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Changing Epidemiology of Acute Appendicitis in the United States: Study Period 1993–2008

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Background. **Addis *et al.* [5] described the epidemiology of appendicitis in the United States from 1970 to 1984. He reported that while overall incidence decreased, the highest incidence of appendicitis occurred in 10- to 19-y-olds. This study examines if the incidence of appendicitis and mean age of diagnosis has changed, and whether demographics are related to the frequency of admissions and incidence rate of acute appendicitis (AA).**

Materials and Methods. **Study questions were assessed using the Nationwide Inpatient Sample (NIS) discharge data and US Census data from 1993–2008. Operatively managed, uncomplicated, and complex cases of AA were included. Incidental appendectomy and right hemicolectomy were excluded. Descriptive, ANOVA, χ^2, and test of proportion statistics were used to evaluate frequency of admissions, incidence rate, and demographic changes in appendicitis.**

Results. **The annual rate of AA increased from 7.62 to 9.38 per 10,000 between 1993 and 2008. The highest frequency of AA was found in the 10–19 y age group, however occurrence in this group decreased by 4.6%. Persons between ages 30 and 69 y old experienced an increase of AA by 6.3%. AA rates remained higher in males. Hispanics, Asians, and Native Americans saw a rise in the frequency of AA, while the frequencies among Whites and Blacks decreased.**

Conclusions. **While AA is most common in persons 10- to 19-y old, the mean age at diagnosis has increased over time. Minorities are experiencing an increase in the frequency of appendicitis. The changing demographics of the US plays a role in the current epidemiology of appendicitis, but is not solely responsible for the change observed.**

Key Words: **appendicitis; appendectomy; epidemiology; gender; race; age trends.**

INTRODUCTION

Acute appendicitis (AA) is the one of the most common abdominal emergencies found in the United States. Approximately 11 in 10,000 people will experience appendicitis in their lifetime [1]. This rapidly progressing inflammatory process requires prompt removal of the appendix to prevent life-threatening complications such as ruptured appendix and peritonitis [1]. The epidemiology of this condition has been revisited multiple times throughout the world, with most studies agreeing that the most likely age group affected is between the ages of 10 and 19 y. Additionally, a common trend seems to be that appendicitis rates are decreasing.

European studies indicate a trend in decreasing rate of appendicitis in young adults, ages 10 to 19 y old. Recently, a Danish study showed a decrease in incidence of uncomplicated appendicitis in the same age range. Between the years 1996 and 2004, there was a 27.8% decrease in AA in males ages 10 to 14 y, and 12.8% decrease in males ages 15 to 19 y. This trend was similar in the female population with a 35.9% decrease in AA in ages 10 to 14 y and a 22.5% decrease in ages 15 to 19 y [2]. Similarly, this trend in decreased incidence was shown through a retrospective review in a small Spanish community during a 10-y study from 1998 to 2007. Frequency of appendectomy in this community displayed a slight descending trend. The female population showed the greatest decrease in AA diagnosis [3].

Studies in North America indicate a similar trend in decreasing rate of appendicitis. An overall 5.1%

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decrease in annual rate of AA between the years 1991 and 1998 was reported by Al-Omran *et al.* in a Canadian study. In females, the decrease was 3.1% and in males it was 6.5%. The incidence was highest in males and females aged 10 to 19 y, and the frequency of AA declined with age increment [4]. In the United States, a study on the epidemiology of appendicitis showed a decreasing trend from 1970 through 1984. Addis *et al.* analyzed data from the National Hospital Discharge Survey (NHDS), and similar to his international counterparts, he found that while the overall incidence decreased by 14.6%, the highest incidence of appendicitis remained in ages 10 to 19 y [5].

At our community teaching hospital, we have observed a trend of older persons, >age 40 y, presenting with appendicitis and wondered whether this trend was occurring on a national level. Data from the United States Census Bureau shows that the population profile in the United States is changing. The mean age has risen to between 30 and 40 for most ethnicities, and additionally the racial profile is becoming more diverse [6]. We hypothesize that the changing demographics of the United States has played a role in changing the epidemiology of appendicitis. In our study, we examine the epidemiology of appendicitis using a nationwide database, looking at possible trends during the period of 1993 to 2008. Our study examines if there has been a shift in the mean age of diagnosis, and if gender and race are still related to the incidence of this disease process.

MATERIALS AND METHODS

Data were extracted from the National Inpatient Sample (NIS), a national database available from the Healthcare Cost Utilization Project (HCUP), which is sponsored by the Agency for Healthcare Research and Quality (AHRQ) [7]. The NIS database contains information on inpatient hospital stays from about 1000 hospitals in 22 states from 1988 through 2008. For our study, we used data from 1993 through 2008 because of sampling design modifications that took effect in 1993. NIS discharge weights were applied to all analyses in order to estimate national trends. According to Burns *et al.* [8], the AHRQ "has developed appropriately scaled discharge weights to generate national estimates of hospitalizations from the NIS. With these weights, national estimates of hospitalizations and hospitalization rates are comparable across years despite the varying number of states participating in each year of the HCUP" (pg. 639).

To determine national estimates of appendicitis, the following CPT codes were used: simple (ICD-9 codes: 540, 540.9, and 541) or complex (ICD-9 codes: 540.0, 540.1, and 542). The number of primary diagnosis of appendicitis (numerator) was determined. These numbers were verified using HCUPnet (http://hcupnet.ahrq.gov/HCUPnet.jsp) website. HCUP data is reported using frequencies. In order to compare it to national data, we utilized the US census and determined a rate per 10,000. Similar methodology was used by Foxman *et al.* [9]. The denominator for incidence rate calculation, United States census data by year [10] was used to determine national rates for appendicitis (number of appendicitis/census number × 10,000).

Once national appendicitis estimates were determined, we further refined our data set to include only patients who also had an appendectomy (CPT code 47.0), laparoscopic appendectomy (CPT code 47.01) or other appendectomy (other/with drainage; CPT code 47.09). Incidental appendectomy (CPT code 47.19), incidental laparoscopic appendectomy (CPT code 47.11) and right hemicolectomy (CPT code 45.73) were excluded. This is an administrative database and it is hard to tell if patients were readmitted for appendicitis; therefore, only cases that had appendicitis and appendectomy were used (termed as AA).

Once all years were converted to SPSS (SPSS Inc., Chicago IL), they were combined to create one Core data file from 1993 to 2008. This data file merged with Hospital Weights files for each year. All analyses were conducted using SPSS ver. 19 and MedCalc (MedCalc Software, Mariakerke, Belgium). Parameters reviewed in the NIS database included gender, race (White, Black, Native American, Hispanic, and Asian), age (age was recoded into 10-y groups), region, hospital bed size, teaching hospital, and cases in urban and rural areas. Each parameter was reviewed by year to determine variability from year to year. No cases were excluded if there was missing data; however, missing data was not used in sub-analysis of relevant variables (e.g., race, gender, age, etc.). Statistics included descriptive, ANOVA, χ^2, and test of proportion statistics to evaluate appendicitis admission frequency, incidence rate and age-related changes by year.

RESULTS

National Trend

The annual rate (per 10,000 population) of all AA increased from 7.62 in 1993 to 9.38 in 2008 (Fig. 1). From 1993 to 1998, the annual rate remained stable at approximately 7.7 cases per 10,000. There has been gradual increase with peak in 2005 at about 9.7 cases per 10,000 and since remained stable at about 9.4 cases per 10,000.

US Demographic Characteristics

A total of 3,913,030 weighted cases met our inclusion criteria in the NIS data set from 1993 through 2008. Table 1 shows characteristics of appendicitis patients at years 1993 and 2008, by four y groups. The left side of Table 1 represents frequencies of admission of acute appendicitis with appendectomy from the HCUP database. The right side of Table 1 indicates the hospitalization incidence rate using census projections for each

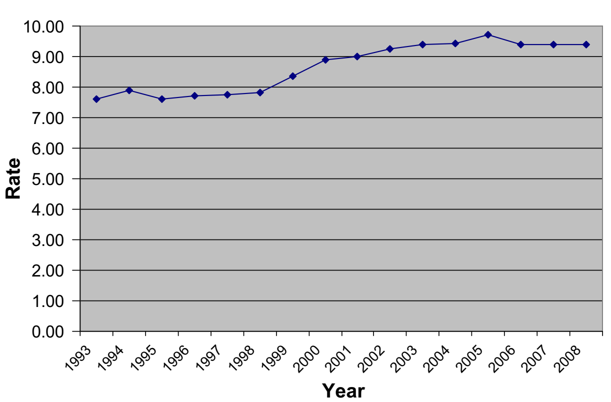

FIG. 1. Rates (per 10,000) by year in US hospitals, weighted to produce national estimates. (Color version of figure is available online.)

TABLE 1

Frequency of Hospitalization in AA and National Estimates of AA rate

	Hospitalization frequency (%)*				National estimated in-hospital appendicitis rate (per 10,000)[†]					
	1993–1996	1997–2000	2001–2004	2005–2008	1993–1996	1997–2000	2001–2004	2005–2008	% Change/ year-group	*P* value
Gender[†1,†2]										
Male	478,678 (59.3)	529,612 (59.0)	608,157 (57.6)	624,357 (56.6)	9.4	9.9	10.7	10.6	4.1%	<0.001
Female	328,665 (40.7)	367,754 (41.0)	447,423 (42.4)	479,065 (43.4)	6.1	6.6	7.6	7.9	8.7%	<0.001
Age Ranges[†3,†4]										
0–9	72,223 (9.1)	81,398 (9.2)	91,683 (8.7)	95,835 (8.6)	4.7	5.2	5.8	5.9	8.3%	<0.001
10–19	218,909 (27.5)	230,010 (26.0)	250,810 (23.8)	255,670 (22.9)	14.9	14.6	15.1	15.3	1.0%	0.324
20–29	169,876 (21.3)	175,189 (19.8)	202,114 (19.2)	216,509 (19.4)	11.4	11.9	12.8	13.0	4.6%	<0.001
30–39	141,375 (17.8)	156,698 (17.7)	181,151 (17.2)	175,659 (15.8)	8.0	9.1	10.7	10.8	10.6%	<0.001
40–49	76,982 (9.7)	98,366 (11.1)	132,207 (12.5)	140,187 (12.6)	5.2	5.9	7.4	7.8	14.9%	<0.001
50–59	49,478 (6.2)	68,673 (7.8)	98,858 (9.4)	113,421 (10.2)	5.1	5.9	7.2	7.3	13.3%	<0.001
60–69	35,516 (4.5)	39,861 (4.5)	52,268 (5.0)	66,274 (5.9)	4.4	5.0	6.1	6.7	15.0%	<0.001
70–79	23,113 (2.9)	24,987 (2.8)	31,287 (3.0)	35,182 (3.2)	3.7	3.9	4.9	5.5	14.0%	<0.001
80–89	7694 (1.0)	8195 (0.9)	11,767 (1.1)	14,387 (1.3)	2.9	2.8	3.5	4.0	12.2%	0.0231
90–99	881 (0.1)	1019 (0.1)	1381 (0.1)	1692 (0.2)	1.8	1.8	2.2	2.2	8.2%	0.2615
100+	31 (0.0)	14 (0.0)	32 (0.0)	19 (0.0)	1.7	0.7	1.5	0.7	0.3%	0.2773
Race[†1,†2]										
White	475,011 (74.3)	493,887 (70.7)	511,102 (66.5)	548,987 (66.0)	6.2	6.3	6.5	6.9	3.9%	0.0187
Black	48,637 (7.6)	46,739 (6.7)	48,891 (6.4)	51,664 (6.2)	3.9	3.5	3.5	3.5	–3.1%	0.1418
Hispanic	87,986 (13.8)	113,147 (16.2)	152,623 (19.9)	166,657 (20.0)	8.2	8.9	9.9	9.5	5.0%	0.0012
Asian	13,153 (2.1)	18,605 (2.7)	22,198 (2.9)	24445 (2.9)	3.8	4.6	4.7	4.6	7.1%	0.0781
Native American	2491 (0.4)	2682 (0.4)	2975 (0.4)	5410 (0.7)	3.2	3.3	3.4	5.9	26.0%	0.0158
Other	12,396 (1.9)	23,492 (3.4)	30,633 (4.0)	34,725 (4.2)	‡	‡	‡	‡	‡	
Region of hospital[†5,†6]										
Northeast	145,758 (18.1)	179,375 (20.0)	212,768 (19.9)	238,556 (21.0)	7.1	8.6	9.8	10.9	15.5%	<0.001
Midwest	198,341 (24.6)	195,389 (21.8)	232,755 (21.7)	226,873 (20.0)	8.0	7.7	8.9	8.6	2.6%	<0.001
South	265,578 (32.9)	288,891 (32.2)	351,282 (32.8)	383,193 (33.7)	7.3	7.5	8.5	8.7	6.4%	<0.001
West	196,893 (24.4)	233,839 (26.1)	275,046 (25.7)	287,654 (25.3)	8.6	9.6	10.4	10.4	6.5%	<0.001

*Percent out of number of hospitalizations for acute appendicitis.

†Hospitalization rates calculated using National US Census projects for each group from 1993 through 2008.

[1]1990–1999 Gender, Race, Hispanic Census Data: http://www.census.gov/popest/archives/1990s/nat-srh.txt.

[2]2000–2009 Gender, Race, Hispanic Census Data: http://www.census.gov/popest/national/asrh/NC-EST2009/NC-EST2009-03.xls.

[3]1990–1999 Age Census Data: http://www.census.gov/popest/archives/1990s/nat-agesex.txt.

[4]2000–2009 Age Census Data: http://www.census.gov/popest/national/asrh/NC-EST2008/NC-EST2008-01.xls.

[5]1990–1999 National and Regional Census Data: http://www.census.gov/popest/eval-estimates/national-regional-state/ST-2000-7.txt.

[6]2000–2009 National and Regional Census Data: http://www.census.gov/popest/states/tables/NST-EST2009-01.xls.

‡National US Census estimates for Other race could not be determined.

year. Therefore the right side of the table takes into account the frequencies presented on the left of the table, and combines them with national census projections to create an incidence rate of AA for each demographic. If changes in AA were directly related to demographics we would expect no change in the number per 10,000 people in our national estimates portion of Table 1. Since there are changes, we show that change in demographics is not the sole factor in the epidemiology of AA except for where race is concerned. These numbers are insignificant alluding to the fact that changes in racial profiles contribute to the epidemiology of AA. This will be further discussed below.

HCUP data (left side of Table 1) reveals that hospitalization frequencies decreased in males and increased in females. Throughout the study period, AA hospitalization rates (right side of Table 1) increased for both males and females, 4.1% and 8.7%, respectively.

HCUP data shows that the highest frequency of AA was found in patients aged 10-19 years old; however, the frequency of AA in this age group decreased by 4.6% from 1993-1996 to 2005-2008, which is significant, ($P < 0.05$). When census data is taken into account, the highest incidence of AA remains ages 10 to 19 y. Across all ages, AA is increasing with the greatest percent change noted in age 30–69 y group. Additional analysis shows that the mean age at diagnosis increased by 3.1 y from 1993 to 1996, to 2005 to 2008 (29.6 to 32.7 y old, $P < 0.001$).

HCUP data showed that Hispanics, Asians, and Native Americans experienced a rise in hospitalization frequency of AA from 1993 to 1996 (13.8%, 2.1%, 0.4%) to 2005 to 2008 (20.0%, 2.9%, 0.7%, respectively), while those among Whites (74.3% to 66.0%) and Blacks (7.6% to 6.2%) decreased during the period. Census data show that race would be a potential contributor to changes in national in hospital AA rate as these values are insignificant and therefore AA trends are associated with race trends.

Concerning geographic area, the Midwest saw a decline in the frequency of admission for AA over the 15-year study period; however, when census data is considered, all regions show an increased rate, with the Northeast having the greatest overall percent change.

As shown in Table 2, the frequency of AA cases at large hospitals increased from 52.1% in 1993–1996 to 59.6% in 2005–2008, whereas frequency decreased ($P < 0.001$) in small and medium hospitals during the period. The number of urban AA cases increased from 82.2% in 1993–1996 to 87.1% in 2005–2008, while the number of rural cases decreased ($P < 0.001$). The number of cases at teaching hospitals also increased from 26.5% in 1993–1996 to 39.6% in 2005–2008 ($P < 0.001$). Though AA numbers at non-teaching hospitals fell during the study period, more cases were admitted to these hospitals compared with teaching centers.

The breakdown of weighted hospitalization data by simple and complex AA by patient characteristics is noted in Table 3. While rates of AA are on the rise, the ratio of simple to complex AA remained about 3:1 during the study period. However the ratio of simple to complex changes at extremes of ages, ages 0–9 and age > 40 y. There are more complex cases with increase in age by age greater than 50 with about 50% experiencing complex cases. Also, a similar trend in seen in those <10 y old, where about 40% present as complex case.

DISCUSSION

The incidence of AA increased from 7.62 per 10,000 in 1993 to 9.38 per 10,000 in 2008. This finding is contrary to our initial hypothesis that the incidence of appendicitis is decreasing. As reported by Addis *et al.*, the incidence of appendicitis was decreasing in the United States between the years 1970 and 1984 [5]. Some of the rise in cases of appendicitis may be attributable to population growth and the changing demographics of the Untied States. However, our study shows that the rise in the cases of appendicitis are not just due to changing demographics. As Table 1 demonstrates, we are seeing more cases per 10,000 individuals with census numbers taken into account. HCUP data is reported using frequencies. In order to compare them to national data, we utilized the US census and determined a rate per 10,000. This is the justification that Foxman and colleagues used to show that demographics were not the sole cause of change in rates of acute pyelonephritis [9]. While rates of AA are on the rise, it does not appear that AA is becoming any more severe. The ratio of simple to complex AA remained about 3:1 during the study period.

Our data suggest that males are still more likely to develop AA, although females experienced an increased rate of AA with an 8.7% percent change over the study period. One possibility for this may be the increased use of CT scans during the last 15 y. In females, pain due to appendicitis can easily be confused with pain due to gynecological pathology, including ovarian torsion, tubo-ovarian abscess, or pelvic inflammatory disease to name a few. More liberal use of the CT scan may lead more readily to diagnosis of an inflamed appendix and an admission for AA *versus* erroneous admission under another pelvic pathology. A nationwide study by Livingston *et al.* showed a parallel rise after 1995 in rates of appendectomy with coincident use of CT imaging [11].

We note a shift in the paradigm toward more elderly patients being diagnosed with AA. History has shown that individuals between the ages of 10 and 19 y are at a higher risk for developing AA. Our data also

TABLE 2

Frequency of Hospitalization in AA Based on Hospital Size, Location, and Teaching Status

	Hospitalization frequency (%)*				
	1993–1996	1997–2000	2001–2004	2005–2008	*P* value
Bed size of hospital					
Small	134602 (16.7)	142801 (15.9)	146262 (13.6)	154005 (13.6)	<0.001
Medium	251150 (31.2)	267392 (29.8)	312577 (29.2)	304561 (26.8)	
Large	419355 (52.1)	486952 (54.3)	613014 (57.2)	677687 (59.6)	
Location of hospital					
Rural	143058 (17.8)	137669 (15.3)	148179 (13.8)	146654 (12.9)	<0.001
Urban	662049 (82.2)	759477 (84.7)	923674 (86.2)	989600 (87.1)	
Teaching status of hospital					
Non-teaching	592017 (73.5)	581397 (64.8)	659229 (61.5)	686248 (60.4)	<0.001
Teaching	213090 (26.5)	315748 (35.2)	412624 (38.5)	450006 (39.6)	

*Percent out of number of hospitalizations for acute appendicitis.

support this, with the highest frequency of AA in this age group. The percent change in this group is only 1%; whereas, the percent change in patients ages 30 through 79 y varies between 10% and 15%. This might be attributable to increasing life span and better diagnostic testing. As with the female population, the differential diagnosis for abdominal pain in the elderly is wider. In diagnosing abdominal pain in the elderly, Berg reminds us that the symptoms they are suffering are more subtle with appendicitis often presenting with vague periumbilical pain and anorexia [12]. At a time before the diagnostic testing now available, these patients may have been admitted under another diagnosis when appendicitis actually existed.

TABLE 3

Frequency of Simple and Complex AA

	Type of case		
	Simple	Complex	*P* value
Gender			
Male	69.2%	30.8%	<0.001
Female	70.8%	29.2%	
Age range			
0–9	60.3%	39.7%	<0.001
10–19	74.9%	25.1%	
20–29	81.0%	19.0%	
30–39	75.9%	24.1%	
40–49	66.6%	33.4%	
50–59	57.9%	42.1%	
60–69	49.5%	50.5%	
70–79	43.7%	56.3%	
80–89	38.2%	61.8%	
90–99	35.6%	64.4%	
100+	46.9%	53.1%	
Race			
White	69.7%	30.3%	<0.001
Black	67.3%	32.7%	
Hispanic	70.3%	29.7%	
Asian	69.4%	30.6%	
Native American	67.4%	32.6%	
Other	72.6%	27.4%	
Year group			
1993–1996	66.6%	33.4%	<0.001
1997–2000	68.2%	31.8%	
2001–2004	70.7%	29.3%	
2005–2008	72.9%	27.1%	

Native Americans are distinguished among ethnic groups with a 26% change per year. Hispanics and Asians also show an increase (7.1% and 5.0%, respectively) whereas, Whites and Blacks show less or a decreased percent change. However, Blacks have about half the incidence than Whites. The lower rate of AA in Blacks has been reported previously. The rise of AA in Hispanics and Asians could be attributable to better counting of race in the recent census. Misclassification of Hispanics and Asians in the earlier hospital discharges could be the cause of underestimation of AA rates in the earlier years [13]. This disparity could potentially be also explained by access to health care. Multiple papers have been published regarding the increased poor outcomes in minorities with appendicitis, stating that poor access to health care and untimely diagnosis are responsible for an increased rate of perforation in these groups. This may remain true; however, more local studies have shown "no significant evidence of this disparity at [our] institution" [14]. One can speculate that the changing scheme of health care and provider awareness is allowing better access for minorities; therefore, the amount of AA diagnosed in these populations has increased.

Changing trends in AA also are noted across regions in the United States. The percent change in the Northeast over the study period is 15.5%, which is much larger than that of the West (6.5%), South (6.4%), and Midwest (2.6%). This may be a reflection of the more well-established comprehensive referral systems available to patients in the Northeast. Regional variation in the incidence of AA has been reported previously by Addis *et al.* [5].

Data presented in Table 2 reflect that large hospitals, urban hospitals and, teaching hospitals are experiencing an increase in AA admissions. This may be explained by a difference in surgical practice, presence of multiple diagnostic modalities, and the demographic discussion from above considering larger city populations with greater ethnic diversity. There has been attention paid to geographic variations due to patterns in dietary fiber consumption. Appendicitis may be more common in more urban industrialized areas where a low-fiber diet consumed, while lower in agrarian rural communities where they may have a diet rich in high fiber [3].

Multiple European studies acknowledge the treatment of appendicitis with antibiotics alone rather than appendectomy [15,16]. This additional method of treatment is not well described in the literature from the United States, which may be a limitation for our study. Ours is an administrative database. While diagnosis of AA and diagnosis and surgical management of AA are presented (Table 1), we have no data on patients that may have been treated with antibiotics or drainage rather than appendectomy, or patients who have been readmitted for appendectomy at a later time after other treatments. Those patients diagnosed with AA who did not go on to appendectomy may have had medical management of the disease, or they may have been diagnosed with a different pathology during their admission. Additionally, we speculate that some of the trends we observed may be due to increased usage of CT scan, although there is no way to know how often CT was used in making the diagnosis of AA in our sample. This parameter is not recorded in our database. However, there has been a parallel rise in diagnosing acute appendicitis with the increase in use of CT scan [13].

CONCLUSION

The incidence of AA is increasing in the United States. Changing demographics are a reason, but not the sole reason, for the increased frequency of hospital admissions due to AA in certain regions and types of hospitals. Changes in racial profiles contribute to the current epidemiology of AA. The percent changes in diagnosis of AA across demographic groups may also result from improved technology, better access to health care, and longer life span.

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