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ORIGINAL RESEARCH CONTRIBUTION

Effect of Testing and Treatment on Emergency Department Length of Stay Using a National Database

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Abstract

Objectives: Testing and treatment are essential aspects of the delivery of emergency care. Recognition of the effects of these activities on emergency department (ED) length of stay (LOS) has implications for administrators planning efficient operations, providers, and patients regarding expectations for length of visit; researchers in creating better models to predict LOS; and policy-makers concerned about ED crowding.

Methods: A secondary analysis was performed using years 2006 through 2008 of the National Hospital Ambulatory Medical Care Survey (NHAMCS), a nationwide study of ED services. In univariate and bivariate analyses, the authors assessed ED LOS and frequency of testing (blood test, urinalysis, electrocardiogram [ECG], radiograph, ultrasound, computed tomography [CT], or magnetic resonance imaging [MRI]) and treatment (providing a medication or performance of a procedure) according to disposition (discharged or admitted status). Two sets of multivariable models were developed to assess the contribution of testing and treatment to LOS, also stratified by disposition. The first was a series of logistic regression models to provide an overview of how testing and treatment activity affects three dichotomized LOS cutoffs at 2, 4, and 6 hours. The second was a generalized linear model (GLM) with a log-link function and gamma distribution to fit skewed LOS data, which provided time costs associated with tests and treatment.

Results: Among 360 million weighted ED visits included in this analysis, 227 million (63%) involved testing, 304 million (85%) involved treatment, and 201 million (56%) involved both. Overall, visits with any testing were associated with longer LOS (median = 196 minutes; interquartile range [IQR] = 125 to 305 minutes) than those with any treatment (median = 159 minutes; IQR = 91 to 262 minutes). This difference was more pronounced among discharged patients than admitted patients. Obtaining a test was associated with an adjusted odds ratio (OR) of 2.29 (95% confidence interval [CI] = 1.86 to 2.83) for experiencing a more than 4-hour LOS, while performing a treatment had no effect (adjusted OR = 0.84; 95% CI = 0.68 to 1.03). The most time-costly testing modalities included blood test (adjusted marginal effects on LOS = +72 minutes; 95% CI = 66 to 78 minutes), MRI (+64 minutes; 95% CI = 36 to 93 minutes), CT (+59 minutes; 95% CI = 54 to 65 minutes), and ultrasound (US; +56 minutes; 95% CI = 45 to 67 minutes). Treatment time costs were less substantial: performing a procedure (+24 minutes; 95% CI = 20 to 28 minutes) and providing a medication (+15 minutes; 95% CI = 8 to 21 minutes).

Conclusions: Testing and less substantially treatment were associated with prolonged LOS in the ED, particularly for blood testing and advanced imaging. This knowledge may better direct efforts at streamlining delivery of care for the most time-costly diagnostic modalities or suggest areas for future research into improving processes of care. Developing systems to improve efficient utilization of these services in the ED may improve patient and provider satisfaction. Such practice improvements could then be examined to determine their effects on ED crowding.

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Testing and treatment have always been routine and important aspects of emergency care, but in recent years the emergency department's (ED) role in delivering more intensive services has expanded. Given that both the use of testing and the treatment are largely controlled by the ED, an improved recognition of how these factors influence length of stay (LOS) and potentially ED crowding could help providers and policy-makers design systems that allow services to be performed more efficiently in this environment. In addition, knowledge of the time costs related to testing and treatment have implications for providers and patients regarding expectations for ED length of visit,[1,2] administrators planning efficient operations and appropriate ED staffing models,[3,4] and researchers attempting to create better models to predict ED flow.[5–7]

Previous studies of prolonged patient LOS in the ED have focused appropriately on understanding the contribution of patient and visit-related factors[8,9] or have evaluated this topic at only one ED,[10] which limits the generalizability of results. While these assessments provide some explanation for factors effecting ED LOS, they have not accounted for recent changes in the complexity of care delivered in this setting. In addition, ED LOSs have been steadily increasing over the past decade,[11,12] and previous assessments may not reflect the current state of affairs.

We therefore examined national practice patterns in common diagnostic tests, advanced imaging studies, and treatment (performing a procedure or administering a medication), using a recent 3-year period of data from the National Hospital Ambulatory Medical Care Survey (NHAMCS), a large nationwide study of ED care across the United States.[13] Our goals were to evaluate the effect these practices had on ED LOS and to determine the extent to which current diagnostic testing and treatment patterns contribute to longer patient LOS.

METHODS

Study Design

We performed a secondary analysis of the ED component of the NHAMCS. The Institutional Review Board of the University of Michigan evaluated this study prior to its initiation and determined it to be exempt from further review or informed consent requirements.

Study Setting and Population

We were interested in studying current testing and treatment patterns and therefore combined and analyzed the recent survey years of 2006 through 2008. Combining survey years incrementally improves the associated standard error of the estimates and ensures an adequate sampling of events.[14] NHAMCS is directed by the Centers for Disease Control and Prevention (CDC) and the National Center for Health Statistics. This survey collects a nationally representative sample of all ED visits in noninstitutional general and short-stay hospitals, excluding federal, military, and Veterans Administration hospitals. Staff at the sampled hospitals, under guidance of NHAMCS field representatives, collected information on patient demographics, visit characteristics, and hospital factors for all ED visits during a randomly assigned 4-week reporting period each year. A detailed description of the data collection, abstraction, and cleaning procedures is available from the CDC.[13] These data are publicly available and anonymous.

Study Protocol

The primary outcome for this analysis was ED LOS. The NHAMCS calculates LOS from the moment of patient arrival until discharged or, if admitted, until the time the patient left the ED. The sample was missing LOS data on 5.6% of the visits, so these visits were not included in the study cohort. Using Pearson's chi-square, there were no important differences among demographic, visit, or hospital characteristics between those visits with LOS data and those without (data not shown, but available on request from the authors).

The primary covariate of interest for this study was receiving a diagnostic test or treatment during an ED visit. We included and analyzed all tests recorded in the NHAMCS database. These tests included obtaining any blood test, urinalysis, electrocardiogram (ECG), radiograph, ultrasound (US), computed tomography (CT), or magnetic resonance imaging (MRI). The variable for blood testing was a composite of several individual blood tests recorded in NHAMCS, including complete blood count, blood urea nitrogen/creatinine, electrolytes, glucose, liver function tests, arterial blood gas, cardiac enzymes, prothrombin time/international normalized ratio, blood alcohol level, blood culture, human immunodeficiency virus serology, or any other blood test. Treatment included provision of one or more medications or a composite measure of performance of any type of procedure (cardiopulmonary resuscitation, endotracheal intubation, nasogastric tube placement, bladder catheterization, intravenous [IV] fluids, nebulizer therapy, wound care, orthopedic care, or other procedure). To provide a general overview of testing and treatment activity, dichotomous outcome categories of receiving any test or any treatment were created. These composite outcomes were chosen out of concern for ensuring an adequate sample size for the multivariable logistic regression modeling.

Data available in the NHAMCS comprised information on patient demographics, visit characteristics, and hospital factors. Patient demographics included age, sex, self-reported race (categories collapsed to white or nonwhite, as there are few other races found in the database and these were therefore combined with black into a single category), ethnicity (Hispanic or non-Hispanic), and insurance status (categories collapsed to uninsured [self-pay, no charge, and charity combined as there are few cases individually in these categories], Medicaid, Medicare, and private or other insurance).

Visit characteristics included year during which the visit occurred (considered as a categorical variable with 2006 as the reference category), ED arrival time (collapsed to four consecutive 6-hour blocks of time, starting with the period with the fewest visits, from 1 AM to 7 AM, which served as the reference), wait time (defined as time of patient arrival until seen by provider, treated as a continuous variable in 5-minute segments to ameliorate the effect of recorded time values that tend to be rounded to the nearest 5-minute digit), day of week, season, mode of arrival (ambulance, public service such as police or social services, walk-in), triage category (recommended immediacy with which patient should be seen of <15 minutes, within 15 to 60 minutes, within 1 to 2 hours, within 2 to 24 hours), pain category (none, mild, moderate, severe), specific type of tests obtained during the visit (blood test, urinalysis, ECG, radiograph, US, CT, MRI), specific type of treatment performed (provision of at least one medication, performance of a procedure), whether the patient was seen by a resident or physician extender, and disposition (categories collapsed to left against medical advice [AMA] or prior to completion of visit [left without being seen, LWBS], died in ED, discharged, transferred, admitted to hospital).

Hospital factors included location, region, teaching status, and hospital ownership as provided by the NHAMCS database. Location was determined by metropolitan statistical areas as urban or rural. Region was divided into areas of South, Northeast, West, and Midwest, according to the U.S. Census Bureau. To adjust for differences between hospitals that were purely nonteaching versus those that engaged in some degree of teaching, hospitals were characterized as a teaching institution if at least one of the ED visits involved a resident or intern during the sample period. Hospital ownership was divided into government (nonfederal), for-profit, and nonprofit.

Data Analysis

All analyses used weights, strata, and primary sampling unit design variables provided by the NHAMCS to generate national estimates.[13] Results were stratified by disposition, to determine if there were disproportionate effects on patient LOS for those who were discharged versus admitted. Discharge was defined as all patients who were discharged home at the end of the visit. Admission was defined as visits ending in hospitalization, either to an intensive care unit or to a general bed. ED visits could also end in transfer, LWBS, left AMA, or died in ED, with these visits being excluded from the disposition aspect of the analysis. Descriptive statistics present median ED LOS with interquartile ranges (IQRs) across testing and treatment modalities stratified by disposition, as well as testing and treatment utilization across patient demographics, visit characteristics, and hospital factors.

To assess the contribution of testing and treatment to ED LOS, two types of multivariable models were constructed. The first was a series of three logistic regression models to provide an overview of how testing and treatment activity affects three dichotomized LOS cutoffs for all ED patients. These models were constructed to evaluate the odds of experiencing a LOS longer than 2, 4, and 6 hours by whether a patient received any type of diagnostic test or treatment. A 4-hour ED LOS corresponds to the former United Kingdom standard,[15] while a 6-hour LOS corresponded to the maximum Canadian standard.[16] The second was a generalized linear model (GLM) with a log-link function and gamma distribution to fit skewed ED LOS data. GLM is a form of regression analysis and is a commonly used technique in health services and social science research.[17] As noted in previous ED time analysis studies, LOS data were not normally distributed.[8,11,18–21] Therefore, this approach was used to allow appropriate modeling of these time data with the ability to report the results in the original time units as opposed to a log-transformed outcome. This model was constructed to determine the contribution of individual tests and treatment to ED LOS, with LOS treated as a continuous variable.

Variables were selected as covariates in the models based on their a priori clinical importance and hypothesized effect on ED LOS. We also tested these assumptions by exploring the relationships between these covariates, the predictor (individual test or treatment modality), and outcome (ED LOS). All covariates were related to both the test or treatment and outcome on univariate analysis at a p-value of less than 0.05. In addition, the models were tested for collinearity by measuring the variance inflation factor. We planned a priori to remove all covariates with an inflation factor of more than 10, but there were none that fit that criterion. Given the large number of covariates used in these models, we also adjusted the p-value for multiple comparisons using the Bonferroni correction from a level of 0.05. We did this to ensure that the relationship was clearly associated with the outcome of interest. However, if the outcome was still statistically significant after this adjustment, we reported at the 95% confidence interval (CI). All main outcomes were statistically significant after this adjustment for multiple comparisons.

The three final logistic regression models exploring the relationship between ED LOS at cutoffs of 2, 4, and 6 hours, and testing and treatment included the covariates of year of study, age, sex, race, ethnicity, insurance, arrival time, wait time, day of week, season, mode of arrival, triage category, pain category, if any test was done, if any treatment was performed, if seen by a physician extender or resident, disposition, hospital location, region, type, and ownership. In addition, interaction terms were included to take into account any multiplicative effects between arrival time and wait time and testing and treatment modalities. The final GLM analyzing the contribution of individual tests and treatment to ED LOS included all of the above covariates, except in place of the covariates for any test or any treatment, variables were utilized for specific types of tests obtained (blood test, urinalysis, ECG, radiograph, US, CT, MRI) and specific categories of treatments performed (medication or procedure), as well as interaction terms between different types of testing and treatment modalities.

In addition, we calculated a Harrell's C-statistic[22] for these models. This statistic provides a measure of the predictive accuracy of the model, similar to the area under the receiver operator curve (ROC). The C-statistic ranges from 0.5 (no predictive ability) to 1 (perfect discrimination), and, for this model, is based on a comparison of the predictive probabilities in ED encounters with and without the outcome of receiving the test or treatment. The C-statistic illustrates how well the model discriminates between patients who had a test or treatment and those that did not. Values greater than 0.80 reflect good discriminatory power. The final logistic regression models provided very good concordance with the predicted probabilities, with associated Harrell's C-statistics of 0.85 (95% CI = 0.84 to 0.86) for the 2-hour cutoff model, 0.83 (95% CI = 0.82 to 0.84) for the 4-hour cutoff model, and 0.80 (95% CI = 0.79 to 0.82) for the 6-hour cutoff model. The final GLM provided moderate concordance with the predicted probabilities, with an associated Harrell's C-statistic of 0.77 (95% CI = 0.76 to 0.78). Results from this model were reported as the average marginal effects on LOS of receiving a test or procedure, stratified by disposition. The result is shown in minutes with associated 95% CIs.

All statistical tests were two-tailed. Data management and analysis were performed with Stata software (version 11.0, StataCorp, College Station, TX) taking into account the complex survey design of NHAMCS with the *svy* package of commands.

RESULTS

Characteristics of ED Visits

The 2006 through 2008 NHAMCS data set included information on 105,473 ED visits sampled at 364 hospitals over the study period. These cases were weighted to represent 359,755,013 visits nationally over the study period. The distribution of ED LOS with median values is shown in Figure 1 for all visits and discharged and admitted patients. As is typical with LOS data, the distribution has a rightward skew. On average, discharged patients had shorter LOS than admitted patients.

Characteristics of Study Subjects

Table 1 displays testing and treatment use across various patient demographics, visit characteristics, and hospital factors. Larger differences were found among those receiving tests and treatment across categories of age, insurance status, mode of arrival, triage, and disposition. Testing occurred in approximately 63% of all ED visits and treatment in approximately 85% of all ED visits. Figure 2 shows the frequency of testing and treatment performed during ED visits by whether tests were ordered, treatments provided, and disposition. In general, across all modalities, admitted patients had more tests and treatments performed during their ED evaluations than discharged patients. Blood tests and radiographs were the most frequent tests obtained. Providing a medication was more commonly done than performing a procedure.

Main Results

Median LOS for the different diagnostic testing and treatment modalities by disposition is shown in Figure 3. Those visits in which tests or treatments were performed were associated with longer median LOS compared to those visits in which no interventions were done. In addition, these differences were more pronounced among discharged patients than admitted patients. For example, the difference in LOS between receiving any test and receiving no tests among discharged patients was 84 minutes, while this difference was 49.5 minutes among admitted patients.

Testing and treatment were both associated with prolonged LOS in the ED. In Figure 4, the adjusted odds of experiencing an ED LOS longer than 2 hours for any test was 5.16 (95% CI = 4.21 to 6.31). While this effect decreased at the longer cutoff points of 4- and 6-hour LOS, it continued to persist. An ED visit associated with any test still had an adjusted odds of 1.48 (95% CI = 1.11 to 1.96) of being longer than 6 hours. In contrast, treatment exerted less of an effect. By the 4-hour mark, the associated adjusted odds of receiving treatment and having a longer ED visit was not significant at 0.84 (95% CI = 0.68 to 1.03).

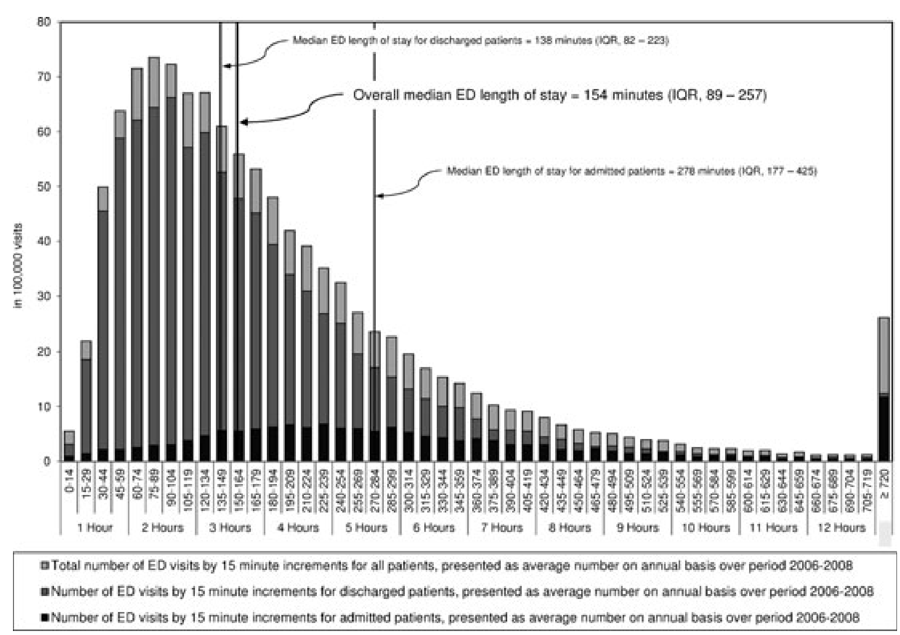

Figure 1. Distribution of ED visit LOS by disposition. LOS = length of stay.

Table 1
Select Baseline Characteristics According to Testing Obtained and Treatment Provided*

	Test Obtained (*n* = 65,586)	Proportion of Visits, % (95% CI)	Test Not Obtained (*n* = 39,887)	Proportion of Visits, % (95% CI)	Treatment Provided (*n* = 88,624)	Proportion of Visits, % (95% CI)	Treatment Not Provided (*n* = 16,849)	Proportion of Visits, % (95% CI)
Overall weighted population	227,019,481	63.1 (62.0–64.2)	132,735,532	36.9 (35.8–38.0)	303,837,487	84.5 (83.6–85.3)	55,917,526	15.5 (14.7–16.4)
Demographics								
Age (yr), mean ± SD	42.1 ± 24.1		28.2 ± 21.2		37.5 ± 23.8		33.8 ± 24.8	
<18	36,134,398	15.9 (15.0–16.8)	44,960,967	33.9 (32.2–35.5)	64,898,115	21.4 (20.2–22.5)	16,197,250	30.0 (26.9–31.0)
18–34	59,200,208	26.1 (25.4–26.8)	40,004,214	30.1 (29.2–31.1)	84,179,765	27.7 (27.0–28.4)	15,024,657	26.9 (25.7–28.0)
35–49	47,750,997	21.0 (20.5–21.5)	26,077,423	19.6 (19.0–20.3)	63,548,259	20.9 (20.4–21.4)	10,280,161	18.4 (17.4–19.4)
50–64	37,894,349	16.7 (16.2–17.1)	13,652,646	10.3 (9.7–10.8)	44,891,416	14.8 (14.4–15.2)	6,655,579	11.9 (11.0–12.9)
65–79	26,354,895	11.6 (11.1–12.1)	5,316,467	4.0 (3.7–4.3)	44,891,416	9.0 (8.6–9.4)	4,347,020	7.8 (7.1–8.5)
>79	19,684,634	8.7 (8.2–9.2)	2,723,815	2.1 (1.8–2.3)	18,995,590	6.3 (5.9–6.6)	3,412,859	6.1 (5.4–6.8)
Sex								
Female	127,831,228	56.3 (55.7–56.9)	67,361,674	50.7 (49.9–51.6)	165,343,021	54.5 (53.9–55.0)	29,849,881	53.4 (52.4–54.4)
Male	99,188,253	43.7 (43.1–44.3)	65,373,858	49.3 (48.4–50.1)	138,494,466	45.6 (45.0–46.1)	26,067,645	46.6 (45.6–47.6)
Race								
Nonwhite	59,585,894	26.2 (23.5–29.0)	40,127,937	30.2 (27.1–33.3)	82,995,943	27.3 (24.5–30.1)	16,717,888	29.9 (26.5–33.3)
White	167,433,587	73.8 (71.0–76.5)	92,607,595	69.8 (66.7–72.9)	220,841,544	72.7 (69.9–75.5)	39,199,638	70.1 (66.7–73.5)
Ethnicity								
Hispanic	28,696,795	12.6 (10.8–14.5)	19,921,786	15.0 (12.8–17.2)	40,783,455	13.4 (11.5–15.4)	7,835,126	14.0 (12.0–16.1)
Non-Hispanic	198,322,686	87.4 (85.5–89.2)	112,813,746	85.0 (82.8–87.2)	263,054,032	86.6 (84.6–88.5)	48,082,400	86.0 (83.9–88.0)
Insurance								
Medicaid	47,701,157	21.0 (19.8–22.2)	37,570,328	28.3 (26.6–30.0)	71,125,689	23.4 (22.1–24.7)	14,145,796	25.3 (23.5–27.1)
Uninsured	33,986,302	15.0 (13.8–16.1)	24,470,023	18.4 (17.0–19.8)	49,161,519	16.2 (15.0–17.3)	9,294,806	16.6 (15.0–18.3)
Private or other	86,639,664	38.2 (36.9–39.4)	49,519,918	37.3 (35.4–39.2)	117,771,210	38.8 (37.4–40.1)	18,388,372	32.9 (30.9–34.8)
Medicare	46,134,626	20.3 (19.4–21.2)	10,102,047	7.6 (7.0–8.2)	48,257,042	15.9 (15.1–16.6)	7,979,631	14.3 (13.1–15.5)
Visit characteristics								
ED arrival time								
1 AM–7 AM	21,916,026	9.7 (9.2–10.1)	12,035,602	9.1 (8.6–9.5)	29,115,532	9.6 (9.2–9.9)	4,836,096	8.6 (8.0–9.3)
7 AM–1 PM	66,438,607	29.3 (28.7–29.8)	35,134,727	26.5 (25.8–27.2)	86,333,024	28.4 (27.9–28.9)	15,240,310	27.3 (26.1–28.4)
1 PM–7 PM	77,826,349	34.3 (33.8–34.7)	45,346,929	34.2 (33.3–35.0)	104,196,725	34.3 (33.8–34.7)	18,976,553	33.9 (32.8–35.0)
7 PM–1 AM	59,271,844	26.1 (25.6–26.6)	38,056,521	28.7 (27.9–29.5)	81,871,063	26.9 (26.5–27.4)	15,457,302	27.6 (26.7–28.6)
Day of week								
Monday	34,584,840	15.2 (15.0–15.5)	20,192,902	15.2 (14.8–15.6)	45,876,533	15.1 (14.9–15.3)	8,901,209	15.9 (15.1–16.7)
Tuesday	33,169,267	14.6 (14.3–14.9)	18,503,462	13.9 (13.5–14.4)	43,652,980	14.4 (14.2–14.6)	8,019,749	14.3 (13.7–15.0)
Wednesday	31,956,653	14.1 (13.8–14.3)	18,549,359	14.0 (13.6–14.4)	42,394,057	14.0 (13.8–14.2)	8,111,955	14.5 (13.8–15.2)
Thursday	31,594,530	13.9 (13.7–14.2)	17,714,988	13.3 (13.0–13.7)	41,516,574	13.7 (13.5–13.8)	7,792,944	13.9 (13.3–14.5)
Friday	31,603,365	13.9 (13.7–14.2)	17,764,813	13.4 (13.0–13.7)	41,401,263	13.6 (13.4–13.8)	7,966,915	14.2 (13.6–14.9)
Saturday	31,792,795	14.0 (13.7–14.3)	19,824,215	14.9 (14.4–15.5)	44,146,942	14.5 (14.3–14.7)	7,470,068	13.4 (12.6–14.1)
Sunday	32,318,031	14.2 (14.0–14.5)	20,185,793	15.2 (14.8–15.6)	44,849,138	14.8 (14.5–15.0)	7,654,686	13.7 (13.0–14.4)
Season								
Winter	58,463,584	25.8 (22.9–28.6)	33,934,398	25.6 (22.5–28.6)	78,524,634	25.8 (23.0–28.7)	13,873,348	24.8 (21.6–28.0)
Spring	59,113,336	26.0 (23.3–28.8)	34,732,460	26.2 (23.3–29.1)	78,190,848	25.7 (23.0–28.5)	15,654,948	28.0 (24.8–31.2)
Summer	58,630,305	25.8 (23.2–28.5)	33,412,053	25.2 (22.4–27.9)	78,662,471	25.9 (23.2–28.6)	13,379,887	23.9 (21.1–26.7)
Fall	50,812,256	22.4 (19.6–25.2)	30,656,621	23.1 (20.1–26.1)	68,459,534	22.5 (19.7–25.3)	13,009,343	23.3 (20.0–26.5)
Mode of arrival								
Ambulance	47,896,843	21.1 (20.1–22.1)	8,102,162	6.1 (5.4–6.8)	47,909,565	15.8 (14.8–16.7)	8,089,440	14.5 (13.3–15.6)
Public service	3,930,837	1.7 (1.3–2.1)	2,290,889	1.7 (1.2–2.3)	4,662,566	1.5 (1.1–1.9)	1,559,160	2.8 (2.2–3.4)
Walk-in	164,160,873	72.3 (71.0–73.6)	113,891,930	85.8 (84.3–87.3)	236,455,085	77.8 (76.5–79.1)	41,597,718	74.4 (72.3–76.5)
Triage category								
<15 minutes	41,272,650	18.2 (16.5–19.9)	10,736,161	8.1 (6.9–9.3)	45,411,481	14.9 (13.5–16.4)	6,597,330	12.0 (10.4–13.2)
Within 15–60 minutes	96,674,390	42.6 (40.3–44.8)	39,984,876	30.1 (27.2–33.1)	117,502,648	38.7 (36.2–41.2)	19,156,618	34.3 (31.8–36.7)
Within 1–2 hours	40,157,070	17.7 (16.3–19.1)	36,752,195	27.7 (25.4–30.0)	65,414,499	21.5 (19.8–23.2)	11,494,766	20.6 (19.0–22.2)
Within 2–24 hours	14,441,800	6.4 (5.3–7.4)	19,135,392	14.4 (12.8–16.1)	27,499,180	9.1 (7.8–10.3)	6,078,012	10.9 (9.7–12.1)
Pain category								
None	42,478,283	18.7 (17.8–19.6)	29,034,581	21.9 (20.6–23.1)	54,887,068	18.1 (17.2–19.0)	16,625,796	29.7 (28.1–31.4)
Mild	27,233,933	12.0 (11.3–12.7)	18,436,289	13.9 (13.0–14.8)	38,811,689	12.8 (12.1–13.5)	6,858,533	12.3 (11.2–13.3)
Moderate	57,738,728	25.4 (24.3–26.6)	26,468,465	19.9 (18.5–21.4)	75,214,656	24.8 (23.5–26.0)	8,992,537	16.1 (14.8–17.3)
Severe	54,471,542	24.0 (22.7–25.3)	24,286,308	18.3 (16.9–19.7)	73,002,476	24.0 (22.6–25.4)	5,755,374	10.3 (9.3–11.3)
Seen by physician extender								
Yes	25,692,398	11.3 (9.7–12.9)	19,736,837	85.1 (83.1–87.1)	40,316,971	13.3 (11.5–15.0)	5,112,264	9.1 (7.7–10.6)
No	201,327,083	88.7 (87.1–90.3)	112,998,695	14.9 (12.9–16.9)	263,520,516	86.7 (85.0–88.5)	50,805,262	90.9 (89.4–92.3)
Seen by resident								
Yes	22,511,675	9.9 (8.1–11.7)	9,501,352	7.2 (5.8–8.5)	28,040,954	9.2 (7.5–10.9)	3,972,073	7.1 (5.7–8.5)
No	204,507,806	90.1 (88.3–91.9)	123,234,180	92.8 (91.5–94.2)	275,796,533	90.8 (89.1–92.5)	51,945,453	92.9 (91.5–94.3)
Disposition								
AMA or LWBS	3,147,601	1.4 (1.2–1.6)	9,275,107	7.0 (6.2–7.7)	2,312,232	0.8 (0.7–0.8)	10,110,476	18.1 (16.6–19.6)
Died in ED	157,757	0.1 (0.0–0.1)	212,259	0.1 (0.1–0.2)	258,746	0.1 (0.1–0.1)	111,270	0.2 (0.1–0.3)
Discharged	169,056,108	74.4 (73.1–75.7)	117,841,478	88.6 (87.5–89.7)	249,253,438	81.9 (80.9–83.0)	37,644,148	67.1 (65.1–69.1)
Transferred	5,424,324	2.4 (2.1–2.7)	724,618	0.5 (0.4–0.7)	4,800,514	1.6 (1.3–1.8)	1,348,428	2.4 (2.0–2.8)
Admitted	47,846,002	21.1 (19.8–22.4)	3,050,863	23.0 (18.8–27.2)	45,030,774	14.8 (13.8–15.9)	5,866,091	10.5 (9.1–11.9)

Table 1
(*Continued*)

	Test Obtained (*n* = 65,586)	Proportion of Visits, % (95% CI)	Test Not Obtained (*n* = 39,887)	Proportion of Visits, % (95% CI)	Treatment Provided (*n* = 88,624)	Proportion of Visits, % (95% CI)	Treatment Not Provided (*n* = 16,849)	Proportion of Visits, % (95% CI)
Hospital characteristics								
Hospital location								
Urban	192,945,437	85.0 (77.5–92.4)	110,676,658	83.4 (75.2–91.6)	255,540,076	84.1 (76.3–91.9)	48,082,019	86.0 (78.7–93.3)
Rural	34,074,044	15.0 (7.6–22.5)	22,058,874	16.6 (8.4–24.8)	48,297,411	15.9 (8.1–23.7)	7,835,507	14.0 (6.7–21.3)
Region								
Northeast	42,444,100	18.7 (16.1–21.3)	25,238,044	19.0 (16.3–21.8)	56,468,338	18.6 (16.1–21.1)	11,213,806	20.1 (16.5–23.6)
Midwest	49,905,438	22.0 (18.0–25.9)	27,896,272	21.0 (16.6–25.5)	65,952,249	21.7 (17.8–25.7)	11,849,461	21.2 (16.1–26.3)
South	93,256,476	41.1 (36.5–45.7)	54,251,911	40.9 (36.1–45.7)	124,940,399	41.1 (36.6–45.7)	22,567,988	40.4 (35.0–45.7)
West	41,413,467	18.2 (13.9–22.6)	25,349,305	19.1 (14.6–23.6)	56,476,501	18.6 (14.1–23.1)	10,286,271	18.4 (14.4–22.4)
Hospital type								
Teaching	119,518,542	52.6 (47.8–57.5)	68,633,814	51.7 (46.8–56.7)	158,661,318	52.2 (47.3–57.2)	29,491,038	52.7 (47.9–57.6)
Nonteaching	107,500,939	47.4 (42.5–52.2)	64,101,718	48.3 (43.3–53.2)	145,176,169	47.8 (42.8–52.7)	26,426,488	47.3 (42.4–52.1)
Hospital ownership								
Nonprofit	172,328,652	75.9 (71.1–80.7)	98,029,712	73.9 (68.6–79.1)	228,085,819	75.1 (70.1–80.0)	42,272,545	75.6 (70.5–80.7)
Government	29,783,584	13.1 (9.6–16.6)	18,814,117	14.2 (10.5–17.9)	40,816,088	13.4 (9.9–17.0)	7,781,613	13.9 (10.1–17.7)
For profit	24,907,245	11.0 (7.1–14.8)	15,891,703	12.0 (7.8–16.2)	34,935,580	11.5 (7.4–15.6)	5,863,368	10.5 (6.9–14.1)

AMA = against medical advice; LWBS = left without being seen.
*Based on study population of 105,473 ED visits, weighted to produce national estimates which are presented. All differences are statistically significant at a level of $p < 0.001$ due to the large database. Percentages may not add to 100 due to rounding and/or missing data. Test refers to ED visit during which any test (blood test, urinalysis, ECG, radiograph, US, CT, MRI) was performed. Treatment refers to ED visit during which either a medication was provided or a procedure performed.

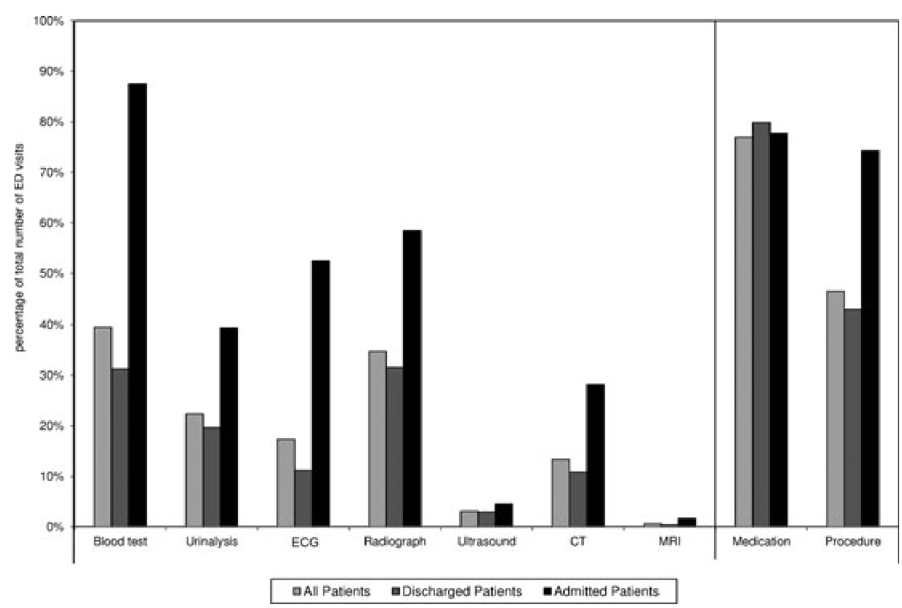

Figure 2. Diagnostic tests and treatment during ED visits by disposition over the study period 2006–2008. CT = computed tomography; ECG = electrocardiogram; MRI = magnetic resonance imaging.

Similar to the results of the logistic regression model, the GLM also demonstrated that diagnostic tests were associated with longer LOS than treatments. Table 2 shows the adjusted average marginal effects of different diagnostic testing and treatment modalities. Most testing modalities affected overall LOS to a greater degree than treatment, with blood tests and advanced imaging having the largest effect. The contribution of testing to ED LOS was exerted differentially on patients who were ultimately discharged compared to those who were admitted (Table 2). In general, testing tended to prolong the LOS of discharged patients more than it did that of admitted patients. For example, the average marginal contribution of blood testing to the LOS of a discharged patient was +71 minutes (95% CI = 65 to 77 minutes), while for an admitted patient it was +25 minutes (95% CI = −17 to 67 minutes).

In comparison, treatment had less of an effect on LOS. In Table 2, the adjusted marginal effects for performing a procedure and for providing a medication were significantly less than for most testing modalities. However, for admitted patients, administration of medications influenced LOS more significantly.

DISCUSSION

We found a significant effect of diagnostic testing on ED LOS, while treatment had only modest overall

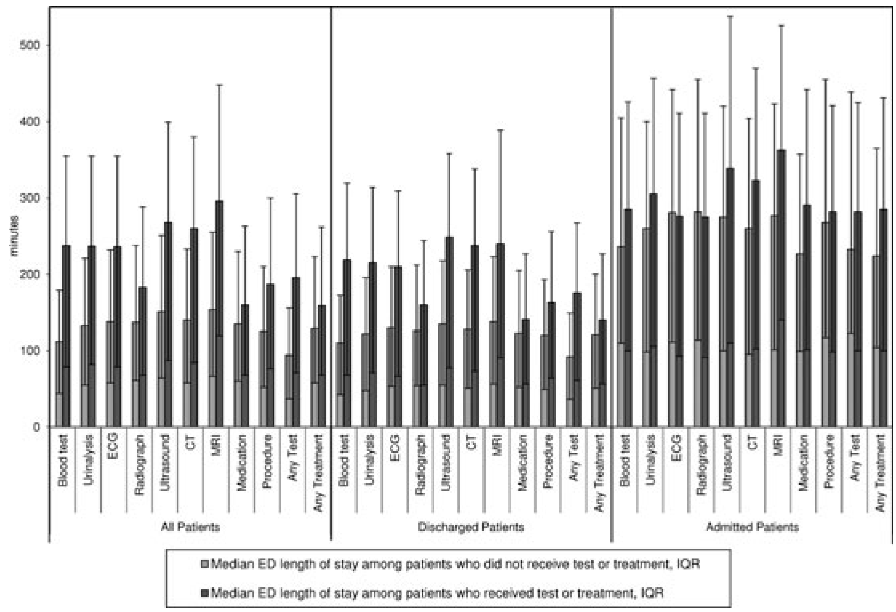

Figure 3. ED visit LOS by diagnostic test, treatment, and disposition. CT = computed tomography; ECG = electrocardiogram; IQR = interquartile range; LOS = length of stay; MRI = magnetic resonance imaging.

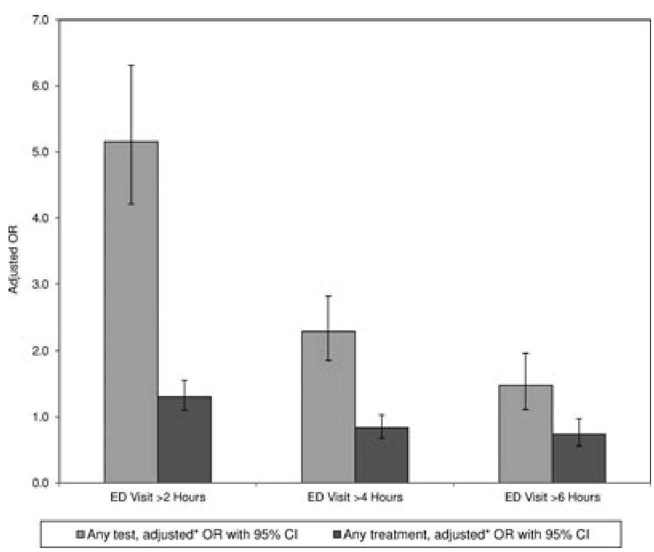

Figure 4. Adjusted odds of experiencing a longer length of ED visit by diagnostic testing and treatment. *Adjusted for year of study, age, sex, race, ethnicity, insurance, arrival time, wait time, day of visit, season, mode of arrival, triage category, pain category, if seen by physician extender, if seen by resident, disposition, hospital location, hospital region, teaching hospital, hospital ownership, if any test obtained, and if any treatment performed.

Table 2
Additional Length of ED Visit Associated with Testing and Treatment by Disposition*

	Overall, Minutes (95% CI)	Discharged Patients, Minutes (95% CI)	Admitted Patients. Minutes (95% CI)
Testing			
Blood test	72 (66 to 78)	71 (65 to 77)	25 (−17 to 67)
MRI	64 (36 to 93)	80 (42 to 118)	50 (2 to 99)
CT	59 (54 to 65)	60 (55 to 65)	51 (32 to 69)
Ultrasound	56 (45 to 67)	58 (47 to 69)	24 (−11 to 59)
Urinalysis	32 (26 to 38)	33 (27 to 40)	29 (10 to 47)
Radiograph	27 (22 to 31)	27 (23 to 30)	7 (−18 to 32)
ECG	12 (6 to18)	14 (9 to 19)	−4 (−22 to 14)
Treatment			
Procedure	24 (20 to 28)	23 (19 to 27)	7 (−18 to 32)
Medication	15 (8 to 21)	12 (7 to 17)	59 (33 to 84)

CT = computed tomography; ECG = electrocardiogram; MRI = magnetic resonance imaging.
*Presented as the adjusted average marginal effects in minutes on length of visit with 95% CI compared to no testing or treatment. Adjusted for year of study, age, sex, race, ethnicity, insurance, arrival time, wait time, day of visit, season, mode of arrival, triage category, pain category, if seen by physician extender, if seen by resident, disposition, hospital location, hospital region, teaching hospital, hospital ownership, specific types of tests obtained (blood test, urinalysis, ECG, radiograph, ultrasound, CT, MRI), and specific treatment provided (medication or procedure).

effect. Blood tests and advanced imaging had the largest effects, with these services each adding more than 50 minutes to the average ED encounter. Given the large numbers of patients being evaluated annually in EDs with diagnostic testing, this finding has implications for operations management in the hospital. For example, in this study, almost 40% of all ED patients received blood testing and more than 13% received a CT scan, suggesting that systems to streamline the use of these common tests in the ED may be useful in diminishing crowding. By comparison, treatment with a medication or procedure had only a small effect on an individual's ED LOS. An additional finding of our study was that the burden of the effect from testing activity fell more heavily on discharged patients than admitted patients, in part because LOS is greater for admitted patients who are subject to pressures external to the ED such as boarding. Discharged patients make up the bulk of all ED patients, constituting of about 85% over the period 2006 to 2008 in NHAMCS, also suggesting the importance of a patient's disposition when evaluating ED throughput processes.

Testing and treatment are integral and essential aspects of the ED evaluation. As our nation's EDs accept a larger and larger role in managing acutely ill patients, diagnostic testing in particular will only continue to expand as more definitive care is delivered in this setting. Increasingly, EDs are becoming diagnostic centers, with patients referred to the ED for rapid evaluation to determine if hospital admission is necessary. It is therefore critical to understand how and under what conditions testing might negatively affect patient flow in the ED to design systems to improve throughput efficiency. This is a particular worry for the ED where the widespread and increasing availability of diagnostic testing, such as CT scanners, creates minimal barriers for its use[23] and potentially means lower thresholds for obtaining tests. For example, there is evidence demonstrating growing use of advanced imaging in the ED, particularly for CT.[24–26] As shown in our study, advanced imaging modalities are especially time-costly on ED LOS. The increasingly longer median LOS in our nation's EDs documented in previous studies[11,12] may therefore in part be related to increased volume of testing being performed during patient evaluations.

In addition, we found that blood testing had similar effects on LOS as some types of advanced imaging. This result may seem surprising, but was likely related to the model's adjustments for ED visit characteristics such as markers of illness severity and other associated testing and treatment modalities performed during the visit. Blood testing was more commonly performed than any other diagnostic modality during ED evaluations and was often done in isolation as the only diagnostic testing modality during a visit, thereby contributing more significantly to LOS in those cases. While a CT or MRI certainly adds significantly to an ED visit, there were often many other factors influencing total LOS in patients undergoing those particular studies.

In our study, discharged patients tended to have their ED LOS affected more significantly by the testing performed during their visits. This result was likely related to two factors: 1) admitted patients' LOS depend substantially on inpatient hospital factors—such as the availability of beds—to determine when they leave the ED, as opposed to discharged patients who do not face this same constraint; and 2) the standard ED practice pattern in which results from laboratory tests and procedures are finalized before the decision is made to discharge a patient from the ED. In contrast, waiting for the results of all tests for patients who are destined to be admitted is not always done. In both cases, the marginal contribution of testing and treatment to LOS will be more likely to affect discharged patients compared to admitted patients, especially as discharged patients tend to have much shorter LOS than admitted patients. Therefore, reducing time costs related to testing and treatment in the presence of long waits for admission will not have as great an effect for admitted patients in comparison to discharged patients.

We see several next steps as necessary to better understand the implications of our findings. First, there has already been significant emphasis on improving ED operations and throughput to improve patient flow.[4,7] Timeliness of care has been strongly correlated to patient satisfaction in the ED.[1,2] Given the effect that diagnostic testing has on ED LOS, this area is potentially ripe for system and process improvements. For example, one of the time costs associated with obtaining a CT scan is the need to provide oral contrast, typically adding 1 to 2 hours to the preparation time prior to scanning[27] and affecting ED LOS.[28] There is evidence supporting the use of noncontrast or IV contrast only CTs for the evaluation of patients with appendicitis,[29–32] a common indication for obtaining an abdominal CT in the ED. As a result, many institutions have already eliminated the routine use of oral contrast for abdominal CT scans performed in the ED.[28] If such protocols are created that still provide for the necessary diagnostic information but allow for quicker scans to be accomplished, this may improve the LOS for individual patients requiring these studies. Another solution may be incorporating point-of-care testing to reduce laboratory turnaround times, which has been shown to improve LOS in certain patient populations.[33] Adopting such protocols may allow for improved diagnostic testing throughput times and decrease testing's effect on LOS.

Second, further research is needed to determine the extent to which diagnostic testing in the ED leads to downstream improvements in resource utilization such as hospitalization decisions and clinical outcomes in the ED. Diagnostic testing may contribute to longer ED LOS, but is also influencing the emergency physician's decision-making regarding admissions and care delivery. Testing, particularly with more time-costly advanced imaging such as CT, MRI, and US, may avoid hospitalization in certain patients if it allows ED providers to diagnose or exclude concerning disease processes.[26] If this testing pattern has developed in the ED, then perhaps longer LOS are acceptable if the return on the investment results in hospitalization savings. Testing and treatment may also be contributing to better patient outcomes, and the downsides of prolonging LOS need to be balanced against the potential for earlier diagnosis, timelier care delivery, and improved health.

LIMITATIONS

Our study should be interpreted in the context of several limitations. There are many factors that may affect ED LOS not measured in the NHAMCS database, including important input, throughput, and output features.[34] For example, NHAMCS is not linked to inpatient hospital administrative data. It has been shown that inpatient level processes, such as the number of elective surgical admissions and hospital occupancy, can affect the LOS for admitted ED patients.[35–37] In addition, input factors such as the number and volume of patients arriving to the ED for evaluation, or throughput factors such as the current state of crowding in the ED at the time of evaluation, are likewise not recorded in NHAMCS. These specific features also would not be accounted for in the multivariable modeling. We attempted to control for some of these factors by including time of ED arrival, day of the week, and season, which may help adjust for some causes of fluctuation in inpatient census.

The NHAMCS also represents national estimates of the effect of testing and treatment on LOS. Therefore, an individual ED's results may not reflect the national experience. In addition, there may be significant daily variability in patient LOS during an ED visit, depending on the setting and local environment, as well as variability in test performance at different EDs. This study represents a general overview of test and treatment performance on a national scale using composite measures for some modalities, suggesting the most time-costly types of testing, and a priority for which might provide the most significant time savings. However, in a local application of these findings, it would be important to look at the actual test performance for the individual institution to determine the likely bottleneck to better address the problem and make improvements to ED throughput efficiency. In addition, some ED testing and treatment is done sequentially in which one test result informs the ordering of an additional test or the performance of a treatment. This database does not allow for the modeling of these scenarios, which may affect the reported time costs contributed by specific tests or treatments. Finally, given the retrospective nature of the database, this study cannot assess the appropriateness of testing or treatment being performed during these visits, which is an important quality of care consideration when evaluating the effect of these activities on ED LOS.

CONCLUSIONS

Testing and treatment are important contributors to length of stay in the ED and should be a factor in the analysis of patient throughput and potential causes of ED crowding. We found that diagnostic testing, especially due to blood tests and advanced imaging, can significantly prolong length of stay. This knowledge may better direct efforts at streamlining delivery of care for the most time-costly diagnostic modalities or suggest areas for future research into improving processes of care. Development of innovative ED operations is needed to ameliorate testing's effect on length of stay while also determining how testing can be better optimized for use in this setting. Efficient utilization of these services in the ED may improve patient and provider satisfaction. Such practice improvements could then be examined to determine their effect on ED crowding.

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