Electronic Health Records and the Frequency of Diagnostic Test Orders

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ABSTRACT

OBJECTIVES: To determine whether electronic health record (EHR) access influences the number of laboratory and imaging tests ordered, which is a frequently cited mechanism for EHR-enabled cost savings.

STUDY DESIGN: We analyzed data on non–federally employed office-based physicians from the 2008 to 2012 Electronic Health Medical Records Survey, a supplement to the National Ambulatory Medical Care Survey.

METHODS: We estimated logistic regressions to determine the relationship between EHR utilization and the volume of laboratory and imaging tests ordered in our study population, controlling for age, sex, race, clinic type, payer type, health status, comorbidities, and new patients.

RESULTS: Physicians who actively used an EHR system ordered more complete blood count (CBC) tests than physicians who did not (odds ratio [OR], 1.34; *P* <.001), even after adjusting for patient demographics, health status, and case mix. EHR-using physicians also ordered more computerized tomography scans (OR, 1.41; *P* <.001) and x-rays (OR, 1.39; *P* <.001); the difference for magnetic resonance imaging scans was not significant (OR, 1.08; *P* = .449). Subgroup analysis highlighted differences in ordering among various patient cohorts.

CONCLUSIONS: Using the most recent available nationally representative data, excluding federal and Veterans Affairs' hospitals, we found that physicians with EHR access ordered more tests than their non-EHR counterparts, thus contradicting a common rationale for EHR implementation. We argue that EHR use may actually increase healthcare expenditures by facilitating the ease of ordering tests. Whether these extra tests carry clinical utility requires further analysis.

Am J Manag Care. 2017;23(1):e16-e23

Over the last few years, the federal government has enacted seminal legislation to promote the adoption and use of health information technology (IT) among physicians. Most notably, in 2009, Congress passed the Health Information Technology for Economic and Clinical Health (HITECH) Act, which established incentive payments both for individual providers and hospital systems that demonstrate "Meaningful Use" of electronic health record (EHR) systems through 2015.[1,2] An estimated $30 billion has been dedicated to this effort, with the goal of improving healthcare quality, cost-effectiveness, and efficiency.[3] Much of this investment was predicated on an influential study by the RAND Corporation, a nonprofit global policy think tank. In 2005, RAND predicted that widespread EHR adoption would save $81 billion annually.[4] A 2012 reassessment, however, altered this estimate: rather than decreasing, healthcare costs have climbed by over $800 billion since the first report was issued.[5,6] Although EHRs are still thought to yield cost and quality benefits, recent studies have shown this effect to be inconsistent at best.[7-9]

The global market for EHRs has grown substantially since HITECH's passage. In the United States alone, it is expected to expand further from $9.6 to $12.2 billion by 2021.[10] Recently, however, physicians adopting EHRs have voiced their concerns about their limitations and cost-effectiveness.[11,12] Given the role of health IT in health reform, it has become increasingly urgent that we determine the financial and clinical impact of the EHR rollout: do EHRs save money while improving quality and efficiency?

In this study, we examined whether the introduction of EHRs in ambulatory medical practices has reduced the ordering of diagnostic and imaging tests. Although some agree that EHRs make data more accessible and reduce the likelihood of duplicate orders, other studies show that the accessibility of EHRs makes tests easier to order thus increasing the number.[3,4,6-8,13]

Our study builds on earlier work.[14] A 2012 *Health Affairs* study analyzed data from the 2008 National Ambulatory Medical Care Survey (NAMCS)—before the passage of the HITECH Act—and found an association between electronic access to results and increased ordering of imaging tests.[14] Nevertheless, because EHR systems have evolved since 2008, an updated evaluation of their effect on test ordering is warranted. We extended this previous analysis to include years 2008 through 2012, the most recent publicly available NAMCS data. We also conducted an extensive subgroup analysis as the impact of EHRs can vary by patient risk and demographics.

TAKEAWAY POINTS

Using the most recently available national data, physicians with electronic health record (EHR) access ordered more tests than their non-EHR counterparts, thus contradicting a common rationale for EHR implementation.

- Against a backdrop of policies suggesting cost savings for EHR use, these results call for a reassessment of the unqualified expectation that EHRs will reduce medical expenditures and increase clinical efficiency.
- Adopting EHRs is not enough; providers must also foster the organizational and delivery processes required to realize systemwide efficiencies.
- Implementing EHR systems may become cost-effective only when complemented by models of care that emphasize quality, value, and efficiency.

METHODS

We analyzed data from the 2008 to 2012 Electronic Health Medical Records Survey, a mail survey supplement to the NAMCS. We included the years 2008 to 2012 to capture patient records both before and after the HITECH Act was implemented in 2009. For 2008 and 2009, the EHR supplement used the same sampling scheme as the NAMCS. In 2010, the NAMCS expanded the sampling scheme to better represent national EHR usage, and in 2012, it implemented 2 sampling designs: one for national, regional, and division-level analysis, and a second to enable state-based analyses for the 34 most populous states in the country. State-based analyses were not incorporated into our study because of their absence from the data prior to 2012. In aggregate, the NAMCS presents data on patient demographics, EHR usage, and laboratory tests for a random sample of office-based physicians with direct patient interaction, excluding pathologists, anesthesiologists, and radiologists.[15]

The basic sampling unit of the NAMCS is 1 physician–patient interaction with a non–federally employed physician. From 2008 to 2011, a multi-stage sampling design was used. First, the primary sampling unit (PSU) comprised counties and county equivalents; second, physicians were selected within PSUs according to their specialty; and third, specific patient encounters were selected within physician offices (**eAppendix Figure A** [eAppendices available at **www.ajmc.com**]). In 2012, this design was simplified to 2 stages: the first stage stratified physicians based on primary care status and the second stage selected individual patient encounters (**eAppendix Figure B**).

For the final stage of both sampling designs, physicians were each assigned a calendar week, and surveys were completed for a systematic random sample of patients that were seen during the assigned week.[15] The CDC compiled survey data into the NAMCS database and, in 2012, they incorporated physicians practicing at community health clinics (CHCs) in a separate survey. Therefore, we excluded all CHCs from our study population.

Sampling and Analysis

We generated national estimates from the NAMCS, accounting for the complex sampling design. Demographic data were compiled for the total study population. Typical variables included, but were not limited to, age, sex, payer type, and clinic type. Median income was analyzed for individuals within the 2008 to 2011 dataset, but was then no longer collected by NAMCS in 2012. Clinic type was defined as private practice or nonprivate practice in the NAMCS.

We analyzed several individual test-ordering practices for our primary outcomes, including complete blood count (CBC) and radiographic studies, because they are common tests, expensive in aggregate, and readily available in EHR systems. For each test, we compared the probability of ordering by physicians using EHRs with that of physicians not using EHRs. We used a Bonferroni correction to adjust for multiple comparisons.

We estimated a patient-level multivariate logistic regression to determine the relationship between the ability to order laboratory tests electronically and the probability of ordering each test. We then computed an adjusted estimate for EHR and non-EHR physicians in which confounders were held at mean values. As covariates, all multivariate logistic regressions included, as available: age, sex, race, clinic type, payer type, health status, major *International Classification of Diseases, Ninth Revision, Clinical Modification* (*ICD-9-CM*) diagnosis categories, and whether the physician had seen the patient before. The *ICD-9-CM* categories included were: infectious/parasitic, neoplasms, endocrine/metabolic/immune disease, blood disease, mental disorders, nervous disease, sense organs disease, circulatory disease, respiratory disease, genitourinary disease, pregnancy/childbirth complications, skin disease, musculoskeletal disease, congenital anomalies, perinatal conditions, ill-defined conditions, injury/poisoning, and external injury.

To assess the overall effect of EHRs on imaging orders, 1 variable combined all major imaging modalities, such as, but not limited to, x-ray, computed tomography (CT), magnetic resonance imaging (MRI), electrocardiogram, ultrasound, and bone mineral density. We also analyzed 3 modalities individually: x-ray, CT, and MRI. For imaging, EHR usage was defined as the presence and usage of an electronic system for viewing imaging results, encompassing both the imaging study and its interpretation. Such computerized systems might be either part or independent of a full EHR, which is assumed to contain patient medical histories, previous laboratory and imaging results, and point-of-decision support. For those occasional patients seen at facilities where the EHR system was

TABLE 1. Office Visit Demographics (n = 183,519)

Demographic	%
Sex	
Female	58.4
Patient status	
New patient	86.2
Age category, years	
<15	16.1
15-24	7.6
25-44	20.0
45-64	29.6
65-74	13.4
≥75	13.3
Payment/insurance type	
Private	53.4
Medicare	25.0
Medicaid	10.9
Worker's compensation	1.2
Self-pay	4.0
Other	5.6
Household income	
<$32,794	19.5
$32,794-$40,625	22.4
$40,626-$52,387	25.6
>$52,387	32.5
Race	
White	84.5
Black	10.5
Other	5.0
Type of office setting	
Private	92.1
Freestanding clinic	3.8
Mental health center	0.4
Nonfederal gov clinic	0.7
HMO	2.7
Faculty practice plan	0.3

HMO indicates health maintenance organization; gov, government.

TABLE 2. Health Status and Case-Mix Demographics (n = 183,519)

Demographic	%
Health status/comorbid conditions	
Arthritis	13.4
Asthma	6.4
Cancer	5.8
Cerebrovascular disease	1.8
Chronic renal failure	2.0
Congestive heart failure	1.8
COPD	4.0
Depression	9.2
Diabetes	11.6
Hyperlipidemia	16.5
Hypertension	27.4
Ischemic heart disease	4.0
Obesity	7.2
Osteoporosis	2.9
Primary *ICD-9-CM* diagnoses	
Infectious/parasitic	2.4
Neoplasms	3.4
Endocrine/metabolic/immune disease	6.2
Blood disease	0.7
Mental disorders	5.2
Nervous disease	2.4
Sense organs disease	6.9
Circulatory disease	8.4
Respiratory disease	9.8
Digestive disease	3.6
Genitourinary disease	4.7
Pregnancy/childbirth complications	0.5
Skin disease	4.9
Musculoskeletal disease	9.0
Congenital anomalies	0.4
Perinatal conditions	0.1
Ill-defined conditions	7.1
Injury/poisoning	4.5
External injury	19.8

COPD indicates chronic obstructive pulmonary disease; *ICD-9-CM*, *International Classification of Diseases, Ninth Revision, Clinical Modification.*

"turned off" or "not used routinely," we categorized observations as occurring at facilities without an EHR system.

RESULTS

The study population (n = 183,519), as described in **Table 1**, includes a higher proportion of female (58.4%) and white patients (84.5%). The modal patient was between 45 and 64 years old (29.6%). Approximately half of the study population had private insurance (53.4%), one-third had a median family income above $52,387 (32.5%), and most were seen in private practice office settings (92.1%).

Table 2 illustrates the health status of our study population, with just over a quarter of patients diagnosed with hypertension (27.4%). Other notable chronic health conditions included hyperlipidemia

(16.5%), arthritis (13.4%), diabetes (11.6%), and depression (9.2%). The most common primary diagnoses were "external causes of injury" (19.9%), "diseases of the respiratory system" (9.8%), and "musculoskeletal disease" (9%).

For physician practices with and without EHRs, **Table 3** shows the probabilities of CBC test ordering. Superscripted notes indicate that the difference between these groups was significant at the 95% confidence interval (CI) after the Bonferroni correction. In subgroup analysis, we found that availability of EHRs was associated with higher rates of CBC testing regardless of sex, race, median household income, or new patient status, and for all individuals over 25 years of age. This correlation was additionally seen in those receiving either Medicare or private insurance and in private or freestanding clinic settings. Furthermore, several comorbid conditions and primary *ICD-9-CM* diagnoses—which are further detailed in Table 3—were associated with higher rates of CBC testing. The availability of an EHR did not statistically significantly reduce the probability of ordering a CBC test in any subgroup.

At the 95% CI using the Bonferroni correction, the probability that a provider would order imaging studies was significantly higher with an EHR system, again, regardless of sex, race, median household income, new patient status, or even age, as shown in **Table 4**. It was higher for those seen in private, health maintenance organization (HMO), and faculty practice plan settings, as well as for all insurance types except worker's compensation and "other," for which the data were not statistically significant. Several comorbid conditions and primary *ICD-9-CM* diagnoses (further detailed in Table 4) were associated with higher rates of CBC testing. In no single subgroup did the availability of EHRs statistically significantly reduce the probability of ordering imaging studies.

Multivariate logistic regressions demonstrated that the probability of ordering a CBC test is significantly greater for physicians with EHR access (odds ratio [OR], 1.34; $P < .001$)—a 30% increase in the adjusted likelihood of ordering a CBC test compared with physicians not using an EHR after adjusting for patient demographic information and a detailed set of clinical risk-adjusters (**Table 5**). Although the difference for MRIs is not significant, physicians using EHRs have a greater probability of ordering CT scans (OR, 1.41; $P < .001$) and x-rays (OR, 1.39; $P < .001$), at a 41% and 37% increase, respectively. Considering imaging in aggregate, physicians using EHRs have a greater probability (OR, 1.26) and a 23% increased adjusted likelihood of ordering imaging than physicians not using EHRs ($P < .001$). A multivariate logistic subgroup analysis shows statistically significant differences among various subgroups (**eAppendix Table**).

DISCUSSION

The availability of an EHR system is associated with a measurable increase in the ordering of CBC and imaging tests in outpatient

TABLE 3. Probability of CBC Performed by EHR Use

	Patients of Physicians Using EHR	Patients of Physicians Not Using EHR	P
Sex			
Female	0.15	0.10	<.001[a]
Male	0.15	0.11	<.001[a]
Age category, years			
<15	0.05	0.05	.774
15-24	0.10	0.08	.094
25-44	0.14	0.10	.001[a]
45-64	0.18	0.12	<.001[a]
65-74	0.19	0.13	<.001[a]
≥75	0.20	0.12	<.001[a]
Payment/insurance type			
Private	0.14	0.10	<.001[a]
Medicare	0.21	0.13	<.001[a]
Medicaid	0.11	0.10	.713
Worker's compensation	0.02	0.02	.610
Self-pay	0.10	0.06	.036
No charge	0.19	0.12	.381
Other	0.13	0.10	.177
Household income			
<$32,794	0.18	0.11	<.001[a]
$32,794-$40,625	0.16	0.10	<.001[a]
$40,626-$52,387	0.16	0.11	.001[a]
>$52,387	0.15	0.11	.010
Race			
White	0.15	0.10	<.001[a]
Black	0.17	0.13	.010
Other	0.16	0.10	.008
Office setting			
Private practice	0.16	0.11	<.001[a]
Freestanding clinic	0.12	0.05	.002[a]
Mental health center	0.11	0.07	.172
HMO/prepaid plan	0.13	0.14	.759
Faculty practice plan	0.08	0.15	.190
New patient			
Yes	0.14	0.09	<.001[a]
No	0.15	0.11	<.001[a]

(continued)

TABLE 3. Probability of CBC Performed by EHR Use *(continued)*

	Patients of Physicians Using EHR	Patients of Physicians Not Using EHR	*P*
Health status/comorbid conditions			
Arthritis	0.20	0.14	.003[a]
Asthma	0.13	0.11	.209
Cancer	0.26	0.21	.058
Cerebrovascular disease	0.20	0.18	.295
Chronic renal failure	0.45	0.31	.014
Congestive heart failure	0.21	0.20	.638
COPD	0.20	0.14	.005
Depression	0.16	0.11	.001[a]
Diabetes	0.22	0.16	<.001[a]
Hyperlipidemia	0.23	0.20	.023
Hypertension	0.22	0.16	<.001[a]
Ischemic heart disease	0.22	0.17	.042
Obesity	0.18	0.17	.439
Osteoporosis	0.27	0.21	.096
Primary *ICD-9-CM* diagnoses			
Infectious/parasitic	0.08	0.09	.488
Neoplasms	0.27	0.24	.394
Endocrine/metabolic/ immune disease	0.26	0.18	<.001[a]
Blood disease	0.51	0.49	.622
Mental disorders	0.10	0.05	<.001[a]
Nervous disease	0.13	0.09	.064
Sense organs disease	0.03	0.02	.200
Circulatory disease	0.24	0.18	.003
Respiratory disease	0.09	0.08	.235
Digestive disease	0.18	0.22	.462
Genitourinary disease	0.16	0.13	.375
Pregnancy/childbirth complications	0.09	0.08	.724
Skin disease	0.07	0.05	.018
Musculoskeletal disease	0.13	0.08	.026
Congenital anomalies	0.05	0.05	.899
Perinatal conditions	0.03	0	.265
Ill-defined conditions	0.19	0.15	.012
Injury/poisoning	0.06	0.03	.001[a]
External injury	0.13	0.09	<.001[a]

CBC indicates complete blood count; COPD, chronic obstructive pulmonary disease; EHR, electronic health record; HMO, health maintenance organization; *ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification.*

[a]Significant at the 95% confidence level with Bonferroni correction for testing multiple hypotheses.

settings, even after adjusting for an extensive set of demographic and case-mix variables. Physicians with EHR access exhibited a higher probability of ordering an imaging study (OR, 1.26; P <.001) and a CBC test (OR, 1.34; P <.001). This difference is particularly pronounced for Medicare patients and patients with private insurance. These findings contradict one of the most common arguments for EHR implementation: that EHRs reduce excessive testing and, subsequently, unnecessary costs.[16-18] Although our results do not differentiate between clinically indicated and redundant tests, rates of both expensive and inexpensive tests are higher in practices with EHRs.

EHR systems have been federally subsidized since 2009, when the HITECH Act earmarked billions of dollars in reimbursement to early adopters. Proponents argued that EHR use would improve care coordination, increase efficiency, expose duplicate testing, and, thereby, reduce costs. Preliminary evidence upheld this potential; however, these studies typically examined health technology systems developed in-house in highly controlled single-clinic or emergency department environments.[19,20]

Evidence on the quality and cost-effectiveness of EHRs beyond these benchmark hospitals has been mixed.[21,22] One study found hospitals across the country with advanced EHRs had a 9.66% lower cost per admission than those without advanced EHRs.[23] By contrast, another study found that inpatient cases cost 7% more in hospitals with advanced EHRs than in those without.[24] A third, analyzing Medicare claims data from 1998 to 2005, found an initial 1.3% increase in billed charges with no evidence of cost savings—even 5 years after adoption.[25] The initial promises of EHRs to "cut waste…reduce the need to repeat expensive medical tests" and "save billions of dollars," have yet to be achieved.[26,27]

We propose 2 possible interpretations of the observed correlation between EHR access and test ordering: one in which computerized access simplifies the ordering process leading to more frequent ordering, and another in which the same physicians who readily adopt EHRs also order more tests for their patients. Our results support the former interpretation. First, we found striking increases in both test and imaging orders for EHR-equipped physicians across nearly every subgroup; no variable, from patient demographics to insurance type to comorbidities, eliminated this effect. Second, from 2008 to 2011—when this data was available—we found that the largest effect of EHRs on test ordering was in large practice settings, such as HMOs, in which individual physicians are least likely to influence institutional IT decisions. In those settings, the argument that doctors who are most likely to adopt EHRs are the same doctors who are most likely to order excessive tests bears less relevance. If the selection bias interpretation was correct, we would have expected a larger difference in test ordering between EHR and non-EHR doctors in small practice settings.[28,29] Because we observed the opposite, selection bias is a less likely interpretation of our results.

Limitations

Our study has a few limitations. Although we used CBC ordering as our single measure for all laboratory testing, other laboratory tests may be affected differently by EHRs. Nonetheless, as CBC is typically among the first-ordered laboratory tests in many clinical situations, it arguably reflects the overall trend for laboratory tests.[30,31] Our measure for EHR implementation represents, at minimum, the capacity to order and view patient diagnostic information, not necessarily advanced clinical decision support—helpful for filtering vast quantities of patient information—because such distinctions were not available from our data source. Still, our results are suggestive of the broader impact of EHRs as it is reasonable to conclude that ordering of laboratory tests and imaging are basic functions of all EHR systems.

Another limitation stems from our lack of data beyond 2012. In 2011, the federal government implemented Meaningful Use regulations, which tied federal incentive payments to specific care delivery improvements enabled by EHRs.[32] Because we reviewed years 2008 through 2012 only, we cannot be certain whether additional functionalities developed in the last 3 years might have reduced the quantity of laboratory and imaging tests ordered. Still, cost data for evolved functionalities like clinical decision support, one of the most publicized of Meaningful Use, remain conflicted to modest at best.[33] Moreover, at a time when less than one-third of office-based providers are meeting Stage 2 Meaningful Use requirements, perhaps it is the EHR programs studied—however rudimentary—that most accurately reflect the current usage and usability of EHRs nationwide.[34] It remains to future studies to evaluate EHR systems as they continue to evolve.

Finally we were limited by the constraints of our data source. Given that our basic sampling unit was a single patient encounter and not the patient, long-term outcome variables, such as mortality and complications, could not be included. Moreover, our study does not cleanly distinguish between clinically necessary and unnecessary tests. We can infer clinical utility for some subsets of patients: those with a primary diagnosis of cancer, for example, for whom imaging was 47% (*P* <.001) more likely to be ordered if EHRs were available. Nonetheless, from our analysis, it also appears that EHRs may simply promote excessive testing more generally. It is interesting, for instance, that this effect holds true—across both imaging and laboratory testing—even for patients seen primarily for depression and mental disorders, diagnoses typically not associated with CBC or imaging requirements. Furthermore, those diagnoses that would almost necessitate CBC testing—specifically, infection and blood diseases—saw no significant difference in ordering frequency between EHR and non-EHR practices. This suggests that physicians will order critical diagnostic tests and imaging regardless of EHR status.

TABLE 4. Probability of Any Imaging Performed by EHR Use

	Patients of Physicians Using EHR	Patients of Physicians Not Using EHR	*P*
Sex			
Female	0.19	0.14	<.001[a]
Male	0.15	0.10	<.001[a]
Age category, years			
<15	0.06	0.04	<.001[a]
15-24	0.16	0.08	<.001[a]
25-44	0.19	0.14	.001[a]
45-64	0.21	0.16	<.001[a]
65-74	0.20	0.15	<.001[a]
≥75	0.18	0.14	<.001[a]
Payment/insurance type			
Private	0.18	0.13	<.001[a]
Medicare	0.20	0.14	<.001[a]
Medicaid	0.12	0.07	<.001[a]
Worker's compensation	0.24	0.23	.740
Self-pay	0.14	0.06	<.001
No charge	0.17	0.03	.002[a]
Other	0.18	0.16	.326
Household income			
<$32,794	0.18	0.13	<.001[a]
$32,794-$40,625	0.17	0.13	<.001[a]
$40,626-$52,387	0.18	0.13	<.001[a]
>$52,387	0.19	0.12	<.001[a]
Race			
White	0.18	0.12	<.001[a]
Black	0.17	0.12	<.001[a]
Other	0.17	0.11	.003[a]
Type of office setting			
Private practice	0.18	0.13	<.001[a]
Freestanding clinic	0.15	0.14	.644
Mental health center	0	0.004	.226
Nonfederal gov clinic	0.20	0.12	.174
HMO/prepaid plan	0.15	0.06	<.001[a]
Faculty practice plan	0.22	0.08	.023
New patient			
Yes	0.26	0.19	<.001[a]
No	0.16	0.11	<.001[a]

(continued)

CONCLUSIONS

Our results demonstrate a positive relationship between EHR implementation and the volume of laboratory and imaging tests

TABLE 4. Probability of Any Imaging Performed by EHR Use *(continued)*

	Patients of Physicians Using EHR	Patients of Physicians Not Using EHR	*P*
Health status/comorbid conditions			
Arthritis	0.26	0.19	.001[a]
Asthma	0.17	0.12	<.001[a]
Cancer	0.22	0.15	<.001[a]
Cerebrovascular disease	0.23	0.21	.522
Chronic renal failure	0.18	0.13	.053
Congestive heart failure	0.20	0.17	.273
COPD	0.19	0.17	. 421
Depression	0.17	0.09	<.001[a]
Diabetes	0.17	0.13	<.001[a]
Hyperlipidemia	0.19	0.16	.025
Hypertension	0.20	0.16	<.001[a]
Ischemic heart disease	0.23	0.18	.013
Obesity	0.18	0.14	.001[a]
Osteoporosis	0.28	0.22	.041
Primary *ICD-9-CM* diagnoses			
Infectious/parasitic	0.05	0.03	.052
Neoplasms	0.21	0.12	<.001[a]
Endocrine/metabolic/ immune disease	0.10	0.08	.045
Blood disease	0.08	0.08	.808
Mental disorders	0.04	0.02	<.001[a]
Nervous disease	0.16	0.13	.225
Sense organs disease	0.06	0.05	.362
Circulatory disease	0.17	0.15	.142
Respiratory disease	0.10	0.09	.224
Digestive disease	0.17	0.12	.284
Genitourinary disease	0.25	0.22	.202
Pregnancy/childbirth complications	0.40	0.30	.080
Skin disease	0.03	0.02	<.001[a]
Musculoskeletal disease	0.32	0.27	.021
Congenital anomalies	0.28	0.24	.419
Perinatal conditions	0.02	0.05	.343
Ill-defined conditions	0.22	0.19	.015
Injury/poisoning	0.38	0.29	<.001[a]

COPD indicates chronic obstructive pulmonary disease; EHR, electronic health record; HMO, health maintenance organization; *ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification*.
[a]Significant at the 95% confidence level with Bonferroni correction for testing multiple hypotheses.

TABLE 5. Adjusted Probability of Test Ordering With and Without EHRs

	With EHR in Clinic	Without EHR in Clinic	% Change	Odds Ratio
CBC testing (n = 183,519)	11.29%	8.66%	30.37% (*P* <.001)	1.34[a] (*P* <.001)
Any imaging (n = 181,892)	12.45%	10.13%	22.90% (*P* <.001)	1.26[a] (*P* <.001)
MRI (n = 185,630)	0. 62%	0.58%	6.90% (*P* <.001)	1.08 (*P* = .449)
CT scan (n = 185,630)	0.99%	0.70%	41.43% (*P* <.001)	1.41[a] (*P* <.001)
X-ray (n = 185,630)	4.39%	3.21%	36.76% (*P* <.001)	1.39[a] (*P* <.001)

CBC indicates complete blood count; CT, computed tomography; EHR, electronic health record; MRI, magnetic resonance imaging.
[a]Significant at the 95% confidence level with Bonferroni correction for testing multiple hypotheses.

that physicians order. Against a backdrop of policies suggesting cost savings for EHRs, these results call for reassessment of the hope that EHRs can reduce medical expenditures and increase clinical efficiency. Adopting EHRs is not enough: providers must also foster the organizational and delivery processes required to realize systemwide efficiencies. Implementing EHR systems may become cost-effective only when complemented by models of care that emphasize quality, value, and efficiency. ■

Acknowledgments

Ibrahim Hakim, BBA; Sejal Hathi, BS; Archana Nair, MS; and Trishna Narula, MPH, contributed equally and are all joint first authors on the paper. The authors alone are responsible for the statements in the paper and for any errors; all had equal access to the data.

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Source of Funding: Dr Bhattacharya acknowledges funding from the National Institute on Aging (NIA) for his work on this project (R37 AG036791 and P30 AG17253).

Author Disclosures: The authors report no relationship or financial interest with any entity that would pose a conflict of interest with the subject matter of this article.

Authorship Information: Concept and design (IH, SH, AN, TN, JB); acquisition of data (SH, AN, TN); analysis and interpretation of data (IH, SH, AN, TN, JB); drafting of the manuscript (IH, SH, AN, TN, JB); critical revision of the manuscript for important intellectual content (IH, SH, AN, JB); statistical analysis (IH, SH, AN, TN, JB); provision of patients or study materials (TN); obtaining funding (JB); administrative, technical, or logistic support (SH); and supervision (JB).

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eAppendix

Table. Multivariate Logistic Regression: Subgroup Adjusted Odds Ratios

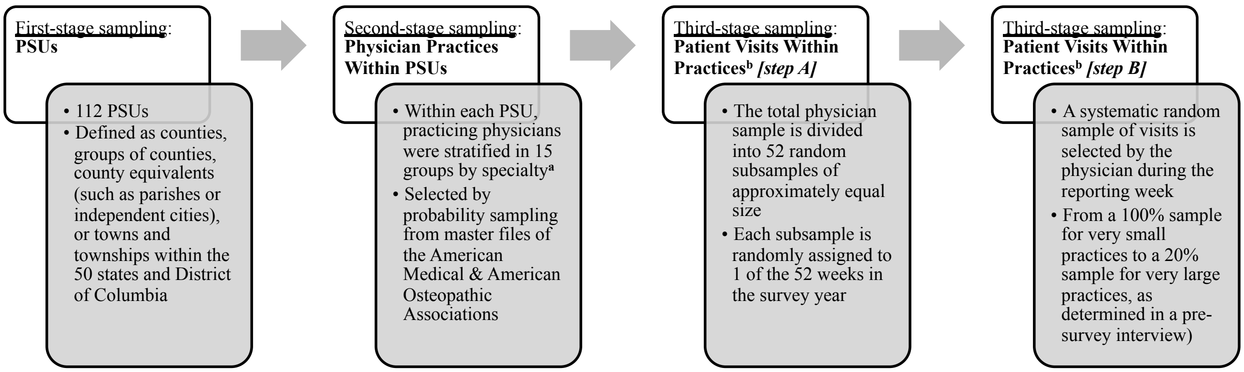
	CBC Testing (n = 183,519)	Any Imaging (n = 181,892)	MRI (n = 185,630)	CT Scan (n = 185,630)	X-Ray (n = 185,630)
Gender					
Male			*Reference*		
Female	0.95 (*P* = .092)	1.26 (*P* <.001)	1.00 (*P* = .991)	0.84 (*P* = .016)	0.83 (*P* <.001)
Age (years)					
<15			*Reference*		
15-24	1.59 (<0.001)	2.3 (<0.001)	3.62 (<0.001)	4.40 (<0.001)	1.37 (<0.001)
25-44	1.92 (<0.001)	3.20 (<0.001)	3.91 (<0.001)	6.65 (<0.001)	1.33 (0.001)
45-64	1.78 (<0.001)	3.70 (<0.001)	4.32 (<0.001)	7,45 (<0.001)	1.53 (<0.001)
65-74	1.51 (<0.001)	3.32 (<0.001)	4.01 (<0.001)	5.96 (<0.001)	1.45 (<0.001)
≥75	1.40 (0.005)	2.83 (<0.001)	2.40 (<0.001)	3.94 (<0.001)	1.21 (0.048)
Payment/insurance type					
Private			*Reference*		
Medicare	0.98 (0.692)	1.02 (0.637)	1.02 (0.809)	1.34 (0.001)	1.10 (0.094)
Medicaid	1.18 (0.030)	0.88 (0.027)	0.95 (0.669)	1.13 (0.404)	0.88 (0.150)
Worker's compensation	0.24 (<0.001)	0.71 (0.002)	1.44 (0.059)	0.64 (0.144)	0.70 (0.004)
Self-pay	0.62 (0.001)	0.54 (<0.001)	0.41 (<0.001)	0.52 (0.006)	0.59 (0.001)
No charge	1.09 (0.718)	0.59 (0.119)	1.20 (0.702)	2.23 (0.111)	0.14 (0.001)
Other	0.95 (0.692)	1.04 (0.675)	1.24 (0.314)	1.45 (0.024)	1.18 (0.268)
Race					
White			*Reference*		
Black	1.16 (0.005)	0.96 (0.372)	1.01 (0.892)	0.88 (0.214)	0.88 (0.039)
Other	1.03	0.98	0.83	0.96	0.87

	(0.732)	(0.742)	(0.168)	(0.842)	(0.231)
Type of Office Setting					
Private, Solo, Group			*Reference*		
Other	1.31 (0.006)	1.18 (0.007)	1.16 (0.277)	1.24 (0.062)	0.98 (0.815)
New patient					
Yes			*Reference*		
No	0.98 (0.688)	0.54 (<0.001)	0.47 (<0.001)	0.59 (<0.001)	0.55 (<0.001)
Health status					
Arthritis	1.32 (<0.001)	1.10 (0.032)	0.87 (0.076)	1.24 (0.070)	1.51 (<0.001)
Asthma	1.00 (0.932)	1.09 (0.058)	1.30 (0.030)	1.33 (0.023)	1.01 (0.889)
Cancer	1.42 (<0.001)	1.19 (0.003)	1.26 (0.025)	1.84 (<0.001)	1.24 (0.014)
Cerebrovascular disease	1.05 (0.521)	1.32 (0.003)	2.26 (<0.001)	1.70 (0.003)	1.05 (0.742)
Chronic renal failure	2.82 (<0.001)	0.80 (0.025)	0.60 (0.152)	1.09 (0.704)	0.94 (0.702)
Congestive heart failure	1.08 (0.349)	1.07 (0.379)	0.67 (0.101)	0.85 (0.423)	1.05 (0.681)
COPD	1.13 (0.046)	1.24 (0.002)	0.55 (<0.001)	1.20 (0.195)	1.51 (<0.001)
Depression	1.00 (0.9288)	0.88 (0.006)	0.93 (0.542)	1.01 (0.914)	0.94 (0.378)
Diabetes	0.98 (0.571)	0.91 (0.021)	0.90 (0.274)	0.92 (0.362)	0.94 (0.256)
Hyperlipidemia	1.46 (<0.001)	1.09 (0.037)	0.85 (0.102)	1.23 (0.026)	1.02 (0.669)
Hypertension	1.35 (<0.001)	1.10 (0.005)	1.14 (0.061)	1.32 (0.001)	1.23 (0.002)
Ischemic heart disease	0.96 (0.525)	1.32 (<0.001)	1.20 (0.223)	1.21 (0.091)	1.17 (0.106)
Obesity	1.09 (0.083)	0.99 (0.866)	0.85 (0.145)	0.98 (0.869)	0.96 (0.542)
Osteoporosis	1.75 (<0.001)	1.45 (<0.001)	1.50 (0.009)	2.07 (<0.001)	1.54 (<0.001)
ICD-9 Diagnoses					
Infectious/parasitic			*Reference*		
Neoplasms	2.21 (<0.001)	2.76 (<0.001)	5.23 (<0.001)	2.11 (0.002)	1.80 (0.014)

Endocrine/metabolic/immune disease	1.67 (<0.001)	1.60 (<0.001)	1.45 (0.475)	0.93 (0.001)	1.26 (0.329)
Blood disease	7.07 (<0.001)	1.40 (0.091)	1.19 (0.796)	0.67 (0.484)	1.58 (0.178)
Mental disorders	0.61 (<0.001)	0.55 (<0.001)	1.55 (0.297)	0.19 (<0.001)	0.48 (0.008)
Nervous disease	0.84 (0.218)	2.57 (<0.001)	14.22 (<0.001)	1.45 (0.264)	2.29 (0.003)
Sense organs disease	0.20 (<0.001)	1.12 (0.473)	1.16 (0.791)	0.35 (<0.001)	0.79 (0.422)
Circulatory disease	1.39 (0.007)	2.74 (<0.001)	2.01 (0.189)	0.62 (0.055)	1.44 (0.115)
Respiratory disease	0.84 (0.168)	2.16 (<0.001)	0.45 (0.187)	1.38 (0.181)	3.85 (<0.001)
Digestive disease	2.11 (<0.001)	2.97 (<0.001)	0.83 (0.758)	2.57 (0.009)	4.56 (0.001)
Genitourinary disease	1.16 (0.316)	5.11 (<0.001)	1.27 (0.674)	1.63 (0.046)	1.80 (0.013)
Pregnancy/childbirth complications	0.80 (0.352)	10.37 (<0.001)	0.23 (0.084)	0.18 (0.098)	0.45 (0.191)
Skin disease	0.53 (<0.001)	0.42 (<0.001)	0.30 (0.077)	0.11 (<0.001)	0.55 (0.023)
Musculoskeletal disease	0.78 (0.057)	6.48 (<0.001)	19.28 (<0.001)	0.49 (0.012)	11.16 (<0.001)
Congenital anomalies	0.52 (0.028)	8.62 (<0.001)	10.29 (<0.001)	3.40 (<0.001)	6.59 (<0.001)
Perinatal conditions	0.22 (0.082)	1.68 (0.359)	0.71 (0.763)	N/A	0.82 (0.841)
Ill-defined conditions	1.61 (0.001)	4.55 (<0.001)	5.56 (<0.001)	2.55 (<0.001)	3.76 (<0.001)
Injury/poisoning	0.34 (<0.001)	10.19 (<0.001)	12.71 (<0.001)	0.1.13 (0.649)	22.59 (<0.001)
External injury	1.13 (0.307)	3.40 (<0.001)	1.20 (0.732)	0.48 (0.002)	1.99 (0.002)

CBC indicates complete blood count; COPD, chronic obstructive pulmonary disease; EHR, electronic health record; HMO, health maintenance organization; *ICD-9-CM, International Classification of Diseases, Ninth Revision, Clinical Modification;* MRI, magnetic resonance imaging.

Figure A. NAMCS Multi-Stage Probability Sampling Design, 2008 to 2011

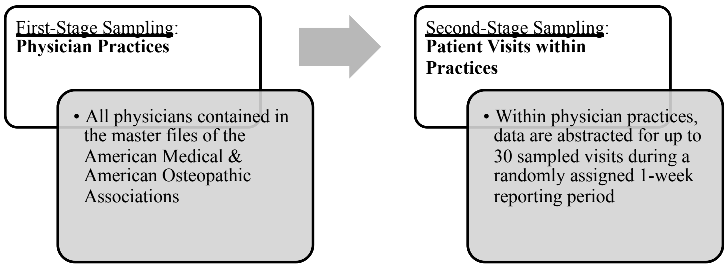


NAMCS indicates National Ambulatory Medical Care Survey; PSU, primary sampling unit.

[a]Fifteen groups: general and family practice, osteopathy, internal medicine, pediatrics, general surgery, obstetrics and gynecology, orthopedic surgery, cardiovascular diseases, dermatology, urology, psychiatry, neurology, ophthalmology, otolaryngology, and a residual category of all other specialties. Physicians in the specialties of anesthesiology, pathology, and radiology are excluded.

[b]Only visits to the offices of non–federally employed physicians classified by the American Medical Association or the American Osteopathic Association as "office-based, patient care" are included. Types of contacts not included are those made by telephone, those made outside the physician's office (for example, house calls), visits made in hospital settings (unless the physician has a private office in a hospital and that office meets the NAMCS definition of "office"), visits made in institutional settings by patients for whom the institution has primary responsibility over time (eg, nursing homes), and visits to doctors' offices that are made for administrative purposes only (eg, to leave a specimen, pay a bill, or pick up insurance forms).

Figure B. NAMCS Two-Stage Probability Sampling Design, 2012



NAMCS indicates National Ambulatory Medical Care Survey.