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RESEARCH ARTICLE

Health Information Technology Adoption in the Emergency Department

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Objective. To describe the trend in health information technology (IT) systems adoption in hospital emergency departments (EDs) and its effect on ED efficiency and resource use.

Data Sources. 2007–2010 National Hospital Ambulatory Medical Care Survey – ED Component.

Study Design. We assessed changes in the percent of visits to EDs with health IT capability and the estimated effect on waiting time to see a provider, visit length, and resource use.

Principal Findings. The percent of ED visits that took place in an ED with at least a basic health IT or an advanced IT system increased from 25.2 and 3.1 percent in 2007 to 69.1 and 30.6 percent in 2010, respectively ($p < .05$). Controlling for ED fixed effects, waiting times were reduced by 6.0 minutes in advanced IT-equipped EDs ($p < .05$), and the number of tests ordered increased by 9 percent ($p < .01$). In models using a 1-year lag, advanced systems also showed an increase in the number of medications and images ordered per visit.

Conclusions. Almost a third of visits now occur in EDs with advanced IT capability. While advanced IT adoption may decrease wait times, resource use during ED visits may also increase depending on how long the system has been in place. We were not able to determine if these changes indicated more appropriate care.

Key Words. Information technology in health, ambulatory care, hospital emergency departments

Proponents of health information technology (IT) suggest that hospital emergency departments (EDs) are uniquely positioned to benefit from an electronic patient management system. Health IT in EDs could allow clinicians to have access to patient information from other providers, improve clinical decision support for complicated cases, and substitute electronic medication and test ordering for time-consuming, paper-based systems. These attributes may improve ED efficiency, reducing the time needed to spend with a

provider or wait for test results (Feid, Smith, and Handler 2004; Landman et al. 2010).

On the other hand, there has been little evidence to support any apparent efficiency gains, and some observers fear possible efficiency losses at least in the short term as providers adjust to accessing and recording information in the new system. Moreover, health IT adoption could result in an increase in treatment intensity since it reduces the effort required to order diagnostic testing and interventions. Recent empirical evidence suggests that health IT implementation may result in higher resource use in hospital inpatient departments and physician offices, and by extension, higher costs (Agha 2012; McCormick et al. 2012).

Knowing how health IT affects efficiency is important since there has been a substantial push for EDs and other ambulatory care settings to adopt health IT. In 2009, the American Recovery and Reinvestment Act provided for financial incentives to adopt “meaningful use” of health IT and reduce Medicaid and Medicare payments if adoption does not take place by 2014 (Blumenthal 2009). Because of this push, it is important to assess whether adoption rates have increased or if the presence of health IT is resulting in observable benefits. Available studies examining the impact of health IT in the ED show lagging adoption rates, though there is some evidence of increased efficiency and quality in EDs that have adopted (Daniel et al. 2010; Schapiro et al. 2010; Handel et al. 2011). However, the scope of the literature has been limited to examining a single year or a limited sample of EDs.

This paper used nationally representative data to examine changes in the percent of visits to EDs with health IT capability between 2007 and 2010. We assessed the distribution of ED visits by health IT capability using thresholds to define basic and advanced IT systems that have been previously defined in the literature for ambulatory care settings (DesRoches et al. 2008). We also examined, at the visit level, which ED and hospital characteristics are associated with health IT capability in 2010. Finally, we assessed whether health IT adoption resulted in changes in various performance and resource-use measures associated with ED visits, such as waiting time, length of visit, and number of tests ordered. Because the design of our dataset is comprised of a set of EDs contacted over time, we were able to control for ED fixed effects,

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allowing us to control for any association between IT adoption and potentially unobserved confounders at the ED level.

DATA AND METHODS

Data Source

Our data are from the 2007 to 2010 ED component of the National Hospital Ambulatory Care Survey (NHAMCS). This survey is conducted annually by the Centers for Disease Control and Prevention's National Center for Health Statistics (NCHS). The NHAMCS collects data on a nationally representative sample of visits to hospital outpatient departments and EDs of non-Federal, short-stay general, or children's general hospitals and uses a multistage probability sample design that is described elsewhere (McCaig and McLemore 1994).

The NHAMCS selects a sample of 550 ED-equipped hospitals using the Healthcare Market Index and Hospital Market Profiling Solution datasets from Verispan, LLC. A subset of this sample is selected each year to participate in the NHAMCS-ED. Each hospital in this subset is randomly assigned to 1 of 16 four-week reporting periods and rotates each year. Each ED within this subset is sampled approximately once every 15 months. As a result, some EDs are observed at least once in each year of our analysis, and most are observed at least three times during the study period. Each sampled ED is anticipated to provide 100 visits per period.

The NHAMCS includes measures of ED efficiency (e.g., waiting time and length of visit) and resource use during visits (e.g., number of tests and images ordered), as well as many characteristics of patients and patient visits, including patient's age, gender, and race/ethnicity, primary expected source of payment, and up to three diagnoses related to the visit. These diagnoses are coded according to the International Classification of Diseases–9th Revision–Clinical Modification (ICD-9-CM). The original NHAMCS-ED survey data from 2007 to 2010 consisted of 138,813 visits to 460 EDs. We dropped 23,995 (17 percent of visits) due to missing information on waiting time or length of visit. We describe below how we tested the sensitivity of our results to this exclusion. We dropped another 7,978 (6 percent of visits) due to missing information on other variables used in the analysis. Finally, we omitted information on 1,131 visits from 18 EDs due to the ED having fewer than 90 visits in our sample. Our final sample consisted of 105,709 visits to 442 different EDs.¹

Measures of Health IT Capability and Other Variables

In 2005, the NHAMCS began collecting data on a variety of individual components of health IT available in the ED. Additional components used in this analysis were added in 2007. We grouped 12 of these individual components into health IT categories that made them consistent with the expectations of meaningful use set by the Office of the National Coordinator for Health Information Technology (DesRoches et al. 2008; Jha et al. 2009; Decker, Jamoom, and Sisk 2012). As done in DesRoches et al. (2008), we identified EDs as having one of two alternative threshold levels of health IT capability. The first threshold level, called a basic system, consists of having a minimum set of components that could affect patient care. These components are the ability to record patient demographics, patient problem lists, patient laboratory results, physician prescription ordering, and the ability to record clinical notes. The second threshold level of adoption is considered to have been reached if an ED also had decision-support and order-execution components (the advanced system). These components are drug interaction warnings, clinical decision support, highlighting out-of-range laboratory values, test ordering, and the electronic transmission of test orders or prescriptions to the laboratory or pharmacy, respectively.

ED health-IT data were collected in the NHAMCS each time the ED was selected for survey participation. In some cases, the respondent providing these data indicated that the presence of a certain component was unknown. If the survey indicated in a previous period that the component was or was not in place, we substituted the unknown response with the last observed response.

This article examined the effect of health IT adoption (either basic or advanced) on measures of ED efficiency and resource use. For our efficiency measures, we used the length of time (in minutes) to see a provider (waiting time) and length of visit (after seeing a provider). For our measures of resource use, we used number of medications prescribed (up to 8), number of laboratory tests ordered (up to 12),² and the number of images ordered (up to 5).³ Control variables included hospital teaching status and location in an urban or rural setting, both of which have been identified in the literature as being related to health IT adoption and the selected outcomes of interest (Jha et al. 2009; Landman et al. 2010; Decker, Jamoom, and Sisk 2012). We also included a control for the natural logarithm of ED annual visit volume, as higher volumes in a given year may be associated with higher wait and visit times. The patient/visit-level controls included patient age, gender, race, pri-

mary expected source of payment, whether the patient is from a ZIP code that had more than 20 percent of households below the poverty line in the 2000 census, whether the patient was seen in the ED for an injury, whether the patient was seen by a resident, immediacy of condition,⁴ number of diagnoses, and controls for the patient's reason for visit.⁵ We also included an indicator variable for whether the patient was discharged home because some of our outcomes may be influenced by inpatient bed availability.

Analysis of Changes in Health IT Capability over Time

We first assessed changes in the level of ED health-IT capability over time by comparing the percent of ED visits in which a basic or advanced IT system was adopted between 2007 and 2010. Because health IT adoption may vary across observed and unobserved ED characteristics, we examined whether visits were more or less likely to take place at EDs with several different observed characteristics using the 2010 sample. These characteristics included ED visit volume, hospital teaching status, and whether the ED was located in an urban or rural setting. For characteristics with more than two categories, we compared the level of IT adoption in each category to a reference category. We used two-tailed *t*-tests to test for differences in adoption across years and ED/hospital characteristics. Lastly, since our fixed effects models described below identify the effect of health IT adoption on visit-level outcomes from EDs that switch health IT status during the study period, we assessed the degree of switching of health IT status that occurred in EDs between 2007 and 2010. Specifically, ED visits (and EDs) were assigned to one of four categories: (1) never adopting a health IT system that meets the basic criteria during the sample period, (2) beginning with a basic or advanced system and remaining the same throughout, (3) switching from having a less-than-basic system to adopting a basic system, and (4) switching from having a less-than-basic system or a basic system to adopting an advanced system. The last category includes those EDs that went from having a less-than-basic health IT system to having a basic system and then adopting an advanced system.

Analysis of the Effect of Health IT on Measures of ED Efficiency and Resource Use

We also assessed whether health IT adoption was associated with a variety of measures of efficiency and resource use. Our specifications took on the following general form:

$$Y_{iet} = \beta_0 + \beta_1 HIT_{et} + \beta_3 X_{iet} + \alpha_e + z_t + \varepsilon_{iet}$$

where Y_{iet} was the outcome of interest for visit i at ED e and time t . Because it is unclear where the threshold of adoption of IT features is for observing effects on patient care, we estimated two separate models in the same manner as DesRoches et al. (2008). In our initial regression, HIT was an indicator variable for whether the ED's health IT system at least met the criteria for a basic system in ED e at time t . In separate regressions, the HIT variable indicated whether the ED met the advanced system criteria. Other controls, X , included controls at the patient, visit, or ED level. Since adoption of health IT systems (and patient outcomes) may vary by unobserved, as well as observed, hospital- or ED-level characteristics, we estimated the above models replacing the controls that varied only by ED/hospital (i.e., teaching status and urban/rural location) with ED fixed effects. We report both sets of health IT marginal effects and test whether the effects in the nonfixed-effect and fixed-effect models are statistically significantly different from each other. Although our main tables only show the estimated effects of health IT adoption on outcomes, Tables S2 and S3 are provided to show all of the parameter estimates used to estimate the fixed-effect models for basic and advanced health IT adoption.

The effect of basic and/or advanced health IT adoption on (1) time waiting to see a provider and (2) length of visit was estimated using a generalized linear model (GLM) assuming a gamma distribution and a log-link function. A zero-inflated Poisson regression was used to estimate parameters for the number of medications prescribed, number of laboratory tests ordered, and number of images ordered. For ease of interpretation, we reported the marginal effects and their standard errors.

Because implementation of health IT into the ED patient-care process would have required a transition period and steady state effects on efficiency or resource use would not have occurred until providers and staff had acclimated to the system, we estimated models that replaced indicators for whether an ED had a basic or advanced system in place with indicators for whether these systems had been in place for at least a year. For this analysis, we dropped all observations for 2007 and some from 2008 so that visits were observed for each ED in at least 2 years, resulting in a reduced sample size of 70,135 visits.

Standard errors in all analyses were adjusted to account for the survey's stratified cluster design, and survey weights were used, yielding nationally representative estimates. Estimates were considered statistically significant at $p < .10$, though we indicate whether estimates are statistically significant at the

10, 5, or 1 percent level. We also perform two sets of sensitivity analyses. First, although we follow previous literature (DesRoches et al. 2008) and report alternative health IT thresholds (basic and advanced), we test the sensitivity of our results to defining three mutually exclusive categories of adoption (less than basic, basic, and advanced) rather than to two alternative thresholds of adoption (basic and advanced). Second, we assessed whether the estimated effect of health IT adoption on outcomes was different for samples including and not including imputed values.⁶ If the missingness in the wait and visit time variables were random, use of the fuller sample (with 135,236 observations) should not have changed the value of the parameter estimates in our models.

RESULTS

Health IT Adoption

Table 1 shows the increase in the percent of visits that occurred in EDs with at least a basic or an advanced system between 2007 and 2010. In 2007, 25.2 percent of visits occurred in EDs that had at least a basic level of health IT. About 3.1 percent of visits occurred in EDs with advanced IT capability. By 2010, 69.1 percent of visits occurred in EDs with at least basic system capability ($p < .001$), while nearly one-third (30.6 percent) of visits occurred in EDs with advanced health IT capability. In 2010, visits were more likely to take place in EDs with some form of health IT system if they took place in large, urban EDs that were part of a teaching hospital (Table 2). For example, about 54 percent of visits to EDs that were part of a teaching hospital had access to an advanced IT system compared to only 26 percent of visits to EDs that were not part of a teaching hospital.

Table 3 presents separately the ED and visit-level samples by “health IT switching status” during the 2007–2010 time period. Over half of the visits in our sample took place in an ED that switched status (less than basic, at least a basic system, advanced system) during the 2007–2010 time period, providing ample variation in IT status within EDs over time for our ED fixed-effect models. Among the visits to EDs that switched status during the study period, about half took place in EDs that switched from less than basic to basic, and the other half took place in EDs that switched to advanced systems (from either basic or less than basic). The majority of visits to EDs that did not switch IT status during the study period took place in EDs with less than a basic system.

Table 1: Percent of Visits by Health Information Technology Category over Time

	2007	2008	2009	2010
Has at least				
Basic system	25.2 (3.6)	50.0 (3.3)	61.6 (4.4)	69.1 (3.7)***
Advanced system	3.1 (1.1)	12.7 (2.4)	20.3 (3.3)	30.6 (3.3)***

Notes. This table presents weighted means expressed as percents. The overall sample size is 105,709 visits. Sample sizes are 24,314, 24,356, 28,063, and 28,796 visits for 2007, 2008, 2009, and 2010, respectively. Standard errors are in parentheses. Differences in the means for “at least basic system” and “advanced system” for 2007 and 2010 were tested using a *t*-test.

The symbol *** indicates that the value is statistically significantly different at the 10%, 5%, and 1% levels, respectively.

Source: National Hospital Ambulatory Medical Care Survey—Emergency Department 2007–2010.

Table 2: Percent of Visits by Health Information Technology Adoption Level and Selected Hospital and Emergency Department Characteristics, 2010

	Less Than Basic System	Basic System	Advanced System
ED visit volume			
≤20,000 (Ref.)	60.0 (5.6)	30.4 (6.1)	9.6 (3.2)
20,001–40,000	38.3 (7.4)**	41.6 (7.8)	20.1 (4.4)**
40,001–60,000	26.7 (6.2)***	35.9 (7.5)	37.3 (7.3)***
>60,000	12.0 (4.5)***	42.9 (5.8)	45.0 (5.9)***
Teaching status			
Nonteaching (Ref.)	33.9 (4.0)	39.8 (4.0)	26.3 (3.7)
Teaching	14.5 (5.7)***	31.6 (6.6)	53.9 (7.6)***
Urbanicity			
Rural (Ref.)	57.8 (7.3)	28.9 (8.5)	13.4 (4.9)
Urban	25.1 (3.8)***	40.5 (3.7)	34.3 (3.7)***

Notes. This table presents weighted percents of visits. ED visit volume is on an annual basis.

The symbols ** and *** indicate that the value is statistically significantly different (based on a *t*-test) at the 10%, 5%, and 1% levels from the reference group, respectively. “Ref.” indicates the reference group. Standard errors are in parentheses. Sample size is 28,976 visits.

Source: National Hospital Ambulatory Medical Care Survey—Emergency Department, 2010.

The Effect of Health IT Capability on Measures of ED Efficiency and Resource Use

We considered whether basic or advanced health IT capability affects wait time, visit length, or measures of resource use during an ED visit. The average visit had a patient wait time of 55.11 minutes to see a provider, and the average length of visit with the provider was 149.53 minutes. On the resource-use

Table 3: Health Information Technology Adoption in the Emergency Department 2007–2010

	<i>Percent of Visits</i>	<i>Percent of Emergency Departments</i>
Switchers		
Switched from less than a basic to basic system	27.1 (2.8)	26.1 (3.4)
Switched from less than a basic or basic system to an advanced system	27.1 (2.6)	20.4 (2.7)
Nonswitchers		
Less than basic system throughout the sample period	27.3 (2.7)	40.0 (4.4)
Began with basic or advanced system and remained throughout the sample period	18.3 (1.7)	13.4 (2.1)

Notes. Switching indicates that the emergency department was observed obtaining the health IT component during the period of analysis. The last category includes those hospitals that switched from none to basic and then switched to an advanced system. The total number of unweighted visits and hospitals is 105,709 and 442, respectively. Standard errors are in parentheses.
Source: National Hospital Ambulatory Medical Care Survey—Emergency Department 2007–2010.

side, patients at the average visit were prescribed 2.07 medications and had 1.72 laboratory tests performed. An average of less than one imaging study was performed per visit.

The first two rows in Table 4 show the marginal effects of having had at least a basic IT system (relative to less than basic) on each of the selected outcome variables. Although we mostly discuss our results with ED fixed effects, the fact that results are different for models with and without ED fixed effects implies that hospitals that adopt health IT systems may have unobserved attributes that are correlated with our measures of resource use and efficiency in EDs. In models estimating the effect of basic health IT adoption on outcomes, we find only that adoption increases the number of tests ordered, an estimate that is significant at the 10 percent level. However, when considering the effect of adoption of an advanced system, results imply that adoption is associated with an increase in the number of tests of 0.15 ($p < .01$), a 9 percent increase relative to the mean of 1.68 tests ordered among visits to EDs without an advanced system. We also find that waiting time to see a physician was 5.99 minutes less in EDs equipped with an advanced health IT system versus those that were not ($p < .05$). This represents about an 11 percent decrease relative to the mean waiting time of 54.39 minutes among visits to EDs without an advanced system. As stated above, we performed two sets of sensitivity

Table 4: The Effect of Health Information Technology on Selected Emergency Department Utilization Measures

	Time to See a Physician	Length of Visit	Number of Medications Prescribed	Number of Tests Ordered	Number of Images Ordered
At least basic system					
With hospital fixed-effects	-3.3182 (2.4784)	-2.5130 (3.7204) ^{††}	-0.0171 (0.0430)	0.0866* (0.0471)	0.0003 (0.0097)
Without hospital fixed-effects	-1.5142 (2.1507)	5.8853* (3.4205)	0.0047 (0.0627)	0.0915* (0.0539)	0.0030 (0.0104)
Advanced system					
With hospital fixed-effects	-5.9904 (2.7930) ^{***,††}	6.9952 (4.7997)	-0.0126 (0.0431)	0.1493 (0.0576) ^{***,†}	-0.0144 (0.0123)
Without hospital fixed-effects	0.2554 (2.6817)	12.8814 ^{***} (4.5204)	-0.0311 (0.0515)	0.0347 (0.0596)	0.0040 (0.0114)
Mean of dependent variable among visits to EDs without a basic system	51.76	135.96	2.02	1.60	0.56
Mean of dependent variable among visits to EDs without an advanced system	54.39	143.86	2.06	1.68	0.57

Notes. Estimates for wait time and length of visit are marginal effects from a generalized linear model under a gamma distribution with a log-link. Estimates for number of medications, tests, and images are marginal effects computed using a zero-inflated Poisson regression. Sample size is 105,709 visits. Controls included but not shown are age, gender, race, insurance status, whether the patient was discharged home, seen for an injury, seen by a resident, the log of the ED's annual visit volume, number of diagnoses, whether more than 20% of households in the patient's ZIP code were below poverty, immediacy of condition, year effects, and quintile controls for reason for visit. The nonfixed-effect regressions also include controls for urban and teaching status. Tables S2 and S3 list the full set of marginal effects.

The symbols *, **, *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively. The symbols [†] and ^{††} indicate a statistically significant difference between the fixed-effect coefficient and its nonfixed-effect counterpart at the 10% and 5% levels, respectively.

analyses. First, we estimated all of our fixed-effect models using imputed data for wait time and length of visit. Our marginal effect estimates using the larger sample were largely consistent with the ones in Table 4 (results available upon request). We also considered an alternative definition of health IT adoption that considers three mutually exclusive categories of health IT adoption (less than basic, basic, and advanced). The p-value on the wait time dependent variable is still less than 5 percent and the effect on number of tests at less than the 1 percent level (see Table S4).

Lagged adoption estimates are reported in Table 5. The first two rows, which show the marginal effects of having a basic system for at least a year, no longer showed a positive, statistically significant effect on the number of tests ordered. Lagged basic-system adoption did not have a statistically significant effect on any of our outcome measures. On the other hand, our fixed-effect results show that the negative effect of advanced health IT adoption on waiting time to see a physician persists more than a year after adoption ($p < .01$) and that the number of medications, tests, and images ordered increased by 0.17 (8 percent relative to visits to EDs without an advanced system), 0.13 (8 percent), and 0.04 (7 percent), respectively.⁷

DISCUSSION

To our knowledge, this article is the first to look at health IT capabilities and adoption in a national sample of EDs over a multiyear period. We found that the percent of visits seen in an ED with at least a basic health IT system more than doubled from 25 percent in 2007 to 69 percent in 2010 and the percent of visits seen in an ED with an advanced system increased 10-fold from 3 to 31 percent. ED located in urban areas, in teaching hospitals, and those having higher visit volumes were more likely to have met the criteria for an advanced health IT system than EDs located in rural areas, in nonteaching hospitals, and with lower visit volumes, respectively. Our analysis updates previous reports on IT adoption among EDs prior to 2007 (Landman et al. 2010) and studies based only on EDs in certain states (Pallin et al. 2011).

The efficiency and resource effects that we find resulting from health IT adoption in our fixed-effects specifications suggest that (1) there may be no observable effects of basic health IT adoption on efficiency or the number of medications or images ordered; (2) the number of tests ordered increases and waiting times are reduced in the presence of an advanced health information technology system; and (3) EDs that have an advanced IT system for at least a

Table 5: The Effect of Lagged Health Information Technology Adoption on Selected Emergency Department Utilization Measures

	<i>Time to See a Physician</i>	<i>Length of Visit</i>	<i>Number of Medications Prescribed</i>	<i>Number of Tests Ordered</i>	<i>Number of Images Ordered</i>
Possessed at least a basic system for at least a year					
With hospital fixed-effects	-1.9644 (2.6819)	0.2791 (5.2022)	-0.0619 (0.0504)	-0.0536 (0.0586)	-0.0065 (0.0127)
Without hospital fixed-effects	-2.8237 (2.4765)	5.3942 (3.7406)	0.0476 (0.0641)	0.0373 (0.0630)	-0.0075 (0.0121)
Possessed an advanced system for at least a year					
With hospital fixed-effects	-5.5614 (2.6410)***	6.0259 (4.2438)	0.1717 (0.0653)**	0.1318 (0.0569)***	0.0397 (0.0182)***
Without hospital fixed-effects	1.6044 (3.3962)	10.9176 (5.9515)	0.0870 (0.0663)	0.0008 (0.0878)	0.0033 (0.0155)
Mean of dependent variable	52.12	136.22	2.05	1.65	0.57
among visits to EDs without a basic system					
Mean of dependent variable	53.50	145.16	2.09	1.72	0.58
among visits to EDs without an advanced system					

Notes. Estimates for wait time and length of visit are marginal effects from a generalized linear model under a gamma distribution with a log-link. Estimates for number of medications, tests, and images are marginal effects computed using a zero-inflated Poisson regression. Sample size is 70,135. Controls included but not shown are age, gender, race, insurance status, whether the patient was discharged home, seen for an injury, seen by a resident, the log of the ED's annual visit volume, number of diagnoses, whether more than 20% of households in the patient's ZIP code were below poverty, immediacy of condition, year effects, and quintile controls for reason for visit. The nonfixed-effect regressions also include controls for urban and teaching status. Tables S4 and S5 list the full set of marginal effects. The symbols ** and *** indicate statistical significance at the 10%, 5%, and 1% levels respectively.

year maintain lower waiting times, but also see increases in the number of medications, tests, and images ordered. The implications of increased resource use are uncertain. It is possible that the increased resource use might primarily be due to the lowering of the effort costs needed to submit an order. However, we are not able to ascertain with the current data whether additional medications, imaging, and testing result in superior patient outcomes. Moreover, if hospitals adopted other process changes at the same time they implemented health IT, our analysis would not be able to differentiate between these effects.

Our analysis was also limited to a time period in which many EDs had possessed their respective health IT capabilities for only a year. It is possible that other effects on patient care require a longer acclimation period and are only observable over a longer time horizon. Although we control for time-invariant factors that vary by ED, the limited number of years in our sample also restricts our ability to control for the possibility that adopters and non-adopters could also have different trends in outcomes.

In sum, we find that health information technology adoption in the ED is associated with a nontrivial and persistent reduction in waiting times. The number of medications, tests, and images ordered per visit also increases once an advanced system is in place for at least a year. When taken in combination with the reduced waiting times and the lack of a detectable increase in the average length of visit, our findings suggest that advanced health IT systems may have an effect on increasing ED efficiency. These possible efficiency gains could prove important because EDs are expected to face increased demand as more people gain insurance coverage in 2014 (Taubman et al. 2014). However, whether these efficiency gains result in superior patient outcomes or reduced costs remains unclear.

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NOTES

1. Visit-level sample statistics are available in Table S1.
2. Lab tests included complete blood count, electrolytes, liver function tests, cardiac enzymes, blood urea nitrogen and creatinine, cardiac enzymes, glucose, arterial blood gases, tests for coagulation, blood cultures, blood alcohol level, toxicology tests, and an “other” category.
3. Diagnostic imaging included X-rays, MRIs, CT scans, ultrasounds, and other.
4. Immediacy is categorized as immediate, emergent, urgent, semiurgent, or non-urgent. A sixth category indicates that this information is missing.
5. A mean of the applicable outcome was calculated for each unique reason-for-visit code. Each reason-for-visit code was then assigned a number ranging from one to five indicating which quintile of the performance measure the code was associated with. Indicator variables for each quintile (with the lowest quintile omitted) were included in all estimates.
6. The percent of observations missing information on wait time or length of visit was not statistically significantly different for EDs with or without a basic health IT system or with or without an advanced health IT system.
7. As a sensitivity test, Table S5 shows an alternative model to Table 5 that considers five mutually exclusive categories of health IT adoption—adopted a basic system in the past year, has had a basic system for at least a year, adopted an advanced system in the past year, and has had an advanced system for at least a year (relative to has less than a basic system). The estimated effect of health IT on wait time and images are still significant for “advanced for at least a year” at less than the 10 percent level and the result on tests is still significant at less than the 5 percent level.

REFERENCES

- Agha, L. 2012. “The Effects of Health Information Technology on the Costs and Quality of Medical Care.” *Journal of Health Economics* 34: 19–30.
- Blumenthal, D. 2009. “Stimulating the Adoption of Health Information Technology.” *New England Journal of Medicine* 360: 1477–9.
- Daniel, G. W., E. Ewen, V. J. Willey, C. L. Reese, F. Shirazi, and D. C. Malone. 2010. “Efficiency and Economic Benefit of a Payer-Based Electronic Health Record in an Emergency Department.” *Academic Emergency Medicine* 17: 824–33.
- Decker, S. L., E. W. Jamoom, and J. E. Sisk. 2012. “Physicians in Nonprimary Care and Small Practices and Those Age 55 and Older Lag in Adopting Electronic Health Record Systems.” *Health Affairs* 31 (5): 1108–14.
- DesRoches, C. M., E. G. Campbell, S. R. Rao, K. Donelan, T. G. Ferris, A. Jha, R. Kausshal, D. E. Levy, S. Rosenbaum, A. E. Shields, and D. Blumenthal. 2008. “Electronic Health Records in Ambulatory Care—A National Survey of Physicians.” *New England Journal of Medicine* 359: 50–60.

- Feid, C. F., M. S. Smith, and J. A. Handler. 2004. "Keynote Address: Medical Informatics and Emergency Medicine." *Academic Emergency Medicine* 11: 1118–26.
- Handel, D. A., R. L. Wears, L. A. Nathanson, and J. M. Pines. 2011. "Using Information Technology to Improve the Quality and Safety of Emergency Care." *Academic Emergency Medicine* 18 (6): e45–51.
- Jha, A. K., C. M. DesRoches, E. G. Campbell, K. Donelan, S. R. Rao, T. G. Ferris, A. Shields, S. Rosenbaum, and D. Blumenthal. 2009. "Use of Electronic Health Records in U.S. Hospitals." *New England Journal of Medicine* 360: 1628–38.
- Landman, A. B., S. L. Bernstein, A. L. Hsiao, and R. A. Desai. 2010. "Emergency Department Information System Adoption in the United States." *Academic Emergency Medicine* 17 (5): 536–44.
- McCaig, L. F., and T. McLemore. 1994. "Plan and Operation of the National Hospital Ambulatory Medical Care Survey." *Vital and Health Statistics* 1 (24): 1–78.
- McCormick, D., D. H. Bor, S. Woolhandler, and D. U. Himmelstein. 2012. "Giving Office-Based Physicians Electronic Access to Patients' Prior Imaging and Lab Results Did Not Deter Ordering of Tests." *Health Affairs* 31: 488–96.
- Pallin, D. J., A. F. Sullivan, J. A. Espinola, A. B. Landman, and C. A. Carmago. 2011. "Increasing Adoption of Computerized Provider Order Entry, and Persistent Regional Disparities, in U.S. Emergency Departments." *Annals of Emergency Medicine* 58 (6): 543–50.
- Schapiro, J. S., K. M. Baumlin, N. Chawla, N. Genes, J. Godbold, F. Ye, and L. D. Richardson. 2010. "Emergency Department Information System Implementation and Process Redesign Result in Rapid and Sustained Financial Enhancement at a Large Academic Center." *Academic Emergency Medicine* 17: 527–35.
- Taubman, S. L., H. L. Allen, B. J. Wright, K. Baicker, and A. N. Finkelstein. 2014. "Medicaid Increases Emergency-Department Use: Evidence from Oregon's Health Insurance Experiment." *Science* 34: 263–8.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of this article:

Appendix SA1: Author Matrix.

Table S1. Visit-Level Sample Statistics for the National Hospital Ambulatory Medical Care Survey—Emergency Department.

Table S2. The Effect of At-Least-Basic Health Information Technology Adoption on Selected Emergency Department Utilization Measures.

Table S3. The Effect of Advanced Health Information Technology Adoption on Selected Emergency Department Utilization Measures.

Table S4. The Effect of Having a Basic or an Advanced System (Relative to Not Having a Basic System) on Selected Emergency Department Utilization Measures.

Table S5. The Effect of Having a Basic or an Advanced System This Year or At Least a Year (Relative to Not Having a Basic System) on Selected Emergency Department Utilization Measures.