National Trends in Emergency Department Occupancy, 2001 to 2008: Effect of Inpatient Admissions Versus Emergency Department Practice Intensity

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Study objective: We evaluate recent trends in emergency department (ED) crowding and its potential causes by analyzing ED occupancy, a proxy measure for ED crowding.

Methods: We analyzed data from the annual National Hospital Ambulatory Medical Care Surveys from 2001 to 2008. The surveys abstract patient records from a national sample of hospital EDs to generate nationally representative estimates of visits. We used time of ED arrival and length of ED visit to calculate mean and hourly ED occupancy.

Results: During the 8-year study period, the number of ED visits increased by 1.9% per year (95% confidence interval 1.2% to 2.5%), a rate 60% faster than population growth. Mean occupancy increased even more rapidly, at 3.1% per year (95% confidence interval 2.3% to 3.8%), or 27% during the 8 study years. Among potential factors associated with crowding, the use of advanced imaging increased most, by 140%. But advanced imaging had a smaller effect on the occupancy trend than other more common throughput factors, such as the use of intravenous fluids and blood tests, the performance of any clinical procedure, and the mention of 2 or more medications. Of patient characteristics, Medicare payer status and the age group 45 to 64 years accounted for small disproportionate increases in occupancy.

Conclusion: Despite repeated calls for action, ED crowding is getting worse. Sociodemographic changes account for some of the increase, but practice intensity is the principal factor driving increasing occupancy levels. Although hospital admission generated longer ED stays than any other factor, it did not influence the steep trend in occupancy. [Ann Emerg Med. 2012;xx:xxx.]

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INTRODUCTION

Background

Since 1992, the number of emergency department (ED) visits in the United States has increased at roughly twice the rate of the population growth,[1,2] whereas the number of nonrural EDs has declined by 27%.[3] In 2006, the Institute of Medicine conducted a comprehensive review of hospital-based emergency care and concluded that it is "at the breaking point."[4] The Institute of Medicine cited several factors that contribute to ED crowding, including relentless growth in ED visits, a shortage of on-call specialists, and lengthy delays before admitted ED patients are moved to inpatient beds, a practice commonly referred to as "boarding." Similar conclusions were reached by the US General Accountability Office[5,6] in 2003 and 2009.

Importance

ED crowding contributes to increased waiting times and dissatisfaction with care.[7] It has also been linked to adverse outcomes, including delays in the provision of critical treatments such as antibiotics for pneumonia and analgesia for acute, painful conditions.[8-10] Crowding has been associated with higher rates of medical errors, more frequent complications, and increased mortality rates among critically ill patients.[8,11-16] When ED crowding reaches crisis levels, many hospitals opt to divert inbound ambulances, a practice that contributes to community-wide delays in care for acute

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Editor's Capsule Summary

What is already known on this topic

The volume of patients treated in US emergency departments (EDs) has increased and is associated with increased ED crowding and boarding.

What question this study addressed

Whether a proxy measure of occupancy based on arrival time and length of stay culled from National Hospital Ambulatory Medical Care Surveys data would provide greater insight into ED crowding than the number of visits alone.

What this study adds to our knowledge

Both the number of ED visits and the duration of ED visits increased from 2001 to 2008. Assuming times in the database are accurate, increased intensity of ED care is a larger driver of increased ED occupancy than the boarding of admitted patients.

How this is relevant to clinical practice

This new proxy for occupancy may help identify interventions to decrease ED crowding.

myocardial infarction and perhaps other time-critical conditions.[15-17]

Recently, researchers have identified the ED occupancy rate—defined as the number of patients in an ED at a single point in time divided by the number of standard treatment spaces—as a simple and valid measure of ED crowding.[18,19]

Goals of This Investigation

We explored changes in mean ED occupancy from 2001 to 2008 in the United States, using a nationally representative sample of ED visits. We hypothesized that mean ED occupancy was increasing even faster than the annual increase in ED visits, principally because of longer stays for admitted patients.

MATERIALS AND METHODS

Theoretical Model of the Problem

Because crowding is a property of individual EDs at a point in time, the ideal causal model would use the ED as the unit of analysis, crowding as the dependent variable, and various ED-level characteristics as potential causal factors (eg, teaching hospital status, annual ED volume, number of ED treatment spaces, percentage of Medicaid visits). However, because the identity and characteristics of individual EDs are not publicly disclosed in national surveys, we used mean hourly occupancy aggregated across all sampled EDs as the dependent variable and characteristics of individual visits as potential causal factors. We limited our study to potential contributors to trends in ED crowding rather than crowding per se.

Study Design

We used a repeated cross-sectional design to test the hypothesis that there have been temporal trends in mean levels of ED occupancy and its determinants: visit frequency and length of visit. A second analysis used the same design to assess potential causes of these trends, grouped by their effect on ED input, throughput, or output.[20]

We used data from the National Hospital Ambulatory Medical Care Survey ED subfile (NHAMCS-ED) for this study. NHAMCS-ED is a nationally representative, multistage, stratified sample of ED visits in the United States. It is performed annually by the National Center for Health Statistics, a branch of the Centers for Disease Control and Prevention. Details of the survey methodology are available online.[21] In brief, US Census Bureau field investigators are contracted by the National Center for Health Statistics to collect a random sample of about 100 standard patient record forms from all visits to specified EDs in a random 4-week period, for each of about 350 EDs chosen from among selected primary sampling units. These units were in turn chosen randomly from among 1,900 county-sized population units first identified for the National Health Interview Study. The National Center for Health Statistics keeps the identity of both hospitals and patients confidential to encourage voluntary participation. The institutional response rate was more than 89% for each of the survey years in this study.

We downloaded public-use files from the Ambulatory Health Care Data Web site.[21] Although the NHAMCS-ED survey has included the month, weekday, and time of arrival since 1995, the total length of the patient's ED visit (in minutes) was first reported in 2001. For this study, we analyzed all publicly available survey years from 2001 to 2008. The resulting database included 287,803 patient record forms, representing a total of 917 million ED visits. All analyses used Stata (version 12; StataCorp, College Station, TX), including complex survey programs when appropriate.

Persistent ED crowding has sparked renewed interest in ED operations, informed by systems engineering and related disciplines.[22-24] Many crowding indices have been developed; 4 were recently reviewed.[25] Most require prospective or electronic data capture and detailed setting-specific information, such as the number of ED bed spaces, hourly staffing levels, and assessment of the urgency of each visit. As a result, they are too complex to support nationwide assessments. However, a recent comparison between one of these more complex indices, the ED Work Index (EDWIN),[26] and a much simpler measure—the ED occupancy rate—revealed that the latter is equally accurate at identifying severe levels of ED crowding, defined as hours when larger numbers of patients leave without being seen or when inbound ambulances are diverted.[19] Among 27 candidate measures, the occupancy rate was recently chosen in a consensus exercise as one of 8 key measures of ED crowding.[27] The ED

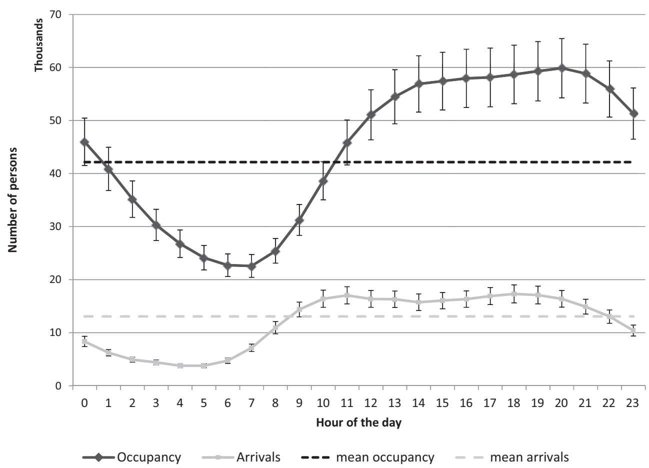

Figure 1. Average daily US ED visits and occupancy, by hour of day, United States, 2001 to 2008 combined. Error bars are 95% CIs.

occupancy rate is defined as the total number of ED patients registered at a defined time divided by the number of staffed treatment spaces at that time.[18] With the time-of-arrival and length-of-visit items in the NHAMCS-ED, it is possible to calculate an aggregate national estimate of average ED occupancy (average number of persons present) for all times of the day. It is not possible, however, to estimate a national occupancy "rate" because the total number of ED treatment spaces available in the United States is not known.

Occupancy varies from minute to minute, whether measured in a single ED or the United States at large. To compare occupancy between years and between potential causal factors, an aggregate measure is required. To calculate average occupancy, one could sum the hourly values and divide by 24. A more practical strategy is to sum all individual lengths of visit for the group of interest. When this single total is divided by the amount of time represented (for an annual sum of lengths of visit measured in hours, this denominator is 365×24), it represents mean occupancy, the quantity plotted as the darker dotted horizontal line in Figure 1. "Mean occupancy" is simply the "total ED hours" estimate and its confidence bound, divided by a constant. This simple method of generating mean occupancy has the added advantage of allowing analysis of sparser samples than more complex crowding measures.

Mean occupancy is much more relevant to ED crowding than simple visit frequency (volume) because, unlike most office visits, ED visits are first-contact visits that accumulate as their acute complaints are investigated. The number of persons present (occupancy) depends on both the number of arrivals and the length of visit. Because the length of visit has markedly skewed distributions, simply multiplying visit frequency by average length of visit may give a misleading estimate of mean occupancy.

We expressed temporal trends as the annual percentage of change, or 100 times the coefficient of survey year taken as a continuous variable, in simple linear regression models with log-transformed annual estimates as data points.

To measure the effect of individual factors on these trends, we simplified the analysis by comparing 2001 and 2008 one factor at a time, accounting for error with statistical significance tests for complex surveys. We initially examined a large number of potential variables, including season, weekend, race, ethnicity, and a range of clinical variables, including a category defined by psychiatric, drug, and alcohol-related diagnostic codes. None of these categories accounted for statistically significant increases in occupancy, in some cases because of low statistical power, and were excluded from the table of results, though available online in Appendix E1 at http://www.annemergmed.com. Because of coding changes between survey years, certain variable definitions required harmonization, including payment type, triage category, blood tests, and imaging.

These details, other variable definitions, the handling of missing values, and selected analysis details are available online in Appendix E1 at http://www.annemergmed.com. For visit frequency, we compared proportions with the Pearson χ^2 test (Rao and Scott correction for survey design). Because length of visit was markedly right-skewed, we interpreted the coefficient on year in a model with log(length of visit) as outcome as the "percentage increase" between 2001 and 2008. A difference in length of visit was considered significant for a factor if the interaction term between that factor and year was significant (the "difference-in-difference" estimator) in a model with the log(length of visit) as outcome. For total ED time (occupancy), we compared sums with Wald tests, using Stata postestimation programs.

RESULTS

During the 8-year study interval, hourly levels of national ED occupancy cycled in a sinusoidal pattern similar to the pattern observed in studies of single EDs.[23] Following a daily nadir at around 7 AM, mean levels of the national ED occupancy increased sharply at midmorning and peaked around 8 PM, an increase sometimes called the daily surge (Figure 1). The daily surge in ED occupancy lags the surge in ED arrivals by approximately 2 hours. Averaged over all hours and all study years (the dotted lines in Figure 1), there were 13,100 arrivals per hour (95% confidence interval [CI] 11,900 to 14,300 arrivals per hour), and mean ED occupancy was 43,200 patients (95% CI 39,200 to 47,200 patients). The ratio of average arrivals to average occupancy (a reflection of operating efficiency[23]) during all study years was 30%.

Simple inspection of the daily surge in visits and occupancy by year immediately suggests that occupancy is increasing faster than visits (Figure 2). To compare trends more directly and without the influence of the daily surge, we plotted percentage change in mean values from the 2001 to 2002 baseline (Figure 3). Although we combined years to obtain greater precision in this figure, we estimated percentage change from annual estimates. The US population increased at a rate of 1.2% per

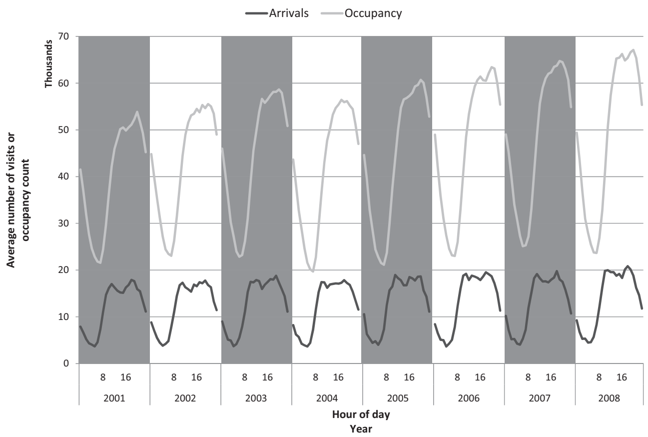

Figure 2. Mean hourly ED arrivals versus mean occupancy, by year, United States, 2001 to 2008.

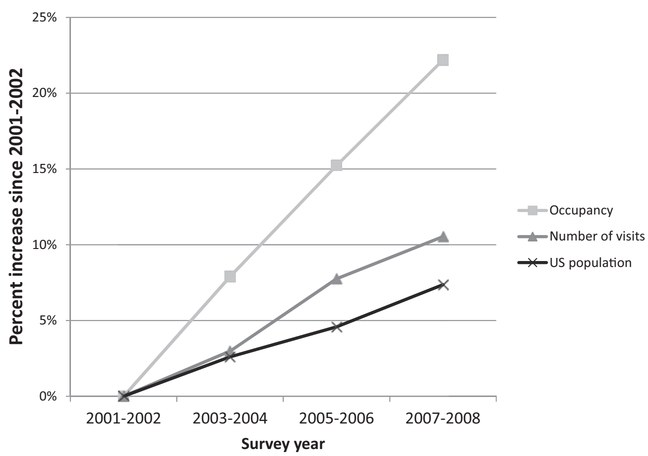

Figure 3. Trends in US population and ED crowding indices, 2001 to 2008. Data points represent percentage increase from 2001 to 2002 baselines in mean counts. Adjacent years are combined to reduce random variation of point estimates.

year from 2001 to 2008. ED visits increased 60% faster than that (1.9% per year; 95% CI 1.2% to 2.5%). The average (geometric mean) length of an ED visit increased more rapidly still, at an annual rate of 2.9% (95% CI 2.0% to 3.7%). The mean level of ED occupancy increased 3.1% annually (95% CI 2.3% to 3.8%), a net increase of 27% during the 8-year period. By 2008, 67,000 patients were undergoing care in US EDs at 8 PM, 14,000 more than 8 years earlier.

The Table shows that from 2001 to 2008, there was an absolute increase of 16.3 million ED visits, a relative increase of 15%. Visits during traditional office hours (Monday to Friday, arrival between 8 AM and 5 PM) increased significantly more than afterhours visits. The visit frequency for Medicare beneficiaries (including dual-eligible patients with both Medicare and Medicaid) and adults aged 45 to 64 years increased faster than that of other payer or age groups, whereas ED visits by persons with private insurance decreased slightly. There was also a disproportionate increase in ED visits associated with higher management intensity, including patients who received intravenous fluids or had a blood test. Use of computed tomography (CT) scans, magnetic resonance imaging (MRI), or ultrasonographic examinations increased fastest in terms of total ED visits involving one or more of these tests. The rate of hospital admissions did not increase significantly, but the proportion of ED admissions to ICUs increased by 114%, a significant increase.

Between 2001 and 2008, the length of an ED visit increased by 21%, somewhat more than their total number. In both 2001 and 2008, ED visits that resulted in hospital admissions had substantially longer lengths of stay than other ED visits. This is likely due, in part, to the greater complexity of these cases, as well as boarding, the practice of holding admitted patients in the ED until a bed becomes available. However, we did not observe a disproportionate increase in boarding time during the study period. The geometric mean duration of ED visits increased in almost all subgroups, but the magnitude of the increase was significantly less ($P<.01$) among patients who were judged at triage to be less seriously ill (14%), among children younger than 15 years (13%), and among patients evaluated with a radiograph (17%) or advanced imaging (7%). Visit duration increased significantly faster among patients who had "any procedure performed" (28%). No other factors varied significantly from the average increase of 21%.

ED occupancy is a function of both the number of patients arriving per hour and the duration of each patient's visit. As noted above, it is the simple but robust proxy for ED crowding.[18,19] According to our analysis, between 2001 and 2008 the mean level of ED occupancy in the United States increased by 27% (Table). This is functionally equivalent to 87 million additional patient-hours in US EDs in 2008 compared with 2001. The factors most strongly associated with increasing levels of ED occupancy were measures of increased management intensity, rather than the prolonged boarding of admitted patients. These factors included more frequent blood testing, greater use of advanced imaging, more frequent administration of intravenous fluids, more than 2 medications coded, and any procedure performed. Increasing use of EDs by Medicare beneficiaries and patients aged 45 to 64 years also accounted for disproportionate increases in ED occupancy. Growth in Medicaid visits and visits by the uninsured were not significant contributors to increasing levels of occupancy, and the increased number of visits during office hours did not translate into a significant increase in occupancy during those hours.

Because boarding of admitted patients can cause lengthy ED stays, it might be an intermediate factor in the causal chain leading to increased treatment intensity. To investigate this possibility, we examined the influence of several factors with the highest effect on occupancy separately by admission or transfer status. A more acute triage category, the use of intravenous fluids, blood tests, and advanced imaging were all associated with greater occupancy increases among nonadmitted than

Table. Trend in ED visit frequency and trend in total ED time, by potential causes of crowding.*

	ED Visits, Millions			Total ED Time, Hours, Millions		
Potential Causes of Crowding	**2001**	**2008**	**Absolute Increase (% Increase)[†]**	**2001**	**2008**	**Absolute Increase (% Increase)[†]**
Total	107.5	123.8	16.3 (15)	330	417	87 (27)
Input variables						
Office hours (8 AM–5 PM, Monday–Friday)	35.0	42.5	7.5[‡] (22)	112.6	149.0	36.4 (32)
Triage category[§]						
High acuity	54.7	67.4	12.6 (23)	180	253	73 (41)
Low acuity	52.7	56.4	3.6 (6)	150	164	14 (10)
Age category, y						
<15	22.2	23.2	0.9 (4)	54	56	1[‡] (2)
15–24	17.4	19.8	2.4 (13)	46	59	13 (29)
25–44	32.7	35.2	2.5[‡] (7)	97	116	19 (20)
45–64	19.3	26.3	7.1[‖] (36)	66	103	36[‖] (55)
64–74	6.6	7.5	0.9 (14)	27	30	3[‡] (12)
≥75	9.3	11.8	2.4 (26)	39	53	14 (37)
Sex						
Male	50.3	56.7	6.4 (12)	151	182	32 (21)
Female	57.2	67.0	9.9 (17)	179	235	55 (31)
Payer status						
Private insurance	43.2	42.9	−0.3[‖] (−1)	126	138	12[‡] (10)
Medicare (including dual-eligible)	15.9	22.8	6.9[‖] (43)	63	97	34[‡] (53)
Medicaid	18.8	25.5	6.7[‡] (35)	54	79	25 (45)
Uninsured	16.9	19.4	2.5 (14)	50	60	10 (21)
Other	5.0	5.6	0.6 (12)	13	18	5 (36)
Throughput variables						
Any blood test	34.2	49.4	15.1[‖] (44)	152	235	83[‖] (54)
Radiograph	37.2	44.0	6.7 (18)	136	171	36 (26)
CT scan, MRI, or ultrasonography	9.0	21.6	12.6[‖] (140)	44	107	64[‖] (146)
Intravenous fluids	19.5	32.9	13.5[‖] (69)	92	163	71[‖] (76)
Any procedure	43.9	57.3	13.3[‡] (30)	157	228	71[‡] (45)
3 or more diagnostic tests	40.6	46.4	5.8 (14)	170	224	55 (32)
2 or more medications	49.3	64.6	15.3[‖] (31)	164	238	74[‖] (45)
Output variables						
Hospital admission	12.6	16.6	3.9 (31)	72	93	21 (30)
Transfer	2.0	2.1	0.1 (6)	9	10	1 (17)
ICU admission	1.0	2.1	1.1[‖] (114)	5	11	7[‡] (145)
Discharged	93.0	105.2	12.2 (13)	250.1	314.7	64.6 (26)

*Total ED time corresponds to mean ED occupancy (see text).
[†]Increases are calculated with actual precision rather than rounded results.
[‡]*P*<.01 for the hypothesis that the relative increase in this category is no different from the increase for other visits.
[§]Four levels of triage (5 levels beginning in 2005) were collapsed to 2, with the 2 least acute levels defined as "nonacute." "Unknown" and "no triage" (17% of visits) are considered nonacute. When these were considered acute, the absolute increase in total ED time for acute visits was 59.2 million, *P*=.37.
[‖]*P*<.001.

admitted or transferred patients (Figure 4). We conclude that hospital admission did not mediate the marked increase in management intensity.

LIMITATIONS

The absence of ED identifiers in the public-use data set prevented us from assigning causes in a multivariable analysis with ED occupancy as the dependent variable. Furthermore, this analysis is subject to the "atomistic fallacy," which describes the potential bias that can occur when individual-level data are used to make inferences at the group level.[28] It is possible that long visit duration and high resource use occurred in different hospitals, leading to an overestimate of the strength of this association. However, we found no statistically reliable deviation from average in the occupancy trends for urban versus rural EDs, the 4 broad geographic regions, or between hospital ownership categories (analysis not shown).

It is likely that many EDs, particularly those with lower volumes and fewer treatment spaces, experienced little or no net change in occupancy levels, whereas others experienced increases well above the national average. Past studies have suggested that crowding is greatest in urban EDs, large hospitals, Level I trauma centers, and EDs that treat large numbers of uninsured patients.[5,29] Nationwide, EDs handling more than 50,000 visits per year represent only 12% of EDs but manage more than 25% of ED visits.[29]

A further limitation is due to missing data. We used multiple imputation to account for missing occupancy. However, we did

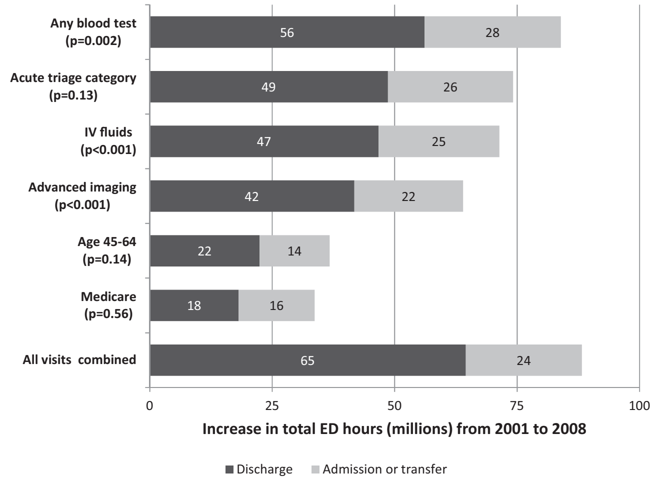

Figure 4. The absolute increase in total ED time from 2001 to 2008 (in millions of hours) for selected subgroups, by disposition. The *P* value is the probability of seeing this result or one more extreme assuming that there is no difference betweeen groups.

not impute length of visit as a dependent variable,[30] so estimates for trends in length of visit exclude those values. It is possible that length of visit is not "missing at random," as occurs when missingness is correlated with the magnitude of the missing variable.

DISCUSSION

We hypothesized that increased boarding of hospital admissions in the ED would be the most important cause of increasing levels of occupancy. This was not the case. Instead, the factors most strongly associated with growth in ED occupancy were throughput factors, most notably an increasing level of both diagnostic and treatment intensity. Although the time required to perform clinical tests and interventions did not change out of proportion, and even decreased somewhat in the case of advanced imaging and radiography, the frequency with which tests and treatments were ordered increased dramatically.

Between 2001 and 2008, annual ED visits increased faster than population growth. However, the average length of an ED visit has been increasing at an even faster pace.[31] The consequence of the simultaneous increase in both visits and length of visit was a sharp increase in hourly levels of ED occupancy, the number of patients physically present in EDs nationwide. Given the likelihood that the number of available ED treatment spaces was either unchanged or declining nationally because of widespread ED closures during this period,[3] this implies a marked increase in the mean occupancy rate in US EDs.

The mean ED occupancy rate is probably a better surrogate for ED crowding than the number of visits, but occupancy has not been previously used to assess ED crowding at the national level, to our knowledge. Our analysis confirms that ED occupancy cyclically increases and decreases daily, but mean occupancy also increased year by year (Figure 2) during the study period. Other studies show that sharp temporal and geographic spikes in crowding can be driven by numerous transient local factors, a fact that complicates efforts to predict staffing and resource needs.[32] But a relentlessly increasing mean occupancy suggests that these periods of ED crowding are becoming more frequent, widespread, and severe.

The 2003 and 2009 General Accountability Office articles observed that the prolonged boarding of ED admissions is a major factor driving ED crowding.[5,6] We confirmed that ED patients who are admitted to the hospital face much longer ED stays than any other group. Reducing the time to hospital admission therefore has a greater potential to reduce ED occupancy than any of the other factors we evaluated. ICU admissions did account for a small but significant increase in total ED hours. This is worrisome because there is strong evidence that ICU patients who spend excessive time in the ED experience poorer outcomes than those who are promptly moved to an ICU.[13]

Some policymakers and media outlets have attributed ED crowding to increasing numbers of nonurgent ED visits. Others have argued that this is a myth.[33-35] Our analysis sheds light on this debate. The NHAMCS-ED survey item "immediacy" combines responses from a mix of triage systems with different numbers of acuity levels, different definitions of levels, and, in some cases, no triage at all. To avoid spurious distinctions, we aggregated responses into only 2 levels (high and low triage acuity) and accounted for missing values by attributing them to each acuity category in turn (Table footnote). Our analysis reveals that on a national level, there has been no net change in the proportion of lower-acuity visits and a marginally significant reduction in the amount of time lower-acuity patients spend in the ED relative to more acute presentations. We therefore conclude that "nonurgent" use of the ED exerted little or no effect on the crowding trend.

Of all the factors associated with disproportionate increases in mean occupancy, only 3 were unrelated to ED operations: (1) a modest decrease in total ED hours involving children younger than 15 years; (2) a marked increase in total ED hours involving older, nonelderly adults (aged 45 to 64 years); and (3) a significant increase in total ED hours involving Medicare beneficiaries, including dual-eligible patients younger than 65 years. The decline in ED use by children may be attributed to the State Children's Health Insurance Program, which expanded coverage and therefore access to primary care for this age group.[36] Adult Medicare patients, on the other hand, likely experienced a loss of primary care access.[2] Perhaps as a result of the aging of the baby boom generation, visits by older, nonelderly adults increased their absolute visit frequency out of proportion to other age groups. Also, because health problems in this age group tend to be more complex than those of younger patients, their visits tend to consume more ED time. One study reported that the population-based ED visit rate among older adults between 1997 and 2007 was lower than for younger adults despite a higher absolute increase in ED visits.[2] This strengthens the baby boom hypothesis as one explanation for worsening ED crowding.[37]

A major driver of the increase in ED occupancy is rapid growth in the use of advanced imaging, particularly CT scanning.[38] In 2008, ED visits involving advanced imaging required substantially more time (median length of visit 253 minutes) than other ED visits (median 137 minutes). The imaging boom is a global phenomenon affecting all clinical settings.[39] In the ED, frequent ordering of advanced imaging inevitably contributes to crowding because, unlike in other settings, these tests cannot be scheduled in advance. However, we found that the net effect of advanced imaging on ED occupancy was smaller than that of several other throughput factors, including more frequent ordering of blood tests, administration of intravenous fluids, performance of clinical procedures, and visits with 2 or more medications mentioned. Although the use of advanced imaging increased much faster than any other factor, it did not have the same magnitude of effect on the absolute increase in occupancy caused by factors with higher base rates.

The general trend toward greater treatment intensity may reflect, in part, increasing numbers of older adults with complex medical problems but probably also represents an increasingly interventionist practice style. This might in turn be attributed to striving for higher quality of care, financial incentives that reward higher intensity of services, or "defensive medicine."[40] Ironically, it is possible that innovations intended to speed ED throughput such as authorizing the early ordering of blood testing, intravenous lines, and radiographic imaging at triage may be bogging down ED operations instead.[41] More optimistically, increasing intensity of care (and longer stays) among ED patients who were discharged may reflect increasing use of diagnostic technology and interventions to reduce the need for hospitalization. A recent study found that admission rates for certain complaints such as abdominal pain decreased as the rate of CT use increased.[42] An extended ED stay is costlier than average and increases crowding but is less costly than a preventable hospitalization. It is also possible that "borderline" patients who were admitted in the past are now being managed entirely in the ED and discharged because the emergency physician has no choice, rather than in a deliberate effort to improve global efficiency.

In conclusion, despite repeated calls for action, ED crowding is probably getting worse, not better. During the past few years, levels of ED occupancy in the United States have increased more than twice as fast as the often-cited growth in ED visits. The largest contributor to this phenomenon is increased practice intensity. These findings have ominous implications for patient safety and access to emergency care in the United States.

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APPENDIX E1.

Part 1: Variable Selection

We measured temporal increases in visit frequency and length of visit to better understand the contribution of individual factors to increased crowding, defined here as the absolute increase in total ED hours between 2001 and 2008. The choice of potential factors is limited to items available on the patient record form in both 2001 and 2008, and includes demographic, payer, clinical categories, resource use, and disposition categories. Categories chosen *a priori* because of potential implication in ED crowding include urgency of visit (determined at triage, and converted from a 4-5 level variable—depending on year of survey—to a binary form with the lower category including the two lowest acuity categories regardless of survey year), and behavioral diagnoses. Chief complaint categories were created using the reason-for-visit (RFV) code[1] in the first of three complaint fields available. We chose five of the commonest adult complaints, including abdominal pain (RFV code 1545, 6.8% of visits), chest pain (RFV code 1050, 5.2% of visits), dyspnea (RFV code 1415, 4.3% of visits), fever (RFV code 1010, 4.3% of visits), cough (RFV code 1440, 2.7% visits), and headache (RFV code 1210, 2.8% visits). The designation of "behavioral diagnosis" was identified as the presence in any of three available diagnosis fields of a psychiatric or substance abuse diagnosis (3-digit ICD9 code ranges 290-293 and 302-319, using the Stata<icd9> functions). None of the race, ethnicity, or clinical variables had a significant impact on occupancy. They were excluded from the paper to simplify presentation, but are shown here:

	ED visits (millions)			Total ED time in hours (millions)		
	2001	2008	Absolute increase (% increase)	2001	2008	Absolute increase (% increase)
Total	107.5	123.8	16.3 (15%)	330	417	87 (27%)
Race/ethnicity						
Non-Hispanic white	72.5	75.6	3.1 (4%)	179.8	235.6	55.8 (31%)
Non-Hispanic black	21.4	27.1	5.8 (27%)	58.7	92.9	34.2 (58%)
Hispanic	10.7	17.3	6.7 (63%)	30.9	55.2	24.3 (79%)
Other	3.0	3.7	0.7 (23%)	6.9	12.1	5.2 (75%)
Clinical categories						
Behavioral diagnosis	15.1	18.6	3.5 (23%)	48.1	74.2	26.2 (54%)
Abdominal pain	6.8	8.7	1.9 (28%)	23.4	38.5	15 (64%)
Chest pain	5.7	6.6	0.9 (17%)	17.3	27.0	9.6 (56%)
Dyspnea	4.6	5.7	1.1 (23%)	13.2	21.2	8 (60%)
Cough	3.1	3.4	0.3 (10%)	6.7	8.6	1.9 (28%)
Headache	3.2	3.3	0.2 (5%)	8.0	11.5	3.5 (44%)
Fever	4.3	5.4	1.2 (27%)	9.7	15.2	5.5 (57%)
Weekend	31.9	36.1	4.2 (13.3)	95.1	115.1	20.0 (21%)

We converted the ordinal variables "number of diagnostic/screening services," and "number of medications coded" into binary forms, using arbitrary thresholds that resulted in large numbers of visits for both alternatives. Included in the definition of "any procedure" were IV fluids, cast, splint or wrap, laceration repair, incision & drainage of abscess, wound debridement, foreign body removal, nebulizer therapy, bladder catheterization, nasogastric tube/gastric lavage, cardiopulmonary resuscitation, endotracheal intubation, or any other procedure (undefined).

Payer status was a single multinomial variable called PAYTYPE from 2001 to 2004, representing the primary payer designated by the hospital when there were multiple payers. From 2005 onward payer status was represented by separate indicator variables for each of the payer categories (PAYPRIV, PAYMCARE, PAYMCAID, PAYWKCOMP, PAYSELF, PAYNOCHG, PAYOTH, PAYUNK) and an algorithm was used to create a derived version of PAYTYPE from these binary variables. From 2005 to 2007 this algorithm assigned "dual-eligible" visits (visits with both Medicare and Medicaid payers) to the category "Medicaid," but in 2008 began assigning them to "Medicare." To maintain consistency across years, we reassigned dual-eligible patients to "Medicare" in the PAYTYPE variable for years 2005-2007, since hospitals will have assigned primary payer status of dual-eligibles to "Medicare" during the years 2001-2004, given generally higher reimbursement levels. This reassignment has a substantial effect on the assessment of trends, and accounts for our disagreement with payer trends in a recent publication.[2]

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Part 2: Missing Values

There was significant item non-response for several variables (unweighted), including especially race and ethnicity (15 and 24 percent, respectively, in 2008 according to survey documentation[1]) length of visit (8.8 percent non-response), payer type (6.4 percent non-response) and triage category (17 percent non-response). Missing payer type was handled by case-wise deletion. We collapsed triage category into a binary form that assigned the

17% of records with missing triage level to the less urgent category, since this group had a lower hospitalization rate, but compared these results with the alternative of assignment to the more acute category in the footnote to the Table. Race and ethnicity were imputed using a hot-deck approach by the NCHS in 2008, but only race was imputed in 2002. We considered only race and ignored ethnicity when generating the single-dimension "race-ethnicity" variable, when ethnicity was missing in 2001.

We found that length of visit was missing more frequently in earlier years and among hospitalized patients, which would bias estimates of the occupancy trend upward and mean occupancy downward. To correct this we developed a multiple imputation model, with missing length of visit values replaced by values predicted by the non-missing values for year, admission status, and the interaction between year and admission status. The Stata<mi> programs use Rubin's combination rules to generate statistically valid inferences by combining multiple random draws from the distribution of predicted results for missing variables.[2] The *P* values for occupancy trend comparisons in the Table used 10 imputations. Point estimates of hourly occupancy in Figures 1 and 2 were obtained by averaging these 10 imputations in cases with missing length of visit. We did not substitute imputed length of visit when length of visit was the outcome variable, instead deleting cases with missing length of visit from the analysis.[3]

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Part 3: Variable Harmonization Across Survey Years

1. Definition of blood test

Using standardized variable names from NCHS-provided SAS input statements (and online documentation files), we considered any of the following a "blood test"

ALL YEARS:
CBC
2001–2002:
HIVSER BUN CREATIN CHOLEST GLUCOSE HGBA OTHBLDCH BLOODCX OTHERLAB
2003–2004:
HIVSER OTHERBLD BUN CREATIN CHOLEST GLUCOSE HGBA ELECTROL BLOODCX BAC
2005–2006:
HIVSER OTHERBLD ELECTROL BAC CARDENZ LFT ABG BUNCREAT
2007–2008:
OTHERBLD GLUCOSE ELECTROL BAC CARDENZ LFT ABG BUNCREAT PTTINR TOXSCREN

2. Conventional ("plain") radiography

Using standardized variable names from NCHS-provided SAS input statements (and online documentation files), we considered each of the following a conventional radiograph

2001–2004:
CHESTXRY EXTRXRAY OTHERXRY
2005–2008:
XRAY

3. Advanced imaging

Using standardized variable names from NCHS-provided SAS input statements (and online documentation files), we considered each of the following a case of advanced imaging

ALL YEARS:
ULTRASND
2001–2004:
MRICAT
2005–2008:
CATSCAN MRI

Part 4: Selected Programming Steps

Calculating hourly occupancy from arrival date-time and length of visit

1. Two input variables are necessary: *arrtime* (arrival time), and *lov* (length of visit in minutes). The variable *arrtime* is provided by NCHS as military time (4-characters, the last 2 being minutes).
2. Generate time of arrival in decimal hours (*atim*) from *arrtime*, using Stata date-time functions (see Stata code below).
3. Generate time of discharge (*dtim*) by adding length of visit in decimal hours to *atim*, subtracting 24 if *dtim* is >24.
4. Initialize 24 occupancy variables, one for each hour of the day (*occ0-occ23*).
5. Assign a value to each occupancy variable: 0 if patient not present during this hour, and 1 if present, using the following conditional statements
   a. Patient is present for a given hour if
      i. *atim* < that hour AND
         1. dtim is > that hour OR
         2. dtim < atim (visit overlapped midnight)
   b. Include the case when given hour is less than arrival time, but visit overlaps midnight and includes the given time
   c. Change the value for occupancy to 2 if the visit overlaps the given hour twice (very few cases)
6. Use survey weights and design variables to sum observations for each of 24 occupancy variables and calculate confidence intervals.

****

Stata code:

```
* recode missing
replace arrtime="" if arrtime=="9999" | arrtime=="-9"
replace lov=. if lov==9999 | lov<0
* create decimal time stamps
destring arrtime,replace
```

```
gen ahour=floor(arrtime/100)
gen amin=mod(arrtime,100)
gen double adt=mdyhms(vmonth,vdayr,vyear,ahour,amin,0) //note:
vdayr=day of week
label variable adt "Arrival date-time"
format adt %tc
gen mslov=lov*60*1000 // convert lov from minutes to msec
gen ddt=adt+mslov // ddt defined as adt + mslov
format ddt %tc
* convert date-time to time only (decimal)
gen atim=hms(hh(adt),mm(adt),ss(adt))
replace atim=atim/(1000*60*60)
gen dtim=hms(hh(ddt),mm(ddt),ss(ddt))
replace dtim=dtim/(1000*60*60)
format atim %6.2f
format dtim %6.2f

* generate 24 variables to accumulate counts for each hour,
* summate and calculate confidence bounds for each hour

forval i=0/23 {
    gen byte occ‘i’=atim<‘i’ & (dtim>=‘i’ | dtim<atim)
    qui replace occ‘i’=1 if atim>=‘i’ & (((lov/60)-(24-atim))>‘i’)
    qui replace occ‘i’=2 if (‘i’-atim>0) & ((lov/60)-24)>(‘i’-atim)
    qui replace occ‘i’=2 if (‘i’-atim<0) & ((lov/60)-24)>((24+‘i’)-atim)
    qui svy: total occ‘i’
    qui lincom occ‘i’ // linear combination
    local bound invttail(e(df_r),.025)*r(se) // define 95% conf bound with correct df
    di as txt "occ‘i’ " as res _b[occ‘i’] " " ‘bound’
  }
```

Regression models used to generate some of the estimates, significance tests, and confidence intervals in Table 1

<u>Bivariate association</u>

<u>Number of visits</u>

1. Create a binary variable (*y08*) for year (2008=1, 2001=0)
2. Define year 2001&2008 subpopulation: *y0108*==1
3. Regress *y08* on each binary factor in turn, using logistic regression with survey weights and design variables
4. Examples using *ct* (advanced imaging if *ct*==1, else *ct*=0)

   logit y08 = beta0 + beta1*(ct)
5. Test significance of beta1
6. Example Stata code

```
svy, subpop(y0108): logit ct y08
test y08
```

<u>Length of visit</u>

1. Dependent variable: Natural logarithm of length of visit in minutes (*lnlov*)

   lnlov = beta0 + beta1*(y08) + beta2*(ct) + beta3*(y08*ct)
2. Test significance of coefficient on interaction term (beta3)
3. Example Stata code

```
svy, subpop(y0108): regress lnlov y08 ct y08*ct
test y08*ct
```

<u>Mean occupancy</u>

1. Dependent variable: sum of lov
2. Test significance of difference between the percent increase of sums, using Stata post-estimation program for multiply imputed data
3. Example Stata code (*ilov* is imputed length of visit)

```
mi estimate, saving(myresults, replace) cmdok:svy,subpop(y0108): total ilov, over(ct y08)
mi estimate (diff: ((_b[_subpop_4]-_b[_subpop_3])/_b[_subpop_3])-((_b[_subpop_2]-_b[_subpop_1])/_b[_subpop_1])) using myresults
mi testtransform diff
di " p= " %5.3f r(p)
}
```