicitis or phlegmon) with increasing total interval to surgery starting at less than 12 h of untreated symptoms.[12]

To explore the effect of age and gender on our findings, we performed multiple sub-analyses. The authors are unaware of previous studies exploring these relationships. Our results summarized above suggest a more aggressive natural history of acute appendicitis in the elderly population as well as possible differences between males and females. Previous research has suggested that a significant proportion of the elderly present with perforation or abscess formation.[14, 15] This has been suggested to be due to delay in presentation in previous analyses. We, however, noted a comparable patient time and system time for patients older than 55 years compared to younger patients. Thus, underlying physiological differences may be a better explanation for rapid perforation in older adults. This assertion has also been suggested historically.[22] Another mechanism that may partly explain the finding of earlier perforation in males and older adults may be differences in perception of pain. Studies have noted females to be at higher risk for clinical pain syndromes and also have more severe postoperative and procedural pain.[23] Similarly, older patients have also been noted to have atypical presentations with lower incidence of right lower quadrant guarding and pain.[24]

This study also brings out interesting differences and similarities between urban and rural populations presenting with acute appendicitis. Robert Packer Hospital is located in Sayre, PA with a population of about 5,500 and outside urbanized areas as defined by the United States Census Bureau in 2000.[25] Although Robert Packer Hospital is a tertiary referral hospital serving a large geographic region that includes urbanized areas, patients with acute appendicitis are generally cared for in local hospitals within those urbanized areas. Recent papers have suggested that the major delay in acute appendicitis is the pre-hospital delay in presentation rather than the system time after presentation to the hospital.[11–13] Our study confirms this finding in a rural population. Although CT scans caused the major

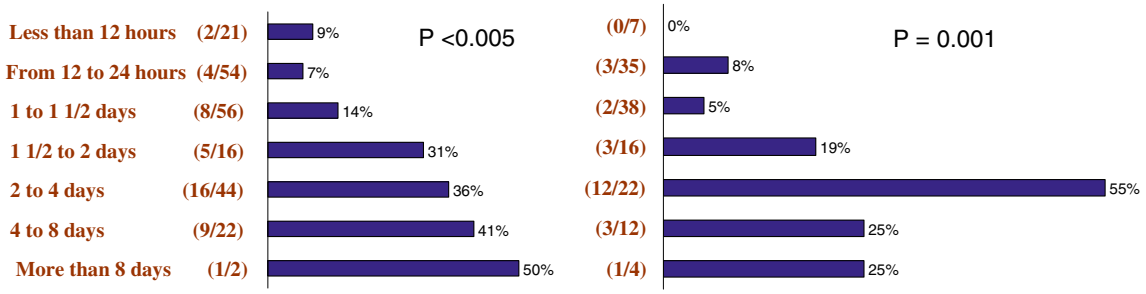

Fig. 2 Graph comparing the relationship between symptom duration (*X* axis) and percentage perforated (*Y* axis): males and females. The *numbers in parentheses* indicate the total number of patients with perforated appendicitis over the total number of patients undergoing appendectomy during the respective time interval. *P* value for trend of percent perforated appendicitis based on symptom duration

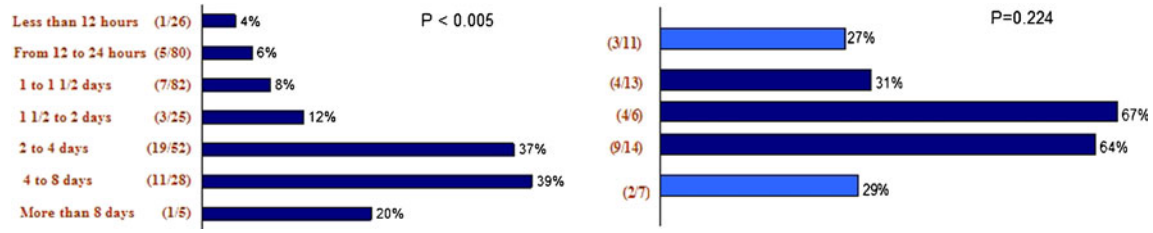

Fig. 3 Graph comparing the relationship between symptom duration (*X* axis) and percentage perforated (*Y* axis): age 55 years or less and age more than 55 years. The *numbers in parentheses* indicate the total number of patients with perforated appendicitis over the total number of patients undergoing appendectomy during the respective time interval. *P* value for trend of percent perforated appendicitis based on symptom duration. For the patients aged 55 years or above, we combined the less than 12-h and 12- to 24-h time intervals as well as the 4- to 8-day and the more than 8-day time intervals due to the small number of patients in these groups

system delay in our study, the delay was less compared to studies from urban centers where it was noted to be as high as 10 h.[13, 26, 27] In a recent paper from this center, CT scans were noted to be associated with an increased risk of perforated appendicitis especially in males.[16] This study provided additional evidence of the mechanism based on increased system time. At our institution, we have continued to implement the policy of surgical consultation before CT scan in males younger than 45 years of age presenting with a leading diagnosis of acute appendicitis. We could not find a recent study providing mean symptom duration prior to presentation for patients in the USA. This is about 38 h for our population. Our study population is mostly Caucasians as compared to urban centers where the population includes a higher percentage of minority groups. We also found that the ratio of males to females in our population is higher than the urban population.[28] We did not find any recent paper reporting distance from the hospital. We did not find any relation between insurance status and perforation in our population. This is also different from urban populations where there might exist a difference in perforation rates based on insurance status.[29, 30]

The retrospective determination of the time of start of symptoms continues to be a significant limitation of this paper. We do, however, believe that our data on symptom duration are not confounded by knowledge regarding the final patient outcome. This was because these data were collected separately by an independent data collector with no knowledge of final patient outcome. Our results are also consistent across all age groups and genders and similar to previously published literature.[2, 12, 13] Insufficient data on adults older than 55 years of age in our dataset limited our analysis of the effects of delay in this age group. Being a mostly Caucasian population, the effects of race also cannot be analyzed in our population.

Our study confirms the relationship between symptom duration and advanced pathology in patients with acute appendicitis in a rural population. We additionally also found varying trends in the rate of perforation based on the age and gender of the patient population. This finding has important treatment and policy implications. Appendectomy should be performed without delay in adults especially males and those older than 55 years once diagnosis is confirmed. The system delays in management of acute appendicitis can be decreased by prudent utilization of CT scans.

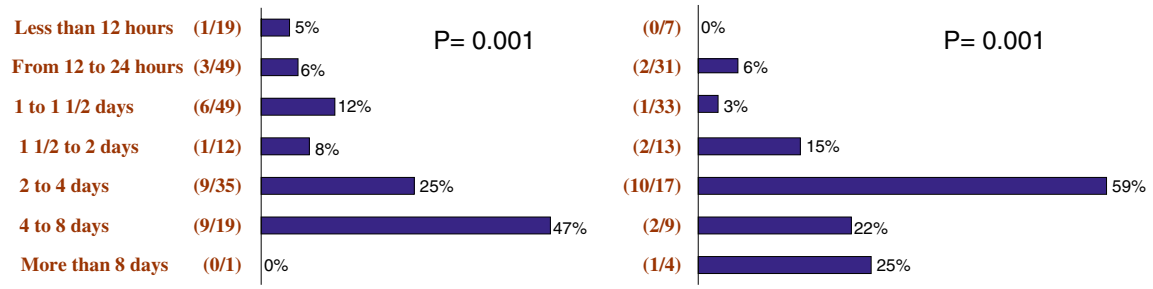

Fig. 4 Graph comparing the relationship between symptom duration (*X* axis) and percentage perforated (*Y* axis): males and females less than or equal to 55 years of age. The *numbers in parentheses* indicate the total number of patients with perforated appendicitis over the total number of patients undergoing appendectomy during the respective time interval. *P* value for trend of percent perforated appendicitis based on symptom duration

Acknowledgments The authors thank Siddharth Bhende MD, Keyur Chavda MD, Anthony Guiffrida, and Catherine Simone for collecting the data for the study.

Disclosure None.

References

1. Cappendijk VC, Hazebroek FW. The impact of diagnostic delay on the course of acute appendicitis. Arch Dis Child 2000; 83: 64–66.
2. Eldar S, Nash E, Sabo E et al. Delay of surgery in acute appendicitis. Am J Surg 1997; 173: 194–198.
3. Temple CL, Huchcroft SA, Temple WJ. The natural history of appendicitis in adults. A prospective study. Ann Surg 1995; 221: 278–281.
4. White JJ, Santillana M, Haller JA, Jr. Intensive in-hospital observation: a safe way to decrease unnecessary appendectomy. Am Surg 1975; 41: 793–798.
5. Thomson HJ, Jones PF. Active observation in acute abdominal pain. Am J Surg 1986; 152: 522–525.
6. Kearney D, Cahill RA, O'Brien E et al. Influence of delays on perforation risk in adults with acute appendicitis. Dis Colon Rectum 2008; 51: 1823–1827.
7. Brender JD, Marcuse EK, Koepsell TD, Hatch EI. Childhood appendicitis: factors associated with perforation. Pediatrics 1985; 76: 301–306.
8. Yardeni D, Hirschl RB, Drongowski RA et al. Delayed versus immediate surgery in acute appendicitis: do we need to operate during the night? J Pediatr Surg 2004; 39: 464–469; discussion 464–469.
9. Surana R, Quinn F, Puri P. Is it necessary to perform appendicectomy in the middle of the night in children? Bmj 1993; 306: 1168.
10. Bachoo P, Mahomed AA, Ninan GK, Youngson GG. Acute appendicitis: the continuing role for active observation. Pediatr Surg Int 2001; 17: 125–128.
11. Abou-Nukta F, Bakhos C, Arroyo K et al. Effects of delaying appendectomy for acute appendicitis for 12 to 24 hours. Arch Surg 2006; 141: 504–506; discussioin 506–507.
12. Ditillo MF, Dziura JD, Rabinovici R. Is it safe to delay appendectomy in adults with acute appendicitis? Ann Surg 2006; 244: 656–660.
13. Bickell NA, Aufses AH, Jr., Rojas M, Bodian C. How time affects the risk of rupture in appendicitis. J Am Coll Surg 2006; 202: 401–406.
14. Franz MG, Norman J, Fabri PJ. Increased morbidity of appendicitis with advancing age. Am Surg 1995; 61: 40–44.
15. Hui TT, Major KM, Avital I et al. Outcome of elderly patients with appendicitis: effect of computed tomography and laparoscopy. Arch Surg 2002; 137: 995–998; discussion 999–1000.
16. Augustin T, Bhende S, Chavda K et al. CT scans and acute appendicitis: a five-year analysis from a rural teaching hospital. J Gastrointest Surg 2009; 13: 1306–1312.
17. Bixby SD, Lucey BC, Soto JA et al. Perforated versus non-perforated acute appendicitis: accuracy of multidetector CT detection. Radiology 2006; 241: 780–786.
18. Kruskal W, Wallis W. Use of ranks in one-criterion variance analysis. J Amer Statist Assoc 1952; 47: 583–621.
19. Mann H, Whitney D. On a test of whether one or two random variables is stochastically larger than the other. Ann Math Statist 1947; 18: 50–60.
20. Whitley E, Ball J. Statistics review 6: Nonparametric methods. Crit Care 2002; 6: 509–513.
21. Papaziogas B, Tsiaousis P, Koutelidakis I et al. Effect of time on risk of perforation in acute appendicitis. Acta Chir Belg 2009; 109: 75–80.
22. Freund HR, Rubinstein E. Appendicitis in the aged. Is it really different? Am Surg 1984; 50: 573–576.
23. Fillingim RB, King CD, Ribeiro-Dasilva MC et al. Sex, gender, and pain: a review of recent clinical and experimental findings. J Pain 2009; 10: 447–485.
24. Burns RP, Cochran JL, Russell WL, Bard RM. Appendicitis in mature patients. Ann Surg 1985; 201: 695–704.
25. United States Census 2000. [cited January 3, 2009]; Available from: http://www.census.gov/main/www/cen2000.html
26. Garfield JL, Birkhahn RH, Gaeta TJ, Briggs WM. Diagnostic pathways and delays on route to operative intervention in acute appendicitis. Am Surg 2004; 70: 1010–1013.
27. Lee SL, Walsh AJ, Ho HS. Computed tomography and ultrasonography do not improve and may delay the diagnosis and treatment of acute appendicitis. Arch Surg 2001; 136: 556–562.
28. DeArmond GM, Dent DL, Myers JG et al. Appendicitis: selective use of abdominal CT reduces negative appendectomy rate. Surg Infect (Larchmt) 2003; 4: 213–218.
29. Bratton SL, Haberkern CM, Waldhausen JH. Acute appendicitis risks of complications: age and Medicaid insurance. Pediatrics 2000; 106: 75–78.
30. Braveman P, Schaaf VM, Egerter S et al. Insurance-related differences in the risk of ruptured appendix. N Engl J Med 1994; 331: 444–449.