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RESEARCH ARTICLE

Patient Panel of Underserved Populations and Adoption of Electronic Medical Record Systems by Office-Based Physicians

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Objectives. To examine the association between patient panels of underserved populations and adoption of electronic medical records (EMRs) among office-based physicians.
Data Sources. Two thousand three hundred and twenty-six office-based physicians who responded and saw patients in the 2005 and 2006 National Ambulatory Medical Care Surveys.
Study Design. This study used a cross-sectional design. The unit of analysis was the office-based physician. EMR adoption was defined based on functionalities (No EMR, Limited, or Comprehensive). An EMR was considered to have "comprehensive" functionalities if it included computerized orders for prescriptions and tests, test results, and clinical notes by physicians. Patient panels of underserved populations were measured as proportions of racial/ethnic minorities, Medicaid recipients, or self-pay/no charge/charity care patients treated by a physician using the reported sociodemographic characteristics in patient records linked to their treating physicians. Data were analyzed using multivariate regression analyses controlling for other patient-panel characteristics and characteristics of physicians and their practices.
Principal Findings. We found a negative association between the proportion of Hispanics treated by a physician and physician adoption of EMRs with "comprehensive" functionalities after adjusting for other covariates.
Conclusions. Physicians treating high shares of Hispanic patients may have lower access to EMRs with essential functionalities.

Key Words. Health information technology, underserved populations

Health information technology (IT) such as electronic medical records (EMRs) has the potential to increase access to health care, reduce medication errors, and improve administrative efficiency and quality of care (Blumenthal et al. 2006; Chaudhry et al. 2006; Amarasingham et al. 2009). Wide adoption of health IT also has the potential to achieve substantial financial benefits

(Wang et al. 2003; Girosi, Meili, and Scoville 2005; Hillestad et al. 2005; Walker et al. 2005), although generalizability of these estimates may be limited (Congressional Budget Office 2008).

Medically underserved populations are those with diminished access to health services (Chang et al. 2004) and lower quality of care when they do have access (Reschovsky and O'Malley 2008; Stockdale et al. 2008). They often experience delayed access to new health technology, too (Ferris et al. 2006). If health IT follows the same pattern, EMRs may diffuse in a way that "systematically disadvantages" these populations and "exacerbates existing health disparities" (Blumenthal et al. 2006). Thus, "monitoring the diffusion of EMRs" among providers who serve disproportionately underserved populations and "understanding the unique barriers" facing those providers should be an important "part of any comprehensive approach to reducing health disparities" in the United States (Blumenthal et al. 2006).

The existing literature, limited by the availability of sufficient data and appropriate methodology, has scant information on the diffusion of EMRs among providers who care disproportionately for underserved populations (Blumenthal et al. 2006; Jha et al. 2006; DesRoches et al. 2008). The few studies that have attempted to address this question relied on physician self-reported patient-panel profile (Grossman and Reed 2006; DesRoches et al. 2008), which may be subject to recall bias (Blumenthal et al. 2006). Linking patient records to their treating physicians, if feasible, was recommended for more accurate measures of patient-panel characteristics (Blumenthal et al. 2006). However, public-use data with such a capacity remain limited.

One exception is the annual National Ambulatory Medical Care Survey (NAMCS), conducted by the National Center for Health Statistics (NCHS). Physicians surveyed in the NAMCS are randomly assigned to 1 of 52 weeks in a year and report information on a systematic random sample of patients treated during that week (National Center for Health Statistics [NCHS] 2007). As such, it enables researchers to link patient records to their treating physicians and use sociodemographic characteristics reported in patient records to directly estimate patient-panel characteristics. Since 2005, the NAMCS

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public-use data file has included information on EMR use at a sample physician's practice and physician-level weights, enabling nationally representative estimates of EMR adoption by office-based physicians. However, the number of patient records *per* physician is often small and the reliability of patient-panel characteristics calculated from a small number of patient records may be questionable (NCHS 2007). Nonetheless, the NAMCS remains the only public-use data with such capacity.

The primary goal of this study was to examine the association between patient panels of underserved populations and EMR adoption among office-based physicians. Recognizing the limitation of the NAMCS, we assessed the robustness of our estimates through a series of sensitivity analyses.

METHODS

Study Design and Data Source

This study used a cross-sectional design. The unit of analysis was the office-based physician. Data were from the 2005 and 2006 NAMCS. At the time of this analysis, these two surveys were the most recent and only annual surveys that were publicly available and had information on EMR use at a physician's practice. The NAMCS is an annual probability survey and is designed to generate nationally representative estimates of nonfederal, office-based physicians providing direct patient care in the 50 states or District of Columbia, excluding radiologists, anesthesiologists, and pathologists. Details on the sampling and estimation process are available at NCHS's website (http://www.cdc.gov/nchs/). To increase estimation precision, we pooled data from the 2005 and 2006 surveys, resulting in a combined sample of 2,326 office-based physicians who responded to the survey and saw patients during their sampled week.

Dependent Variable: Adoption of EMRs

In both 2005 and 2006, sample physicians were asked if their practices used full or partial (i.e., part paper, part electronic) EMRs. If they responded "yes" to either full or partial EMRs, they were asked whether their EMR systems included any of the following features: patients' demographic information, computerized orders for prescriptions, computerized orders for tests, electronic access to test results, clinical notes by physicians, reminders for guideline-based interventions/screening tests, or public health reporting capacity. The 2006 survey elicited further details on each of these functionalities (NCHS 2008). Only the common set of questions listed above were used to define EMR adoption.

We defined EMR adoption by the comprehensiveness of available functionalities at three distinct levels (No EMR, Limited, or Comprehensive). Following Burt and colleagues, we considered an EMR system to be "comprehensive" if it included *all* four of the following features: (1) computerized orders for prescriptions, (2) computerized orders for tests, (3) electronic access to test results, and (4) clinical notes by physicians (Burt, Hing, and Woodwell 2006; Hing, Burt, and Woodwell 2007). This definition is consistent with the four minimally required functionalities of an EMR proposed by an expert panel (Hing, Burt, and Woodwell 2007). If an EMR had some but not all four features, we defined it as having "limited" functionalities. The comparison group was physicians who reported no EMRs at their practices.

Key Independent Variables: Patient Panels of Underserved Populations

The key independent variables were patient panels of underserved populations measured as proportions of these population groups treated by a physician. The medically underserved populations were regarded as those experiencing diminished access to health services (Chang et al. 2004). To distinguish them from medically vulnerable populations who are at "high risk for health care problems," the Health Resources and Services Administration (HRSA) regards medically underserved populations as those with "economic barriers (low-income or Medicaid-eligible populations), or cultural and/or linguistic access barriers to primary medical care services" (HRSA 2009). However, many medically underserved are also medically vulnerable and the two terms have been used interchangeably in the literature. With respect to "tracking access to EMRs and their potential implications for health disparities," the highest priority groups were identified by expert consensus as "racial and ethnic minorities and low-income patient populations" (Blumenthal et al. 2006).

We specified the underserved populations as racial/ethnic minority groups (Hispanics, non-Hispanic blacks, *compared with* non-Hispanic whites or other racial/ethnic groups) or those with public or limited insurance coverage (Medicaid, self-pay/no charge/charity care, *compared with* Medicare, private insurance, or other sources of payment). The proportions of underserved populations treated by *each* physician were calculated by first linking all patient records in the data to their treating physicians and then applying patient-level weights to calculate weighted proportions of patients in *each* of these population groups treated by a sample physician. However, the sample weights included in the public-use file are visit-level weights and the sum of the visit sample weights yields an "unbiased estimate of the annual number of visits"

not patients (Hing and Burt 2009). Because some patients may have multiple visits in a given year, the annual number of visits overestimates the number of patients. To generate patient-level weights, the visit sample weights were adjusted by a multiplicity factor calculated based on the number of visits to a sample provider by a patient in the last 12 months, including the sample visit (Burt and Hing 2007).

Other Covariates

We controlled for other characteristics of the patient panel (weighted mean age and proportion of female patients) and characteristics of physicians and their practices such as specialty (primary care, surgical care specialty, or medical care specialty), geographic region (Northeast, Midwest, South, or West), location in a metropolitan statistical area (MSA), whether a solo practice (SOLO), ownership by a health maintenance organization (HMO), a community health center setting (CHC), and the number of contracts with managed care plans. We included interaction terms to account for potential differential effects of solo practices owned by HMOs and those in CHC settings. An indicator for 2006 was also included to control for temporal changes between the 2 years.

Data Analysis

We first compared the unadjusted characteristics of patient panels, physicians, and their practices across the three EMR adoption groups. The statistical significance of any differences was tested using adjusted Wald tests for continuous variables (patient panel characteristics) and design-adjusted Pearson χ^2 tests for categorical variables (characteristics of physicians and their practices). Given that majority (73 percent) of the physicians reported no EMR adoption, we first estimated a logistic regression to examine whether patient panels of underserved populations are associated with adoption of any EMRs. We then used multinomial logit (MNL) regression models to examine the association between EMR adoption at different levels of functionalities and patient panels of underserved populations. All models controlled for the other covariates. We tested the MNL model assumption of Independence of Irrelevant Alternatives using a generalized Hausman test that takes into account the survey design (StataCorp LP 2007) and found no violation of the assumption.

All analyses were conducted using SVY commands in *Stata* 9.2 to take into account the complex sample survey design in the NAMCS. The standard

errors were calculated nonparametrically by applying the Jackknife resampling technique. Statistical significance was determined at $p<.05$.

Sensitivity Analyses

We performed sensitivity analyses to further explore the relationship between patient panels of underserved populations and EMR adoption using an alternative model specification and different definitions of both the dependent variable and the key independent variables. All analyses were conducted using MNL regression models (unless indicated otherwise) and adjusted for the other covariates.

Alternative Definitions of the Key Independent Variables

Categorization of Patient Panels of Underserved Populations. To allow nonlinearity in the relationship between patient panels of underserved populations and physicians' adoption of EMRs, we categorized the proportion of each underserved population into quartiles. As the number of physicians with >25 percent of patients in each underserved population group was small (15 percent physicians with >25 percent Hispanic patients, 11 percent with >25 percent black patients, 17 percent with >25 percent Medicaid recipients, and 8 percent with >25 percent patients who self-paid, or received charity care/no charge), we also dichotomized the proportions at 25 percent (>25 versus 25 percent or less). Alternatively, we dichotomized the proportion of each underserved population at the national average among all physicians; in 2005 and 2006 NAMCS, the average proportion of Hispanics in a physician's panel was estimated to be 11 percent and those of blacks, Medicaid patients, and patients who self-paid, or received charity care/no charge were 9, 11, and 5 percent, respectively.

Physician-Reported Revenue from Different Payment Sources. Several previous studies have used physician-reported revenues from Medicaid as a proxy for patient panels of Medicaid recipients (Burt, Hing, and Woodwell 2006; Grossman and Reed 2006; Hing, Burt, and Woodwell 2007; DesRoches et al. 2008). During the NAMCS physician induction interview, sampled physicians were asked to report the percentage of patient-care revenue from Medicaid, Medicare, private insurance, patient payment (2006 NAMCS only), or other sources (including charity, research, CHAMPUS, VA, etc.). In the public-use files, revenues from different payment sources were coded in quartiles. Physicians with missing information were grouped in a separate category. In sensitivity analyses, we substituted quartiles of the shares of

Medicaid and Medicare patients defined using physician-reported revenues for the quartiles based on patient panels. Revenues from patient payment (i.e., self-paid) or charity were not consistently reported between the 2 years and, therefore, were not used in this analysis.

Combinations of Race/Ethnicity and Insurance Coverage. Because of the disparity in access to insurance coverage across racial/ethnic groups, minority patients are also more likely to be uninsured or enrolled in Medicaid programs. To explore the correlations between patient's race/ethnicity and insurance coverage, we redefined the underserved populations by the combinations of race/ethnicity and insurance coverage. Twenty mutually exclusive groups were defined (four race/ethnicity group and five insurance coverage groups). The reference group was non-Hispanic whites who are covered by private insurance.

Alternative Definition of the Dependent Variable

We adapted a more restrictive functionality-based definition from DesRoches et al. (2008). DesRoches and colleagues used more refined information on the functionalities of EMRs than those available in the 2005 NAMCS. The 2006 NAMCS has all the items used in DesRoches et al. (2008) except "patient problem lists" and "electronic list of medication taken by patients." Our definition approximated theirs as closely as possible based on information available in both the 2005 and 2006 surveys. As can be seen from Table 1, the definition of a "fully functional" EMR required additional features (e.g., patient demographic information and reminders for guideline-based interventions/screening tests) relative to the "comprehensive" systems defined earlier. Thus, this exercise allowed us to further examine the variability in the association between patient panels of underserved populations and the adoption of EMRs with greater functionalities.

Alternative Model Specification

Because the capacity of EMRs increases with the level of adoption we defined (No EMR, Limited, Comprehensive), we reanalyzed using an ordered logistic regression model.

RESULTS

Table 2 reports the unadjusted characteristics of patient panels, physicians, and their practices across the three EMR adoption groups. In 2005 and 2006, a total of 2,326 physicians (1,058 in 2005 and 1,268 in 2006) responded to the

Table 1: Survey Items Defining the Adoption of Electronic Medical Records (EMRs)

	EMR Adoption			*Alternative Definition**		
	No EMR	*Limited*	*Comprehensive*	*Other*	*Basic*	*Fully Functional*
Does your practice use EMRs excluding billing records?						
Yes (partial or full EMRs)	0	100	100	17.01 (0.83)	100	100
[If your practice uses EMRs], does the EMR system include the following?						
Patient demographic info	0	85.12 (1.82)	96.08 (1.22)	13.72 (0.76)	100	100
Computerized orders for prescriptions	0	36.03 (2.46)	100	4.97 (0.48)	100	100
Computerized orders for tests	0	20.89 (2.08)	100	4.42 (0.46)	60.50 (4.50)	100
Test results	0	48.83 (2.56)	100	7.42 (0.58)	100	100
Physicians' notes	0	63.45 (2.46)	100	10.13 (0.67)	100	100
Reminders for guideline-based interventions/ screening tests	0	27.68 (2.29)	69.80 (2.88)	4.18 (0.44)	21.85 (3.80)	100
Public health reporting	0	13.84 (1.77)	32.94 (2.95)	2.16 (0.32)	25.21 (4.00)	36.42 (3.67)

Notes. Values in the table are percentages and those in ( ) are standard errors.
*Alternative definition was adapted from DesRoches et al. (2008).

NAMCS survey and saw patients during their sampled week, representing a national estimate of 618,328 office-based physicians in the 2-year period (or 309,164 office-based physicians annually). An estimated 27 percent of physicians worked at a practice with an EMR system. Of those, less than half (41 percent) had EMRs with all four minimally required functionalities (11 percent of total office-based physicians). The average proportions of patients in each underserved population group were not statistically different across different levels of EMR adoption except patients who self-paid, received no charge or charity care, or paid from other sources. Among physicians' practice characteristics, geographic region, MSA location, solo practice, HMO ownership, and the number of managed-care contracts were all significantly associated with EMR adoption. However, no statistically significant differences in EMR adoption were found between physicians who practice in a CHC setting and others, or across physician specialty groups. Overall,

Table 2: Unadjusted Characteristics of Patient Panels, Physicians, and Their Practices by EMR Adoption

		EMR Adoption			
	All	*No EMR*	*Limited*	*Comprehensive**	*p-Value*
Total *n*	2,326	1,688	383	255	
Total weighted *n* (annually)	309,164	224,328	49,627	35,210	
Weighted %	100%	72.56%	16.05%	11.39%	
Patient panel characteristics					
Race/ethnicity					
% Hispanic (mean)	11.94	12.12	12.11	10.54	.525
% Non-Hispanic black (mean)	9.05	9.27	9.41	7.13	.172
% Other (mean)	5.41	4.68	6.61	8.36	.092
% Non-Hispanic white (mean)	73.60	73.92	71.87	73.96	.600
Insurance coverage					
% Medicaid/SCHIP (mean)	10.99	11.28	11.84	7.96	.057
% Medicare (mean)	19.30	19.85	17.79	17.95	.265
% Self-pay/no charge/charity care (mean)	6.36	7.07	4.45	4.53	.006
% Other payment sources (mean)	9.31	7.99	12.60	13.11	.004
% Private insurance (mean)	54.03	53.80	53.33	56.45	.509
Mean age	45.14	45.06	45.40	45.31	.954
Gender					
% Female (mean)	58.36	58.78	55.68	59.49	.154
% Male (mean)	41.64	41.22	44.32	40.51	.154
Characteristics of physicians and their practices					
Region					
Northeast	20.94	79.47	14.09	6.43	<.001
Midwest	20.75	72.61	17.84	9.56	
South	35.47	75.91	14.10	9.98	
West	22.83	60.96	19.26	19.78	
MSA					
No	10.93	82.80	12.65	4.55	.010
Yes	89.07	71.30	16.47	12.23	
Solo practice					
No	63.99	67.46	17.88	14.66	<.001
Yes	36.01	81.61	12.81	5.57	
Specialty					
Primary care specialty	50.38	73.24	14.30	12.45	.341
Medical care specialty	28.10	71.97	18.16	9.87	
Surgical care specialty	21.52	71.73	17.40	10.87	
HMO ownership					
No	97.43	73.83	16.00	10.18	<.001
Yes	2.57	24.53	18.12	57.35	

continued

Table 2. *Continued*

		EMR Adoption			
	All	*No EMR*	*Limited*	*Comprehensive**	*p-Value*
Number of managed care plan contracts					
None	10.43	78.09	11.69	10.22	<.001
<3	9.03	59.78	19.56	20.66	
3–10	35.82	76.71	15.57	7.72	
>10	40.94	71.67	16.36	11.97	
Blank	3.78	58.13	20.93	20.93	
Community health center					
No	98.35	72.77	16.02	11.20	.056
Yes	1.65	59.80	17.79	22.41	
Year					
2005	51.28	75.32	14.45	10.23	.089
2006	48.72	69.65	17.74	12.61	

*An EMR system is considered to have comprehensive functionality if it includes the following features: (1) computerized order for prescriptions, (2) computerized order for tests, (3) test results, and (4) physicians' notes.

there was no statistically significant difference in EMR adoption between 2005 and 2006.

Table 3 reports adjusted odds ratios (OR) for adopting any EMRs regardless of their available functionalities from the logistic regression. Among patient-panel characteristics, only the proportions of patients with other payment sources were associated with the adoption of any EMRs (adjusted OR: 1.010, $p = .006$). Physicians who practiced in the northeastern region (adjusted OR: 0.476, $p = .006$) or in a solo practice (adjusted OR: 0.546, $p < .001$) were significantly less likely to adopt any EMRs in their practices. On the other hand, physicians who practiced in an MSA (adjusted OR: 1.727, $p = .030$), under HMO ownership (adjusted OR: 4.848, $p = .001$), or had one to three managed-care contracts (adjusted OR: 1.853, $p = .021$) were significantly more likely to adopt some EMRs.

Table 4 reports estimates from the MNL regression model, distinguishing EMRs with "comprehensive" functionalities from those with only limited functionalities. We report separately the adjusted relative risk ratios (RRR) of adopting EMRs with limited or "comprehensive" functionalities versus no EMR adoption. The adjusted RRRs were calculated by taking the exponential of the estimated coefficients (StataCorp LP 2007). With this distinction, we found a previously unidentified negative association between the proportion of Hispanic patients treated by a physician and the likelihood of adopting

Table 3: Adjusted Odds Ratio (OR) of Adopting Any EMRs Using Logistic Regression Model

	Any EMR versus No EMR		
	Adjusted OR	*95% CI*	*p-Value*
Patient panel characteristics			
Race/ethnicity			
% Hispanic	0.993	(0.985, 1.000)	.055
% Non-Hispanic black	0.998	(0.988, 1.008)	.682
% Other	1.005	(0.992, 1.017)	.448
% Non-Hispanic white (reference)			
Insurance coverage			
% Medicaid/SCHIP	1.003	(0.994, 1.011)	.519
% Medicare	0.992	(0.982, 1.002)	.103
% Self-pay/no charge/charity care	0.994	(0.983, 1.005)	.255
% Other payment sources	1.010	(1.003, 1.018)	.006
% Private insurance (reference)			
Mean age	1.011	(0.999, 1.022)	.066
Gender			
% Male (reference)			
% Female	0.996	(0.990, 1.002)	.166
Characteristics of physicians and their practices			
Region			
Northeast	0.476	(0.279, 0.810)	.006
Midwest	0.675	(0.406, 1.120)	.128
South	0.648	(0.378, 1.109)	.113
West (reference)			
MSA			
No (reference)			
Yes	1.727	(1.053, 2.833)	.030
Solo practice			
No (reference)			
Yes	0.546	(0.397, 0.751)	<.001
Specialty			
Primary care specialty (reference)			
Medical care specialty	1.024	(0.712, 1.472)	.899
Surgical care specialty	0.972	(0.706, 1.339)	.863
HMO ownership			
No (reference)			
Yes	4.848	(1.966, 11.952)	.001
Number of managed care contracts			
0 (reference)			
1–3	1.853	(1.097, 3.129)	.021
4–10	1.233	(0.747, 2.034)	.412
>10	1.554	(0.925, 2.612)	.096
Blank	2.164	(1.056, 4.436)	.035

continued

Table 3. *Continued*

	Any EMR versus No EMR		
	Adjusted OR	*95% CI*	*p-Value*
Community health center			
No (reference)			
Yes	1.439	(0.611, 3.393)	.405
Year			
2005 (reference)			
2006	1.297	(0.988, 1.702)	.061
Interaction terms			
Solo practice with HMO ownership	0.619	(0.187, 2.052)	.432
Solo practice at CHC setting	7.704	(1.069, 55.539)	.043

EMRs with "comprehensive" functionalities by the physician (adjusted RRR: 0.984, $p = .009$). The previously found higher adoption rates among physicians at practices with HMO ownership or in MSAs were for the adoption of EMRs with "comprehensive" functionalities, not for those with limited functionalities. Physician practices owned by HMOs were nearly seven times more likely to adopt EMRs with "comprehensive" functionalities (adjusted RRR: 7.999, $p < .001$) and those practicing in MSAs were nearly two times more likely to adopt EMRs with "comprehensive" functionalities (adjusted RRR: 2.844, $p = .029$). On the other hand, the higher adoption rate found among physicians reporting one to three managed-care contracts were for the adoption of EMRs with limited functionalities (adjusted RRR: 1.962, $p = .036$) only.

The associations of solo practice, location in the northeastern region, and proportions of patients paid by other sources with EMR adoption were significant for both EMRs with limited and with "comprehensive" functionalities. Physicians at solo practices were 34 percent less likely to adopt EMRs with limited functionalities (adjusted RRR: 0.657, $p = .026$) and 60 percent less likely to adopt EMRs with "comprehensive" functionalities (adjusted RRR: 0.399, $p < .001$). Compared with physicians in the western region, physicians in the northeastern region were 40 percent less likely to adopt EMRs with limited functionalities (adjusted RRR: 0.595, $p = .033$) and 68 percent less likely to adopt EMRs with "comprehensive" functionalities (adjusted RRR: 0.320, $p = .014$). An increase in the proportion of patients paid by other sources was associated with an increase in the likelihood of adopting both EMRs with limited functionalities (adjusted RRR: 1.010, $p = .026$) and those with "comprehensive" functionalities (adjusted RRR: 1.011, $p = .016$). No

Table 4: Adjusted Relative Risk Ratio (RRR) of Adopting EMRs with Limited or Comprehensive Functionalities versus No EMR Adoption Using Multinomial Logit Regression Model

	Limited EMR versus No EMR			*Comprehensive EMR versus No EMR**		
	Adjusted RRR	*95% CI*	*p-Value*	*Adjusted RRR*	*95% CI*	*p-Value*
Patient panel characteristics						
Race/ethnicity						
% Hispanic	0.997	(0.988, 1.006)	.502	0.984	(0.973, 0.996)	.009
% Non-Hispanic black	1.002	(0.990, 1.014)	.766	0.991	(0.977, 1.005)	.218
% Other	1.005	(0.992, 1.019)	.454	1.004	(0.988, 1.019)	.655
% Non-Hispanic white (reference)						
Insurance coverage						
% Medicaid/ SCHIP	1.005	(0.995, 1.015)	.376	0.998	(0.983, 1.013)	.811
% Medicare	0.990	(0.978, 1.002)	.101	0.995	(0.982, 1.009)	.487
% Self-pay/no charge/ charity care	0.992	(0.977, 1.007)	.296	0.996	(0.981, 1.011)	.557
% Other payment sources	1.010	(1.001, 1.019)	.026	1.011	(1.002, 1.021)	.016
% Private insurance (reference)						
Mean age	1.010	(0.996, 1.024)	.169	1.012	(0.997, 1.028)	.123
Gender						
% Male (reference)						
% Female	0.993	(0.985, 1.000)	.058	1.001	(0.993, 1.009)	.841
Characteristics of physicians and their practices						
Region						
Northeast	0.595	(0.369, 0.958)	.033	0.320	(0.128, 0.796)	.014
Midwest	0.851	(0.543, 1.332)	.479	0.465	(0.196, 1.106)	.083
South	0.683	(0.407, 1.147)	.149	0.603	(0.246, 1.477)	.268
West (reference)						
MSA						
No (reference)						
Yes	1.337	(0.743, 2.406)	.333	2.844	(1.116, 7.247)	.029
Solo practice						
No (reference)						
Yes	0.657	(0.454, 0.950)	.026	0.399	(0.250, 0.636)	<.001

continued

Table 4. *Continued*

	Limited EMR versus No EMR			*Comprehensive EMR versus No EMR**		
	Adjusted RRR	*95% CI*	*p-Value*	*Adjusted RRR*	*95% CI*	*p-Value*
Specialty						
Primary care specialty (reference)						
Medical care specialty	1.311	(0.877, 1.961)	.186	0.673	(0.388, 1.169)	.160
Surgical care specialty	1.160	(0.819, 1.643)	.403	0.725	(0.420, 1.248)	.245
HMO ownership						
No (reference)						
Yes	2.166	(0.791, 5.930)	.132	7.999	(2.547, 25.117)	<.001
Number of managed care contracts						
0 (reference)						
1–3	1.962	(1.047, 3.677)	.036	1.643	(0.716, 3.768)	.241
4–10	1.465	(0.909, 2.363)	.117	0.908	(0.396, 2.080)	.819
>10	1.658	(0.992, 2.770)	.054	1.396	(0.564, 3.456)	.470
Blank	2.071	(1.014, 4.231)	.046	2.238	(0.664, 7.549)	.194
Community health center						
No (reference)						
Yes	1.094	(0.351, 3.409)	.877	2.947	(0.992, 8.752)	.052
Year						
2005 (reference)						
2006	1.286	(0.905, 1.826)	.160	1.322	(0.890, 1.964)	.167

*An EMR system is considered to have comprehensive functionality if it includes the following features: (1) computerized order for prescriptions, (2) computerized order for tests, (3) test results, and (4) physicians' notes.

statistically significant differences were found between physicians who practice in a CHC setting and others, or across physician specialties. Few physicians were in solo practices owned by HMOs ($n = 2$) and in a CHC setting ($n = 12$). The effects of the interaction terms were estimated with very large errors; consequently, we reanalyzed the model without these interaction terms.

Sensitivity Analysis

The following discussion focused on patient panels of underserved populations. Effects of other patient-panel characteristics (i.e., age, gender), physician

specialties, and the characteristics of physician practices were generally consistent across sensitivity analyses (results will be provided upon request).

Categorizing the proportions of patients in each underserved population group into quartiles revealed that physicians with >25–50 percent Medicaid patients were significantly less likely to adopt EMRs with "comprehensive" functionalities compared to those with 25 percent or less Medicaid patients (adjusted RRR: 0.338, $p = .014$). However, when we substituted physician-reported revenues from Medicaid for patient panels of Medicaid patients, we did not find a significant association between revenues from Medicaid and the adoption of an EMR. Nor did we find statistically significant differences when proportions of Medicaid patients were dichotomized at 25 percent or at the average. Physicians with above-average proportions of patients who self-paid or received charity care/no charge were significantly less likely to adopt EMRs with limited functionalities than physicians at average or below (adjusted RRR: 0.561, $p = .002$). Using combinations of race/ethnicity and insurance coverage revealed that as the proportions of Hispanic patients with other insurance or non-Hispanic black patients who self-paid or received charity care/no charge increase the likelihood of adopting EMRs with "comprehensive" functionalities decreases; the adjusted RRRs were 0.954 ($p = .001$) and 0.889 ($p = .042$), respectively. Using the alternative definition of EMR adoption adapted from DesRoches et al. (2008), we found an even stronger association between the proportion of Hispanic patients treated by a physician and adoption of a "fully functional" EMR (adjusted RRR: 0.972, $p < .001$). When an ordered logit regression model was fitted to the data, we continued to find a statistically significant negative association between the proportion of Hispanic patients and adoption of EMRs with greater functionalities.

DISCUSSION

The existing literature contains scant information on the diffusion of EMRs among physicians who serve disproportionately underserved populations (Blumenthal et al. 2006; Jha et al. 2006). We provide important insights into this question by exploring the NAMCS, the only public-use database that has nationally representative information on EMR adoption by physicians and the capacity to link patient records to treating physicians, enabling direct estimates of the share of underserved populations in physicians' panels. We found a negative association between the proportion of Hispanic patients treated by a physician and the likelihood of adopting EMRs with all four minimally

required functionalities after controlling for other patient-panel characteristics and characteristics of physicians and their practices.

Our results demonstrate the importance of a functionality-based definition for EMR adoption. The lack of agreement regarding the definition of an EMR remains a major challenge in assessing EMR adoption in the United States (Blumenthal et al. 2006). Evaluating the general use of EMRs has yielded a wide range of adoption rates (Jha et al. 2006; DesRoches et al. 2008). Variations in the perception of what constitutes an EMR may explain a substantial part of the differences (Blumenthal et al. 2006; Jha et al. 2006). To facilitate comparison across different surveys and studies, a definition based on multiple functionalities of an EMR was recommended (Blumenthal et al. 2006). We used a definition that approximates the four core functionalities specified by an expert panel for any system to be called an EMR (Hing, Burt, and Woodwell 2007). By distinguishing EMRs with all of the essential functionalities from those with limited functionalities, we were able to detect a negative association between the proportion of Hispanic patients treated by a physician and adoption of EMRs with "comprehensive" functionalities, but not those with limited functionalities. The logistic regression analysis of general EMR adoption did not find a statistically significant association, masking the lower EMR adoption rate among physicians treating a disproportionate share of Hispanic patients.

Previous studies that examined the associations between patient panels of racial/ethnic minorities and physicians' adoption of EMRs or similar IT technology were limited and generally inconclusive. DesRoches et al. (2008) found insignificant associations and Grossman and Reed (2006) found either similar or better access to health IT for the clinical activities examined among physicians treating larger proportions of minority patients. Both were physician-level studies, the same as ours. However, they relied on physician self-reported patient-panel profiles. From the patient perspective, Hing and Burt (2009) found that uninsured black or Hispanic patients, and Hispanic patients with Medicaid coverage, were less likely than privately insured white patients to have primary care physicians using EMRs with all four minimally required functionalities. Consistent with their findings, we found a negative association between the proportion of black patients who self-paid or received charity care/no charge and adoption of EMRs with all four minimally required functionalities. Burt, Hing, and Woodwell (2006) linked the zip code-level population characteristics to physicians who practice in that zip code and found no association between neighborhood characteristics, including the proportions of minority or Hispanic populations, and EMR adoption.

We did not find an overall significant association between EMR adoption and the proportion of Medicaid patients treated by a physician. However, compared with physicians with 25 percent or less Medicaid patients, physicians with >25–50 percent Medicaid patients were less likely to adopt EMRs with "comprehensive" functionalities. Previous studies used physician-reported Medicaid revenue as a proxy for patient panels of Medicaid recipients (Burt, Hing, and Woodwell 2006; Grossman and Reed 2006; DesRoches et al. 2008). Using the 2005 NAMCS, Burt and colleagues found a significant relationship between the percent of Medicaid revenue reported and physicians' having EMRs with all four minimally required functionalities (Burt, Hing, and Woodwell 2006). As a sensitivity analysis, we substituted physician-reported revenues from Medicaid for patient panels of Medicaid recipients. No statistically significant association was found after we adjusted for other patient-panel characteristics and characteristics of physicians and their practices.

We did not find a statistically significant difference in EMR adoption between physicians who practice in a CHC setting and others. However, the number of physicians in a CHC setting was small ($n = 171$), and the resulting estimates may not be generalizable. A much larger survey, the first national survey of federally funded CHCs ($n = 725$) found that nationally 26 percent of CHCs reported some EMR use but only 13 percent had the minimally required EMR functionalities in 2006 (Shields et al. 2007). These estimates are comparable with our estimates of the overall adoption rates among office-based physicians (27 percent adopted some EMRs and 11 percent had EMRs with "comprehensive" functionalities).

The major limitation of this study was the small number of patient records used to measure the proportions of underserved populations in *each* physician's panel. We conducted a series of sensitivity analyses with alternative definitions of the dependent and key independent variables and a different model specification. The results of these analyses give us some confidence in our estimates. However, more rigorous assessment was not feasible with the data. For instance, according to the NAMCS documentations, 210 physicians (90 in 2005 and 120 in 2006) only participated minimally (i.e., fewer than half of the expected number of patient report forms were submitted) and patient-panel characteristics calculated for these physicians are likely to be less accurate. Although excluding these physicians may increase the accuracy of our estimates, these physicians are not identifiable from public-use data. Therefore, caution should be exercised when extrapolating our findings.

Other limitations include the lack of information on physicians' demographic characteristics and practice size. Physician age or gender may impact

their willingness to adopt new health technology (Fuji, Galt, and Serocca 2008; Simon 2008; Pagan, Pratt, and Sun 2009). However, a previous study found only age to be significantly associated with EMR adoption (Hing, Burt, and Woodwell 2007), and the effect became statistically insignificant after controlling for practice size (Burt and Sisk 2005). Practice size was the most important factor affecting the EMR adoption, with a uniformly increasing trend in the adoption rate as the number of physicians rises (Burt and Sisk 2005; Hing, Burt, and Woodwell 2007). We controlled for the practice size to some extent through an indicator for solo practices and found that physicians in solo practices had a lower adoption of both EMRs with limited and with "comprehensive" functionalities. Additionally, one of the assumptions underlying the multiplicity method used in generating patient-panel characteristics is that "the characteristics of the sample visit were the same for all visits made [by the same patient] during the year" (Burt and Hing 2007). This assumption is applicable to demographic characteristics such as race and ethnicity, but may not hold for insurance status because patients' insurance coverage may change within a year.

In summary, a higher proportion of Hispanics in a physician's panel was found to be associated with a lower likelihood of adopting EMRs with essential functionalities by the physician. To the extend that a fully functional EMR may increase efficiency and quality of health care services, this finding suggests that existing disparity in health care may have been further exacerbated. Adopting an EMR requires large up-front costs, which is the main barrier to EMR adoption (Miller and Sim 2004) but may be particularly challenging for physicians treating disproportionately minority patients (Reschovsky and O'Malley 2008). The recently passed stimulus package includes provision to promote EMR adoption among physicians by providing up to "U.S.$40,000 to U.S.$65,000 per eligible physician" over 5 years through Medicare or Medicaid incentive payments (Steinbrook 2009). This may provide some relief for those who can act fast and demonstrate "meaningful use" of EMRs. However, the amount that could be received by a physician practice depends on the percentage of Medicare and Medicaid patients at the practice (Neclerio et al. 2009). This may be less helpful among physicians treating large shares of Hispanics as the uninsurance rate among Hispanics is two to three times that of non-Hispanic whites (Doty 2003). Apart from the initial implementation costs, to maintain a fully functional EMR requires long-term technical support and maintenance costs, which may remain a challenge among physicians in high-minority practices after implementation, as majority of minority patients (43 percent) were treated by physicians in solo or partner practices (Hing and Burt

2009). Additional financial support or partnership with large hospital systems for continuing support may be developed (Dolan 2009).

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SUPPORTING INFORMATION

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

Appendix SA1: Author Matrix.

Table SA1: Sensitivity Analysis—Alternative Definitions of Key Independent Variables: Quartiles of Patient Panel Characteristics.

Table SA2: Sensitivity Analysis—Alternative Definitions of Key Independent Variables: Dichotomized Patient Panel Characteristics.

Table SA3: Sensitivity Analysis—Alternative Definitions of Key Independent Variables: Patient Care Revenue.

Table SA4: Sensitivity Analysis—Alternative Definitions of Key Independent Variables: Combination of Race/Ethnicity and Insurance Coverage.

Table SA5: Sensitivity Analysis—Alternative Definitions of EMR Adoption Adapted from DesRoches et al. (2008).

Table SA6: Sensitivity Analysis—Alternative Model Specification: Ordered Logistic Regression.