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Trends in visits, imaging, and diagnosis for emergency department abdominal pain presentations in the United States, 2007–2019

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Abstract

Objectives: Abdominal pain is the most common reason for visit (RFV) to the emergency department (ED) for adults, yet no standardized diagnostic pathway exists for abdominal pain. Optimal management is age-specific; symptoms, diagnoses, and prognoses differ between young and old adults. Availability and knowledge of the effectiveness of various imaging modalities have also changed over time. We compared diagnostic imaging rates for younger versus older adults to identify practice patterns of abdominal imaging across age groups over time.

Methods: We analyzed weighted, nationally representative data from the National Hospital Ambulatory Medical Care Survey 2007–2019 for adult ED visits with a primary RFV of abdominal pain. We included 23,364 sampled visits, representing 123 million visits.

Results: From 2007 to 2019, total visits increased for ages 18–45 ($p < 0.001$), 46–64 ($p < 0.001$), and 65+ ($p = 0.032$). The percentage of visits with primary RFV of abdominal pain increased from 9.4% to 11.6% for ages 18–45, 7.8%–9.0% for ages 46–64, and 6.0%–6.5% for 65+. Computed tomography (CT) scan rates increased over time

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from 26.2% of all patients receiving a CT scan to 42.6%. Relative percentage change in abdominal CT scans was greatest for older adults, with a 30.3% increase, compared to 24.0% for middle-aged adults and 15.0% for young adults. Test positivity, defined as receiving an emergency general surgical diagnosis after CT or ultrasound, increased from 17.2% in 2007 to 22.9% in 2019 ($p < 0.01$). Of the older adults with abdominal pain in 2019, 13% received an X-ray only, which is neither sensitive nor specific for acute pathology in older adults.

Conclusions: Despite more abdominal pain ED visits and increased imaging rates per visit, test positivity continues to rise. Our findings do not support claims that CT and ultrasound are being used less appropriately over time, but demonstrate widespread use of X-rays, which are potentially ineffective for abdominal pain.

INTRODUCTION

Abdominal pain is the leading chief complaint among emergency department (ED) visits, accounting for 8.8% of all visits.[1] In addition to being the immediate concern for many index visits to the ED, abdominal pain accounts for nearly a quarter of all return visits within 72 h.[2] Although an ED chief complaint of abdominal pain carries high morbidity and mortality for older adults, its significance in younger and middle-aged adults remains poorly characterized.[3–6]

Computed tomography (CT) scans can improve the diagnosis and management of abdominal pain cases, especially in older adults,[7] and initially were shown to reduce negative exploratory surgery.[8] These benefits extend beyond the ED visit. Abdominal CT scans for patients with abdominal pain in the ED reduced the rates of return to the ED within 30 days.[9] CT scans may be particularly effective for diagnosing the oldest older adults[10] (80 years and older) in whom 43% of positive CTs resulted in clinically unsuspected diagnoses prior to CT.[11]

However, as CT has become widely available in United States EDs in the past two decades, controversy as to their use in a broader range of indications have emerged. Wide variation in CT ordering between individual ED physicians suggested potential over- and under-testing and sparked interest in optimizing imaging. Several guidelines have been compiled to address the risks and benefits of imaging to patients as well as the cost of care. In 2010, the American College of Emergency Physicians updated their clinical policies to provide guidelines for imaging decision making for risk stratification for potential appendicitis cases as well as guidelines for CT imaging without IV or enteric contrast for acute appendicitis cases.[12] The Society for Academic Emergency Medicine (SAEM) Guidelines for Reasonable and Appropriate Care in the ED 2 (GRACE-2)[13,14] for low-risk, recurrent abdominal pain does not provide a consensus on whether repeat CT imaging of abdomen and pelvis can be safely avoided or routinely recommended if a patient has received a prior negative CT within the past 12 months. The 2015 Academic Emergency Medicine Consensus Conference[15,16] focused on optimizing diagnostic imaging utilization in the ED and acknowledged the barriers to knowledge translation from existing guidelines to clinical practice. The conference outlined four research questions to encourage evidence-based interventions for optimal ED imaging to advance patient-centered outcomes[17] and improve adherence to optimal management strategies.

Unlike CT, hepatobiliary ultrasound does not use ionizing radiation. It represents a potentially effective diagnostic modality for upper abdominal pain or other symptoms suggesting a hepatobiliary origin.[18] In contrast to either modality, abdominal X-rays are poorly sensitive and poorly specific for clinically significant disease and are potentially misleading.[2]

Prior literature has demonstrated that utilization of imaging modalities increased as they have become more available. The rate of abdominal CT scans for all indications increased 17.5-fold from 1990 to 2009.[19] Additionally, abdominal pain grew to become the leading chief complaint among those who underwent a CT scan in United States EDs from 1995 to 2007.[20] The probability of obtaining a specific diagnosis via CT scan increases with age,[21] yet for older adults with abdominal pain, nearly one in six ED visits[22] has been shown to receive an X-ray without ultrasound or CT, a potentially ineffective test in older adults,[23] and this occurs more often for older women.[24,25] Little evidence is available from the past decade to understand whether the rapid initial growth[18] of these modalities used to assess abdominal pain has continued, whether changes in utilization are differential across age groups, and whether increased imaging rates have resulted in greater rates of clinically significant diagnoses.

We hypothesized prior to data collection that a continuous increase in CT and ultrasound imaging modalities and a decrease in X-ray use occurred from 2007 to 2019. To test these hypotheses, we used nationally representative ED data to describe trends in ED visits for abdominal pain chief complaints from 2007 to 2019, including the growth of abdominal pain visits, the rate of imaging for different modalities, and the diagnoses received. We analyze these trends across three subgroups of age (young adult, middle age, and older adult) who differ in their typical physiology, comorbidities, symptoms, and etiologies of their abdominal pain.[26]

METHODS

Study design and data source

This study analyzes retrospectively collected, repeated cross-sections of ED visits using data from the National Hospital Ambulatory Medical Care Survey (NHAMCS) for years 2007 to 2019. NHAMCS is a nationally representative sample of visits to nonfederal, general, acute care hospitals in the United States conducted annually by the National Center for Health Statistics. For descriptive statistics comparing change between the beginning and end of the study period, we combined 3 years of data for additional power, 2007–2009 and 2017–2019. Of note, coding changed from ICD-9 to ICD-10 in 2016 and diagnosis trees were used as opposed to specific diagnoses.

Participants

NHAMCS records a primary reason for visit (RFV) for each sampled ED visit. Following our prior work,[22] we considered ED visits for abdominal pain to include primary RFVs of lower or upper abdominal pain, abdominal cramps or spasms, abdominal distention or fullness, hernia of abdominal cavity, abdominal swelling, change in abdominal size, and abdominal mass or tumor. The majority of patients reported an RFV of "abdominal pain, cramps, spasms, not otherwise specified." Data were aggregated into three age categories; age groups were based on clinical and management characteristics. Visits from patients aged 18–45 were classified as young adults, 46–64 as middle-aged adults, and 65+ as older adults.[27,28] We excluded pediatric demographics because of differences in management and imaging practices for pediatric care in the ED.

Variables

We examined the imaging modalities of ultrasounds, X-rays, and CT scans obtained in the ED. Prior to 2013, NHAMCS did not record the target site of CT scans and dichotomized CT scans as head CT scan or nonhead CT scan. To account for this, we assigned all nonhead CTs administered for visits with chief RFV of abdominal pain in years 2007–2012 as CTs of the abdomen or pelvis.

To examine the medical etiologies identified by diagnostic testing, we used the principal diagnosis code. NHAMCS 2007 to 2015 captures the principal diagnosis using International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) codes. NHAMCS 2016–2019 captures diagnoses using the 10th Revision (ICD-10-CM). Principal diagnosis was the diagnosis at discharge: the ED discharge diagnosis for patients discharged from the ED or the hospital diagnosis for admitted patients. Principal diagnoses were identified as emergency general surgery (EGS) diagnoses if their ICD code matched a specific abdominal EGS condition, excluding ICD codes for nonspecific "abdominal pain."[29] We considered only ICD codes diagnosed for a patient visit in determining if an EGS diagnosis was present, consistent with prior literature showing that many EGS conditions continue to lead to significant morbidity and mortality and are diagnosable using imaging but are now commonly managed using nonsurgical options.[30] To identify patterns in broad diagnosis groups, ICD-10 codes were aggregated to diagnosis categories by using the associated EGS subcondition category.[28] The "other EGS" category consisted of the ICD codes in diagnosis categories not belonging to the top 10 diagnoses. Analyses using these diagnosis categories were restricted to the later time period to avoid comparison across the ICD-9 to ICD-10 transition.

Demographic variables included race, payment type, urbanicity (determined by NHAMCS coding of metropolitan statistical area; not available in 2010 to 2012), and Emergency Severity Index 5-level triage. Hospitals with a 4-level triage score were recoded to a 5-level score by NHAMCS analysts. We report race and ethnicity as recorded by NHAMCS from their chart abstraction, combining categories with fewer than 30 observations into an "other, non-Hispanic" category. This reduced misleading interpretations of noisy data due to limited power, at the expense of combining the experiences of disparate individuals into a single group.

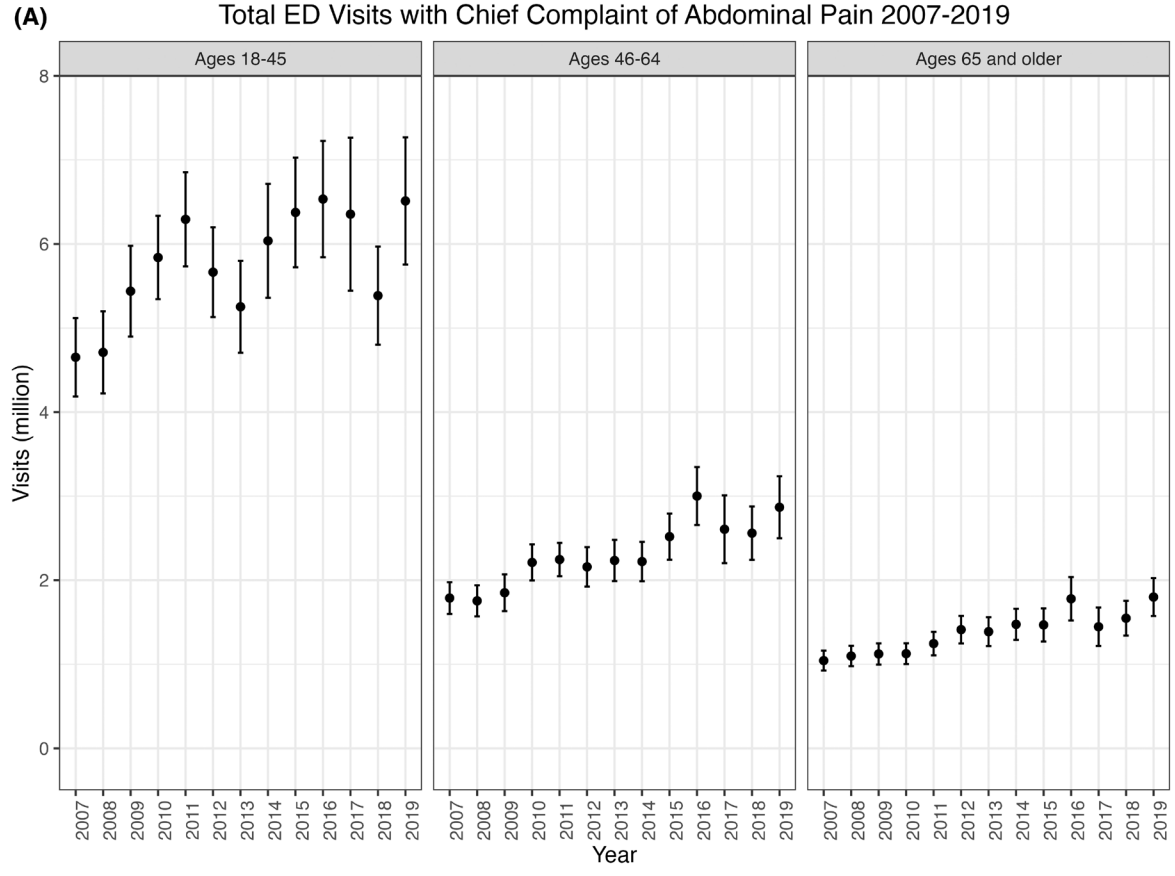
Statistical methods

We applied NHAMCS four-level probability-based sample weights to obtain nationally representative estimates of counts, percentages, and confidence intervals (CIs). Standard descriptive statistics were used to report rates of imaging. Survey-weighted descriptive statistics and chi-square tests compared binary and categorical variables. We used two-tailed hypothesis tests with $\alpha = 0.05$. Table cells with 30 or fewer participants were suppressed or aggregated into "other" categories, except for in the EGS reporting for disease categories less prevalent than appendix-related disease and in the "other categories" in Data S8, in which table cells with fewer than 30 cells were reported due to the subset sample size. All analyses were conducted with R statistical software, Version 4.1.1.

RESULTS

After applying exclusion criteria, we analyzed 23,364 ED visits for abdominal pain, which after weighting represented 123,022,141 estimated visits nationally across 13 years (mean 9.46 million visits per year). The number of visits increased significantly for age groups 18–45 ($p < 0.001$), 46–64 ($p < 0.001$), and 65+ ($p = 0.049$) from 2007 to 2019 (Figure 1A). The percentage of visits with a primary RFV of abdominal pain trended from 9.4% in 2007 to 11.6% in 2019 for ages 18–45, 7.8%–9.0% for ages 46–64, and 6.0%–6.5% for 65+.

Patients aged 18 to 45, aged 46 to 64, and aged 65 and older represented 61.0%, 24.4%, and 14.6% of all abdominal pain ED visits (Table 1). Female patients comprised 72.7% of abdominal pain visits in younger ages and 58.3% and 60% in middle and older



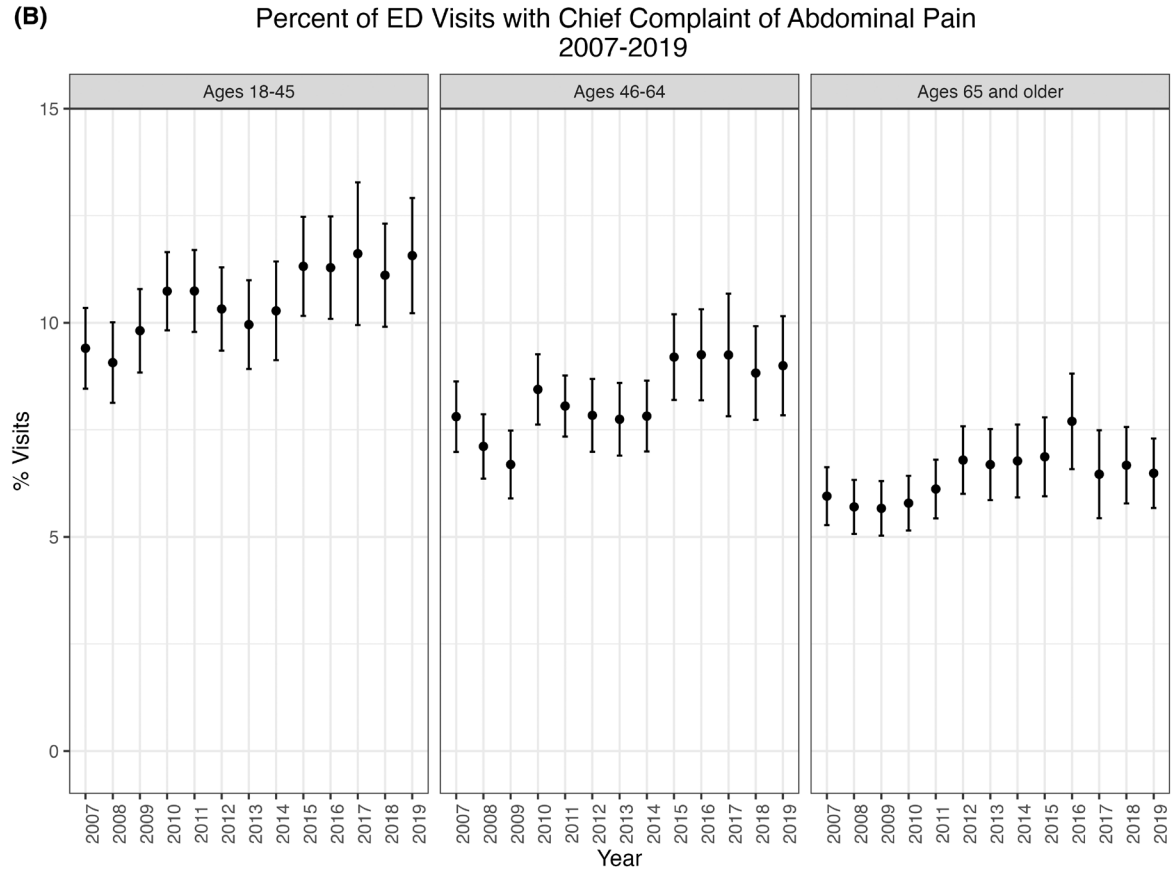


FIGURE 1 Legend on next page

FIGURE 1 (A) Total national number of ED visits with chief RFV of abdominal pain from 2007 to 2019, by age group. Age groups included 18–45, 46–64, and 65 years and older. Error bars represent survey-weighted 95% CIs. (B) Percentages of all ED visits where patient reported a chief reason for visit of abdominal pain from 2007 to 2019, by age group. Error bars represent survey-weighted 95% CIs. RFV, reason for visit.

TABLE 1 Demographics of sampled ED visits.

	Number of ED visits over 12-year period (2007–2019), millions (%)				
		Ages 18–45	Ages 46–64	Ages 65+	
Patient characteristics	**Total**	**75,050,354 (*n* = 14,405)**	**30,019,159 (*n* = 5661)**	**17,952,627 (*n* = 3298)**	***p*-value**
Gender					
Female	82.9 (67.4)	54.6 (72.7)	17.5 (58.3)	10.8 (60.0)	<0.001*
Race					
White only, non-Hispanic	72.6 (59.0)	40.9 (54.4)	18.8 (62.7)	12.9 (71.6)	<0.001*
Black only, non-Hispanic	26.5 (21.5)	18.1 (24.1)	5.8 (19.3)	2.6 (14.4)	
Hispanic	19.9 (16.2)	13.6 (18.1)	4.5 (15.0)	1.8 (10.0)	
Other, non-Hispanic[a]	4.0 (3.3)	2.4 (3.2)	0.9 (3.0)	0.7 (3.9)	
Insurance					
Medicaid	30.7 (25.0)	23.6 (31.4)	6.2 (20.7)	0.9 (5.0)	<0.001*
Medicare	21.6 (17.6)	3.1 (4.1)	4.6 (15.3)	13.9 (77.4)	
Private	39.5 (32.1)	25.1 (33.4)	12.7 (42.3)	1.7 (9.5)	
Self-pay	16.6 (13.5)	13.3 (17.7)	3.1 (10.3)	0.2 (1.1)	
Unspecified	14.7 (11.9)	9.9 (13.2)	3.5 (11.7)	1.3 (7.2)	
Hospital geography[b]					
Urban	97.8 (79.5)	59.9 (86.3)	24.3 (87.1)	13.6 (82.4)	0.005*
Nonurban	16.0 (13.0)	9.5 (13.7)	3.6 (12.9)	2.9 (17.6)	
Triage level					
Immediate	0.7 (0.6)	0.5 (0.7)	0.1 (0.3)	0.1 (0.6)	<0.001*
Emergent	7.3 (5.9)	3.7 (4.9)	2.1 (7.0)	1.5 (8.3)	
Urgent	73.5 (59.7)	44.4 (59.0)	18.5 (61.9)	10.6 (58.9)	
Semiurgent	13.9 (11.3)	9.5 (12.6)	2.7 (9.0)	1.7 (9.4)	
Nonurgent	2.3 (1.9)	1.6 (2.1)	0.4 (1.3)	0.3 (1.7)	
Unspecified/other/ blank	25.4 (20.6)	15.5 (20.6)	6.1 (20.3)	3.8 (21.1)	
Hospital status					
Admitted	20.5 (16.7)	7.8 (10.4)	6.6 (22.1)	6.1 (34.0)	<0.001*
Admitted to surgery	3.0 (2.5)	1.4 (1.9)	0.9 (3.0)	0.7 (3.8)	
Died during care or on arrival	0.6 (0.5)	0.2 (0.3)	0.2 (0.5)	0.2 (1.3)	

[a]Asians, Native Hawaiians and Pacific Islanders, American Indians and Alaskan Natives, and multiple races.

[b]Geography numbers excludes years 2010 and 2012. Variable was not recorded during years 2010 and 2012.

ages. The majority of patients were White, making up 54.4% of the youngest adults, 62.7% of the middle-aged adults, and 71.6% of the oldest adults. Meanwhile, Black patients made up 24.1%, 19.3%, and 14.4%, respectively. The non-Hispanic other category, which included Asians, Native Hawaiians and Pacific Islanders, American Indians and Alaskan Natives, and multiracial groups, aggregated due to small sample size, remained relatively constant across age groups.

For younger adults, 5.6% of abdominal pain ED visits were triaged to ESI Levels 1 or 2, compared to 7.3% and 8.9% of middle-aged and older adults ($p < 0.001$). Additionally, 10.4% of younger adults presenting to the ED with abdominal pain were admitted to the hospital compared to 22.1% and 34.0% of middle-aged and older adults ($p < 0.001$). This upward trend remained consistent for admission to the operating room and death in the ED or on arrival.

CT scan rates increased consistently over time from 26.2% of all patients with abdominal pain visits receiving a CT scan in 2007 to 42.6% in 2019 ($p < 0.001$, Figure 1; Data S2). The relative percentage change in abdominal CT scans, calculated as the change each year compared to number of CTs in 2007, was greatest for older adults, with a 30.3% change from 2007 to 2019, compared to 24.0% change for adults aged 46 to 64 and 15.0% for adults aged 18 to 45 ($p < 0.01$ for all age groups, Data S3). From 2007 to 2012, only two variables were recorded for CT scans: head CT and nonhead CT. From 2013 to 2019, a third variable for abdominal CT was added, and 98% of the nonhead CT scans among patients with abdominal pain chief complaints were administered for the abdominal region, with 100% of abdominal CTs captured within the nonhead CT category.

Ultrasound use increased for all age groups from 2007 to 2019: 17.4% of abdominal pain visits for adults 18–45 years old received an ultrasound compared to 25.0% in 2019, 9.8% compared to 17.4% for ages 46–64, and 5.5% compared to 12.2% of adults 65+. X-ray use decreased for the young and middle-aged adults, by 46.2% and 25.2%, respectively, but remained more consistent for older adults, decreasing by 8.6%: 16.7% of the youngest adults received an X-ray in 2007 compared to 9.0% in 2019, 31.3% compared to 23.4% for the middle-aged adults, and 39.6% compared to 36.2% for older adults (Figure 2). Across all ages and all years, we found that only 3.6% of the visits were assigned diagnoses that would typically be found with imaging method other than CT (e.g., gastritis, pancreatitis, gastrointestinal [GI] bleeding, or melena). Additionally, 13% of older adult visits in 2019 received an X-ray as their only imaging test (Data S4). Among those who received an X-ray without CT scan or ultrasound, 0.5% had a kidney stone diagnosis and less than 0.01% had a gastronomy diagnosis (Data S5).

For the middle-aged (38.6%) and older adult groups (42.7%), administering only an abdominal CT scan was the most common imaging strategy. For younger adults, the most common practice was no imaging testing (38.5%, Data S4).

To test whether individual years stood out from the overall linear trend over time, results from a linear probability model with logistic regression as a sensitivity analysis for each imaging modality were not statistically distinguishable in the overall linear time trend for any imaging modality except 2012 for ultrasound, after Bonferroni correction (Data S6A). In a test of whether there were additional time



FIGURE 2 Trends in use of CT scans, ultrasounds, and X-rays from 2007 to 2019 during ED visits for abdominal pain. Survey weights on NHAMCS observations were used to produce nationally representative data. Visits may have received multiple imaging modalities; counts included are not mutually exclusive. NHAMCS, National Hospital Ambulatory Medical Care Survey.

trend differences within year groupings (2007–2010, 2011–2014, 2015–2019) distinguishable from the overall trend in CT, ultrasound, and X-ray utilization trends, results were statistically distinguishable in the 2011–2014 time period for the CT and ultrasound regression models and in the 2015–2019 time period for the CT model only (Data S6B).

Comparing imaging across gender by age group for CT scans, there were no differences between genders in the middle and older age groups. Among young adults, male patients received 11% more CT scans ($p<0.01$), but this did not increase over time ($p=0.396$; Data S7A). For ultrasound, across age groups, female patients received 9% more ultrasounds than male patients ($p<0.01$), but the difference also did not increase over time ($p=0.521$; Data S7B).

The proportion of abdominal pain visits attributable to an EGS condition increased with patient age and over time (Data S8). The number of younger adults diagnosed with an EGS condition increased from 7.6% in 2007 to 13.8% in 2019, middle-aged adults increased from 9.0% to 23.5%, and older adults increased from 15.7% to 24.7%.

Test positivity, defined by receiving an EGS diagnosis among patients imaged with cross-sectional imaging (CT or ultrasound), increased for all abdominal pain ED visits from 2007 to 2009 (11.3%) to 2017–2019 (17.8%). This increase was similar in all age groups. Test positivity was highest among older adults in both 2007–2009 (8.7% younger, 14.0% middle-aged, 17.2% older adults) and 2017–2019 (14.4%, 21.7%, and 22.9%) (Table 2).

The percentage of abdominal pain visits in which patients were diagnosed with an EGS condition increased with age (Figure 3; Data S9). In order of most to least frequent, the top diagnoses were gallstones and related diseases, diverticular disease, bowel obstruction, gastritis, pancreatitis, appendix-related disease, colitis, bleeding, peritonitis, and ileus. Frequency of each diagnosis comprising the "other EGS" category is included in Data S10.

Older adults had a broader set of EGS conditions diagnosed during their abdominal pain ED visits, including diagnoses rarely seen in younger ages such as peptic ulcer disease, intussusception, anorectal disease such as abscess and hemorrhage, liver failure, and complications of gastrostomies (Data S10).

TABLE 2 Test positivity for patients who received a CT scan and/or ultrasound and diagnosed with an EGS condition.

	2007–2009, % (SE)	2017–2019, % (SE)	*p*-value
Age 18–45	8.7 (0.86)	14.4 (1.4)	<0.01
Age 46–64	14.0 (2.0)	21.7 (2.2)	<0.01
Age 65+	17.2 (2.1)	22.9 (3.0)	<0.01
All Ages	11.3 (0.8)	17.8 (1.2)	<0.01

Note: Test positivity, defined as the percent of patients with abdominal pain in an age group who received a CT scan and/or ultrasound and diagnosed with an EGS condition.

Abbreviation: EGS, emergency general surgery.

DISCUSSION

This analysis described national trends in imaging from 2007 to 2019 during ED visits for abdominal pain across the adult life course. We found that ED visits for abdominal pain are increasing both in absolute number and relative to other chief complaints. Extending previous trends for abdominal pain ED visits,[29,31] CT imaging continued to increase, resulting in a 62.6% relative rise from 2007 to 2019 for all ages. This increase was greatest for older adults, who potentially stand to benefit the most from potentially definitive imaging given the variety of diagnoses, lack of specificity of their history and physical examination, and high morbidity and mortality associated with patient ED presentations for abdominal pain.[22] Analysis showed the increase in CT scans was not driven by a specific gender, despite overall higher usage by male patients. The overall trend toward increased CT imaging of abdominal pain slowed by approximately 7% below trend in the middle period (2011–2014) and 9% in the final period (2015–2019). In addition, the overall trend toward increased ultrasound imaging of abdominal pain slowed by approximately 4% in the middle period. This may reflect increased attention to the appropriateness of imaging during this period, culminating in the consensus conference around imaging in 2015.[32,33] This trend was matched by a rise in ultrasound for all age groups during the study period. Use of ultrasound in older adults remained approximately half that in younger adults (Figure 2). Rising rates of EGS diagnoses among individuals receiving imaging suggest that claims that this additional imaging is inappropriate[34,35] or wasteful[36–38] may be premature, especially since negative imaging can also be appropriate in clinical decision making and helps when diagnostic confidence is low.[39]

Abdominal X-rays are neither sensitive nor specific for acute pathology in older adults in the ED.[40] In contrast to ultrasound and CT scan use patterns, over the 2007–2019 time period X-ray administration decreased for all age groups. Despite this decline, use remains high, particularly in the older adult population where 13% of abdominal pain visits received an X-ray as the sole diagnostic imaging modality in 2019. While NHAMCS does not indicate the anatomical target of X-ray imaging, in this population who presented with abdominal pain, the majority of X-rays likely are abdominal plain films. Abdominal X-ray is an appropriate imaging modality for confirming gastric tube placement or identifying kidney stones, but we did not find evidence that these uses contributed meaningfully to utilization of this imaging technique. We also did not find evidence that EGS diagnoses where X-ray without CT is an appropriate means of diagnosis (e.g. gastrostomy tube confirmation) accounted for relatively high rates of plain film use. This suggests that dissemination of knowledge about this potentially ineffective[41,42] and relatively high radiation dose[43] abdominal imaging modality may reduce overuse and improve outcomes.

Female patients comprise 55% of overall ED visits nationally,[1] but 67% of abdominal pain visits. This difference was primarily driven by visits from reproductive age women, for whom there is additional diagnostic complexity[14,44,45] due to chronic, painful conditions such as dysmenorrhea and endometriosis, due to pregnancy, and due to

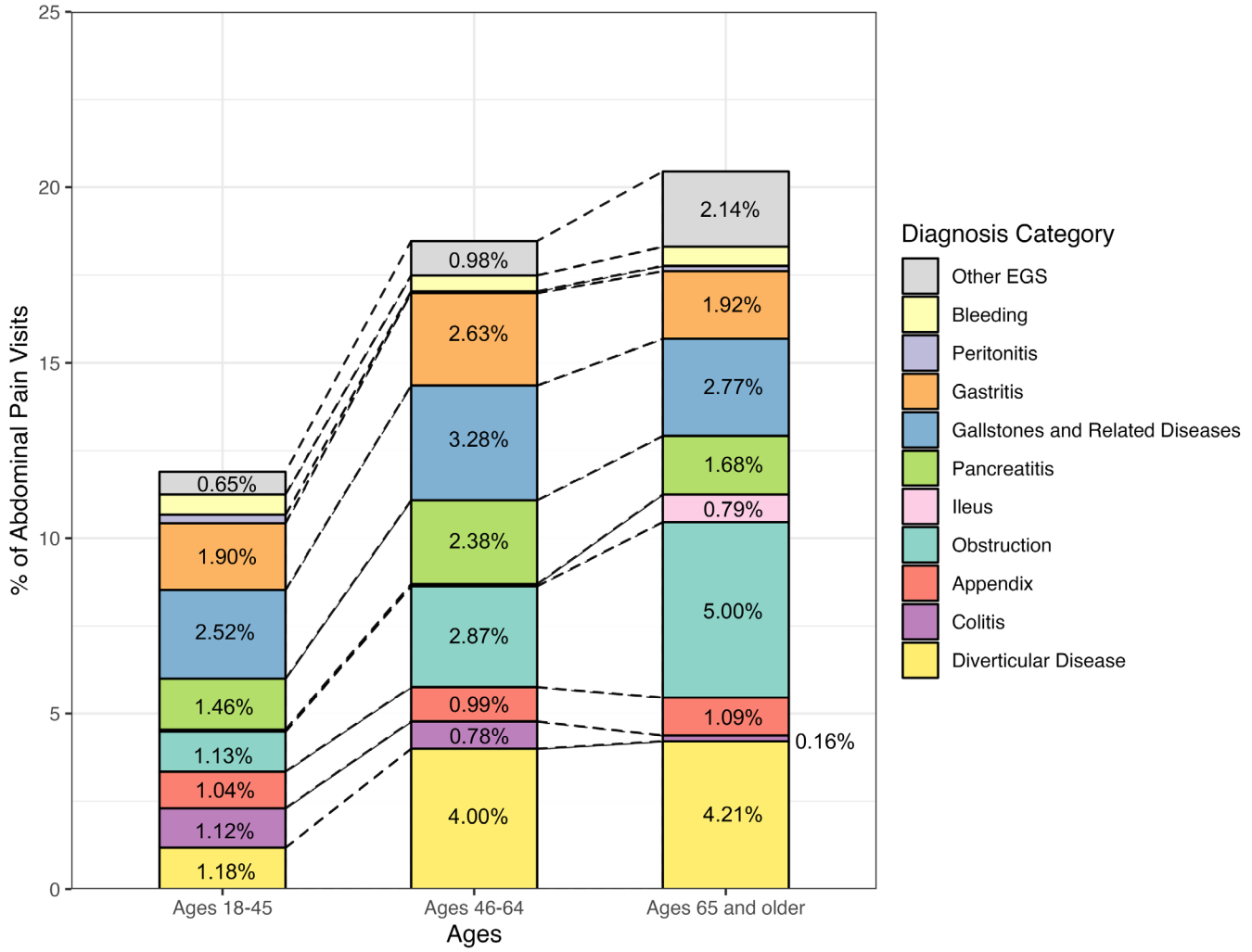


FIGURE 3 Top 10 EGS diagnosis categories by age group aggregated in total for years 2017–2019. Bars represent EGS conditions aggregated to diagnosis categories by their ICD-10 code. The 10 most frequent diagnoses categories across all ages are shown, with additional categories aggregated to "other EGS." Diagnosis categories are ordered from mouth to anus, top to bottom within each age group. Overall height of the stacked bars reflects the proportion of all abdominal pain visits that were diagnosed with an EGS condition for that age group. By increasing age group, bleeding was 0.58%, 0.45%, and 0.55% of all abdominal pain visits, while peritonitis was 0.24%, 0.05%, and 0.15%. EGS, emergency general surgery.

acute conditions that can present with pain such as ovarian torsion and ovarian cyst rupture. Because NHAMCS does not record the anatomical target of ultrasounds, a proportion of the ultrasounds in younger ages may be for diagnosis of adnexal or uterine conditions as well as for gestational age. The presence of pregnancy may also complicate the decision to image the abdomen with ionizing radiation. Nonetheless, differences by age group and ultrasound between young and middle-aged adults were not explained by increased use of ultrasound for ED visits by women of childbearing age.

In a previous study, older patients with abdominal pain compared to all other reasons for visit were found to have a lower probability of being triaged to the "emergent" (ESI 2) acuity on arrival but were more likely to be admitted directly to the operating room,[22] suggesting undertriage. In this analysis, triage categories varied by age group, suggesting recognition of the increased risks and resource utilization among older adults with abdominal pain; future work focused on outcomes could help determine whether this proportional increase is sufficient to account for the rise in the risk and time sensitivity of ED abdominal pain presentations with age.

ED visits for abdominal pain increased across all age groups. There are a number of potential factors that might underlie these trends, including substitution from other sites of care due to declining primary care,[46] colorectal surgeon, or GI specialist access[47]; greater patient demand for medical evaluation for a given level of abdominal discomfort, an increase in the incidence of acute abdominal pain and the etiologies which cause it in the population; or a change in the classification of patient's symptoms at triage to favor abdominal pain over other reasons for visit. If patients are lowering their threshold to visit the ED for abdominal pain due to changing patient preferences,[48,49] increased access to ED care, or declining access to alternative sites of evaluation, this would raise concerns of poor resource utilization across the health system. This explanation

is belied by the increasing proportion of abdominal pain ED visits diagnosed with an EGS condition. Further research is needed in this area; the Academic Emergency Medicine Consensus Conference proposed elicitation of four patient-centered outcomes research (PCOR) questions[50] to understand patient preferences with regard to imaging.

When patients do visit the ED for abdominal pain, in every age group they were more likely to receive a CT scan over the 13-year study period. Although some radiologists have been critical of increased use of CT imaging practices over time,[34] the relative increase in CT imaging differs by age, with the oldest age group showing a higher relative percentage increase than the younger ages. Practice patterns are thus incorporating evidence that older adults with abdominal pain are at high risk of adverse outcome from a missed diagnosis by directing imaging resources toward them.[4–8] In comparison, younger adults are both at lower risk of adverse outcomes from a missed diagnosis and at higher risk of cancer from ionizing radiation, although the absolute risk remains low.[51,52]

The appropriateness of the documented increase in imaging depends on the relative balance of benefits, harms, and costs, each of which may differ by age group. The ideal study would identify the causal effect of the additional imaging in each age group on improved outcomes, cost, and adverse outcomes such as contrast nephropathy, radiation-induced malignancy, and the harms of incidental findings. In the absence of these data, assessing the final diagnoses after imaging provides some evidence of the efficacy of CT scans or lack thereof.

A potential explanation for the observed increase in imaging is that ED clinicians utilize their expertise to sort patients into a continuum of risk of clinically significant, intervenable intraabdominal diagnoses and then respond to increasing availability of CT over this period by lowering the testing threshold to include patients at a lower but still clinically meaningful risk of making such a diagnosis on CT. For example, in the case of renal colic, consensus recommendations from multiple specialty experts favor imaging as presentations become higher risk and as symptoms become less typical and the risk of diagnoses other than kidney stones become more likely.[53] If this were the case for other high-risk conditions, we would anticipate that the proportion of patients diagnosed with an EGS condition at the end of an ED visit during which a CT was performed (test positivity) would decline as the rate of imaging increased. Instead, we found that increases in test positivity occurred for every age group, suggesting increased EGS diagnosis in the population or improved funneling of patients experiencing symptoms of EGS to the ED. This increased test positivity with CT scans also provides a partial explanation for the increasing proportion of abdominal pain ED visits diagnosed with EGS conditions overall: greater CT utilization means more EGS conditions are being found, resulting in fewer missed diagnoses. This may be particularly important for older adults, who are at greater risk of morbidity[4,54,55] and mortality[56] for a given diagnosis. Especially in younger ages, however, the importance of making these additional diagnoses rather than watchful waiting requires further investigation.

EGS conditions are a useful measure of test positivity because they are captured in administrative data sets, are concrete diagnoses with clinical significance, typically require intervention, and frequently lead to morbidity or mortality.[57] As new medical and procedural options have evolved, EGS diagnoses no longer exclusively lead to surgery. EGS conditions typically require operative or nonoperative management, which can include antibiotics, analgesia, inpatient medical or surgical management, interventional procedures, and/or surgery. Although we interpreted our test positivity as a CT scan leading to a diagnosis, NHAMCS does not observe the timing at which the diagnosis is made. There are three potential cases for timing. Given the sensitivity and specificity of CT scans for common EGS diagnoses, diagnosis decision making based on CT scans is likely the most common scenario. In some cases, the diagnosis may be strongly suspected based on clinical signs and symptoms, and CT merely confirms a diagnosis. In others, CT could be obtained anticipating negative imaging to rule out a high-risk diagnosis. This latter use case is unlikely to vary over time, however. There appeared to be a visual increase in EGS diagnoses in the later period. While increased CT and ultrasound utilization seems to account for a substantial portion of this rise, as shown by the individual imaging time trends, an additional potential explanation includes imaging being conducted on those with higher probability of disease. This could come about due to improved clinical targeting of patients at risk of disease or due to selection in the patients presenting to the ED due to their own judgment or due to outpatient provider referrals. However, we cannot rule out the possibility that clinicians are utilizing EGS diagnosis codes more liberally in these observational data based on chart abstraction. Confirmation with prospective cohort studies is needed to differentiate between these potential mechanisms.

Whether outcomes for abdominal pain patients have changed with additional imaging requires additional study using data sets other than NHAMCS, which does not record outcomes after the ED visit and any subsequent hospitalization. For pulmonary embolisms, increased use of CT angiography yielded additional diagnoses but those diagnoses were less severe and of unclear clinical significance.[58,59] The impact of additional diagnoses on population health depends on the natural history of untreated compared to treated disease. For instance, patients with small gallstones diagnosed by CT or ultrasound might be overintervened upon once diagnosed, perpetuating overutilization of health care,[60] whereas early appendicitis diagnoses allow for successful antibiotic treatment or laparoscopic surgery before a perforation can occur.[60]

The distribution of diagnoses categories within EGS condition varied across age groups. Appendicitis was a top 10 diagnosis for all age groups, contrary to clinical guidelines that suggest it is more prevalent at younger ages, although in absolute terms it remains more common at younger ages.[61,62] Colitis was in the top 10 diagnoses for younger adults but not for older ages; these acute colitis diagnoses may represent overdiagnosis, where viral or other benign infectious or inflammatory causes of colitis are being uncovered by CT, resulting in potentially inappropriate antibiotic prescription. Biliary disease, primarily calculi, and cholecystitis were prevalent in

all ages, but ultrasound—a methodology well suited to these diagnoses—was used approximately twice as much in younger compared to older adults. This may reflect a clinical suspicion of alternative diagnoses, greater diagnostic complexity, or less confidence in physical examination for the older adult abdomen. Diverticular disease, classically a disease of middle-aged and older adults, was more common in these age groups but still present in younger adults, which may reflect poor diet in this U.S.-based study.[63,64] Visits for bowel obstruction and ileus became more common with increased age, consistent with the accumulation of scar tissue from prior surgery and increased malignancy risk with age. Pancreatitis was modestly more prevalent in middle-aged adults but remained a top 10 diagnosis in all age groups. Consistent with the hypothesis that older adults have greater diagnostic complexity, the proportion of EGS diagnoses outside the top 10 for older adults was found to be larger than for the younger ages, showing that older adults have a wider variety of potential common diagnoses compared to their younger counterparts.[65] It is important to note that although there is an increase in CT scans, the top 10 EGS diagnoses for patients with abdominal pain only account for approximately 15% of all patients who have abdominal pain in the middle and older age groups and a little over 10% of younger adults.

LIMITATIONS

Our study includes several limitations. One main limitation is that NHAMCS does not include a patient identifier, and therefore we cannot determine if a visit represents a visit for acute pain or a repeat presentation for subacute or chronic abdominal pain. Second, the visits included were based on a primary RFV of abdominal pain; if a patient represented abdominal pain and other symptoms as being equal at triage, which RFV chosen as primary would essentially be random, resulting in some abdominal pain visits not being captured. Third, for some years and imaging modalities, target site was not available; therefore, even for a chief RFV of abdominal pain, concomitant symptoms may have made imaging appropriate for other target sites (e.g., a patient with abdominal pain who also had a cough and received a chest X-ray). Because the population of this study presented with a primary RFV of abdominal pain, we assume that X-rays and ultrasounds obtained were most likely of the abdomen. This assumption is supported by data from CT scans, where nonhead CT imaging had 98% specificity and 100% sensitivity for identifying visits with abdominal CTs in years where the target site was available for confirmation. Fourth, we relied on previously used age groups, including a cutoff at 65, which is customary because it is the age at which Medicare begins. Transitions to middle age and older adulthood in terms of risk of disease, pathophysiology, and medical care are likely continuous, making any grouping arbitrary; however, these groupings facilitate comparison with other findings in the literature. Fifth, while using EGS codes allows us to study the likely diagnoses made or confirmed by CT imaging, the alignment of an EGS diagnosis code with CT-diagnosable disease is imperfect. We were unable to determine whether imaging was done to or following a definitive diagnostic test (such as visual melena, elevated lipase and amylase, or hematemesis). If imaging was done following a positive test, this could increase the positivity rate of EGS in imaged patients. Furthermore, not all EGS conditions have equal clinical import. For instance, colitis can be extensive inflammatory or infectious colitis on imaging leading to hospitalization for IV antibiotics and close monitoring, or it can be a limited viral colitis, which suggests that CT imaging may not have been required. Additionally, NHAMCS data on patient race are derived from ED charts, and therefore our race and ethnicity variables are likely to reflect an admixture of patient self-identification and hospital staff identification of the patient's identity; there is little transparency into whether the value is patient-reported or nurse-designated. However, potential errors arising from this method are unlikely to be systematic according to imaging patterns. Finally, NHAMCS relies on human chart abstraction, which may introduce error. However, the consistency of results over time, the use of trained Census workers for data entry, and increased use of electronic chart abstraction reassure against data entry errors.

CONCLUSIONS

Cross-sectional imaging in the ED has increased substantially over more than a decade. Rising rates of emergency general surgery diagnoses suggest that this increase in imaging may be resulting in additional diagnoses of intervenable disease. We urgently need data sources that link ED visitation to 30-day outcomes to determine whether these rising rates of imaging-driven diagnoses lead to improvements in health.

AUTHOR CONTRIBUTIONS

Study concept and design: Ari B. Friedman, Rachel R. Wu, Rachel R. Kelz, Gregory L. Peck, Ula Hwang, Anne R. Cappola. Acquisition of data: Ari B. Friedman. Data analysis and interpretation: Rachel R. Wu, Michael N. Adjei-Poku, Ari B. Friedman, Rachel R. Kelz. Manuscript drafting: Rachel R. Wu, Michael N. Adjei-Poku, Ari B. Friedman. Critical revision of manuscript: Ari B. Friedman, Rachel R. Wu, Michael N. Adjei-Poku, Rachel R. Kelz, Gregory L. Peck, Ula Hwang, Anne R. Cappola. Statistical expertise: Ari B. Friedman, Rachel R. Wu, Michael N. Adjei-Poku. Funding acquisition: Ari B. Friedman.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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