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Physician EHR Adoption and Potentially Preventable Hospital Admissions among Medicare Beneficiaries: Panel Data Evidence, 2010–2013

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Objective. To test for correlation between the growth in adoption of ambulatory electronic health records (EHRs) in the United States during 2010–2013 and hospital admissions and readmissions for elderly Medicare beneficiaries with at least one of four common ambulatory care–sensitive conditions (ACSCs).

Data Sources. SK&A Information Services Survey of Physicians, American Hospital Association General Survey and Information Technology Supplement; and the Centers for Medicare & Medicaid Services Chronic Conditions Data Warehouse Geographic Variation Database for 2010 through 2013.

Study Design. Fixed effects model estimated the relationship between hospital referral region (HRR) level measures of physician EHR adoption and ACSC admissions and readmissions. Analyzed rates of admissions and 30-day readmissions per beneficiary at the HRR level (restricting the denominator to beneficiaries in our sample), adjusted for differences across HRRs in Medicare beneficiary age, gender, and race. Calculated physician EHR adoption rates as the percentage of physicians in each HRR who report using EHR in ambulatory care settings.

Principal Findings. Each percentage point increase in market-level EHR adoption by physicians is correlated with a statistically significant decline of 1.06 ACSC admissions per 10,000 beneficiaries over the study period, controlling for the overall time trend as well as market fixed effects and characteristics that changed over time. This finding implies 26,689 fewer ACSC admissions in our study population during 2010 to 2013 that were related to physician ambulatory EHR adoption. This represents 3.2 percent fewer ACSC admissions relative to the total number of such admissions in our study population in 2010. We found no evidence of a correlation between EHR use, by either physicians or hospitals, and hospital readmissions at either the market level or hospital level.

Conclusions. This study extends knowledge about EHRs' relationship with quality of care and utilization. The results suggest a significant association between EHR use in ambulatory care settings and ACSC admissions that is consistent with policy goals to improve the quality of ambulatory care for patients with chronic conditions. The null findings for readmissions support the need for improved interoperability

between ambulatory care EHRs and hospital EHRs to realize improvements in readmissions.

Key Words. Electronic health record, EHR, health IT, meaningful use, ambulatory care–sensitive conditions, hospitalizations, readmissions

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Hospital admissions and readmissions for ambulatory care–sensitive conditions (ACSCs) are costly and may signal poor quality of care. Although many patient factors affect both of these measures of hospital use (for example, the patient's diagnosis, severity of illness, and health care seeking behavior), health service delivery factors are important as well (for example, care coordination, case management, and the availability and quality of postdischarge care). Private- and public-sector organizations have been seeking and experimenting with ways to reduce potentially preventable hospital admissions and readmissions, including those for ACSCs. The Centers for Medicare & Medicaid Services (CMS) has launched several programs that target improved transitional care and care coordination for Medicare high-risk patients. CMS has also launched programs that rely on financial incentives to reduce ACSC admission and readmission rates (James 2013). Their success at achieving their intended goals has varied (Brown et al. 2012; Peikes et al. 2013; Carey and Lin 2015).

The Health Information Technology for Economic and Clinical Health (HITECH) Act, part of the American Recovery and Reinvestment Act of 2009, created the Electronic Health Record (EHR) Incentive Program to increase the adoption and use of EHRs by hospitals and physicians. HITECH's central concept was to encourage meaningful use (MU) of electronic health information in both hospital and ambulatory care settings as a way to enhance individual and population health outcomes. MU requirements were envisioned as evolving in three stages, becoming increasingly sophisticated as the capacity of health IT grew. Although the MU Stage 1 criteria deliberately included only basic EHR applications, they did include applications designed to better manage patients' clinical information, including discharge summaries, condition-specific patient lists, and up-to-date problem lists for each patient. They also included tools for sending reminders to

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patients for preventive and follow-up care. These applications could result in more timely and effective care, thus helping to prevent the exacerbation of chronic conditions that can lead to unnecessary hospital admissions and readmissions. Half of primary care physicians and two-thirds of nurse practitioners (NPs) and physician assistants (PAs) responding to a national survey said that use of health IT in ambulatory care settings has a positive effect on their ability to provide quality care to their patients (Ryan et al. 2015). In contrast, only one-third of physicians and 40 percent of NPs and PAs believed medical homes were having a positive effect and fewer than one-third of those participating in an accountable care organization (ACO) thought ACOs were having a positive effect on the quality of care provided to patients enrolled in them.

Most nationwide studies of the role of EHRs in improving quality of care, whether in terms of processes of care (McCullough et al. 2010; Miller and Tucker 2011; Appari, Johnson, and Anthony 2013; McCullough, Parente, and Town 2013) or outcomes for patients (Miller and Tucker 2011; McCullough, Parente, and Town 2013; Agha 2014), have focused on EHR use by hospitals. Several studies have examined the impact of physician use of interoperable EHRs and electronic health information exchange, usually in one community or region of the United States (Frisse et al. 2012; Kaushal, Edwards, and Kern 2015; Vest et al. 2015), and a few recent studies have examined the relationship between health IT use in ambulatory care settings, including EHR use and disease registries, and ACSC admissions (Han et al. 2014; O'Malley, Reschovsky, and Saiontz-Martinez 2015).

The evidence of an association between the extent of provider adoption and use of health IT and hospital admissions or readmissions has been mixed. An early study of the relationship between EHR use and health care quality among Massachusetts physicians in 2005 found no association between use per se and performance on HEDIS measures, but it did find an association for several specific EHR features (Poon et al. 2010). A number of more recent studies have found use of health information exchange systems to be associated with reductions in admissions and readmissions (Frisse et al. 2012; Vest et al. 2014, 2015), whereas others found no link between EHRs and the two use measures (Agha 2014; Han et al. 2014; Kaushal, Edwards, and Kern 2015). In one study, hospital admissions by patients with Type 2 diabetes, with and without congestive heart failure (CHF), were examined; the study found that use of an electronic diabetes registry in a primary care setting was associated with a lower likelihood of an ACSC admission only for diabetes patients without CHF (Han et al. 2014). Another study found no direct link between

health IT and ACSC admissions, although it was noted that use of health IT in conjunction with care coordination between primary care physicians and specialists significantly lowered ACSC admissions relative to care coordination alone (O'Malley, Reschovsky, and Saiontz-Martinez 2015). Yet another study revealed that different uses of health IT, including electronic medication, lab orders, and clinical documentation, have had varying degrees of statistically significant associations with admissions and readmissions (Jones, Friedberg, and Schneider 2011), and in one more study, use of EHRs was associated with lower readmissions only after a preventable patient safety event, such as complications from anesthesia or infections due to medical care (Encinosa and Bae 2011). Additionally, a recent systematic review found that results in studies of health information exchange were largely dependent on study design; nearly all reviewed studies using cohorts or cross-sectional samples found a significant beneficial effect of health information exchange on hospital admissions and readmissions, but none that used randomized or quasi-experimental samples found a similar relationship (Rahurkar, Vest, and Menachemi 2015).

Although this evidence shows an unclear relationship between health IT use and hospital admissions, particularly those related to ACSCs, all but one of the studies described above (Han et al. 2014) used data collected before the enactment of the HITECH Act. Thus, the results of these earlier studies may not be indicative of the effects of the more sophisticated health IT systems developed since HITECH was implemented, nor the lessons learned as more ambulatory care physicians and other providers implement health IT.

We expand on the existing evidence by examining data from 2010 to 2013, which spans a period beginning immediately before the launch of the HITECH Act and continuing through the early years of its implementation. We hypothesize that EHRs enable physicians in ambulatory care settings to better manage complex clinical information, particularly for patients with chronic conditions who are at risk for greater utilization of inpatient services. Many of the MU Stage 1 objectives for Eligible Professions contribute, in theory, to improving the clinician's ability to track relevant clinical information for each of their patients and provide more effective consulation to their patients about care. As one example among many, the objective of "maintaining an up-to-date problem list of current and active diagnoses" should help physicians to consider the complete clinical circumstance of a patient and thereby make more clinically relevant recommendations to the patient. Furthermore, the MU objectives to implement drug–drug and drug allergy checks, as well as generate and transmit prescriptions electronically, are associated with reduced likelihood of adverse drug events in both ambulatory care

settings and hospitals (Encinosa and Bae 2015; Powers et al. 2015). The MU objective to send reminders to patients for preventive and follow-up care (CMS 2012) has the potential to increase the frequency of contact with outpatient care, and the MU objective to incorporate clinical decision support rules can, for example, alert providers of abnormal test results and give reminders to clinicians about evidence-based protocols (Shelley et al. 2011). These MU-related EHR features may prevent exacerbations of chronic conditions that would otherwise lead to inpatient stays.

We test for correlations between the market-level growth in EHR adoption and use by ambulatory care physicians during 2010–2013 and hospital admissions and readmissions for Medicare beneficiaries with at least one of four common ACSCs—chronic obstructive pulmonary disease (COPD), CHF, diabetes, and ischemic heart disease (IHD). Since such patients with chronic conditions are at risk for high health care utilization, they present an important test case for the impact of new adoption and use of EHRs on utilization. We use the hospital referral region (HRR) as our definition of a market. HRRs are defined by the Dartmouth Atlas of Health Care as regional markets based around hospitals providing major cardiovascular surgical procedures and neurosurgery to Medicare patients (Dartmouth Atlas of Health Care Working Group 1998). By focusing on market-level measures of health care utilization and EHR diffusion, this study contributes to understanding whether policy interventions such as incentivizing EHR use can alter otherwise persistent variation in health care utilization that has been documented to occur across health care markets (Skinner 2011; Chicklis et al. 2015).

We find that increases in EHR penetration among physicians in ambulatory care settings are correlated with decreases in ACSC admissions for these Medicare patients. When we examine each of the four chronic conditions separately, we find that CHF patients show the largest magnitude decrease in ACSC admissions correlated with physician EHR adoption. We find no correlation between hospital EHR and ACSC admissions nor between either measure of EHR and 30-day all-cause readmissions to hospitals.

Data and Methods

Data and Study Population

We constructed our hospital admissions and readmissions measures using data from the Medicare Provider Analysis and Review files. Our EHR measures

for ambulatory care physician practices comes from the SK&A Information Services Survey of Physicians. The EHR measure for hospitals comes from the IT Supplements to the American Hospital Association (AHA) Annual Survey. Our study population consists of Medicare beneficiaries aged 65 and older who have at least one of four common chronic conditions and who were enrolled in Medicare Parts A and B for all 12 months of the calendar year, or for all months during which the beneficiary was alive in the cases of those who died during a given year. After applying these selection criteria, we had a sample of approximately 14.9 million beneficiaries in each year from 2010 through 2013; the sample members were grouped according to residence into 306 HRRs, identified by the Dartmouth Atlas of Health Care as regional health care markets.

Outcome Measures

We identified all hospital stays involving members of our sample of Medicare beneficiaries, using the Agency for Healthcare Research and Quality's criteria for ACSC admissions (also referred to as prevention quality indicators) related to the four chronic conditions of interest (Davies et al. 2001, 2009; AHRQ 2013). We used the hospital stay-level data to construct rates of admissions per beneficiary at the HRR level (restricting the denominator to beneficiaries in our sample). In particular, we aggregated ACSC admission rates into condition-specific rates as well as one overall composite rate; all rates were adjusted for differences in the Medicare beneficiaries' age, sex, and race distributions across HRRs. In addition to calculating HRR-level averages of ACSC admission rates for this sample, we also calculated HRR-level averages of demographic characteristics to use as covariates.

We also applied methods developed by the Yale New Haven Health Services Corporation/Center for Outcomes Research and Evaluation to construct our 30-day, all-cause, unplanned hospital readmission rates (at the hospital level) for short-term acute care hospitals. Our calculations of readmission rates capture unplanned readmissions within 30 days of discharge and are risk-adjusted to account for clinically relevant variables, including age, principal discharge diagnosis, and comorbid diseases (Horwitz et al. 2012). We also constructed a 30-day, all-cause, unplanned readmission rate per 10,000 beneficiaries with at least one of the four conditions at the HRR level. We analyzed readmissions at these two different levels because health IT may change the denominator of the hospital readmission rate by affecting the ACSC admission rate—that is, reducing the number of ACSC

admissions also reduces the number and type of discharges at risk of a readmission. Since there may be changes in both the numerator and denominator of the hospital readmission rate due to EHRs, examination of hospital-level rates alone may obscure overall reductions in the number of hospital readmissions. For example, if improved care coordination and case management through increased use of EHRs led to reductions in the number of ACSC admissions and readmissions of equal proportions, the hospital-level ratio of readmissions to admissions would stay the same while the population level ratio of readmissions to total beneficiaries would decrease (Brock et al. 2013; Lynn 2014).

EHR Measures

We created two measures of EHR penetration at the market level for our analysis—one physician EHR measure and one hospital EHR measure. The measure of hospital EHR market penetration is intended to capture the degree to which hospitals in the HRR have met MU Stage 1 criteria. We used the SK&A database to calculate our measure of EHR penetration among physicians—the percentage of physician respondents in the HRR who were working in a medical office that reported use of an EHR. SK&A is a market research firm that collects information in each quarter from a census of ambulatory health care sites having at least one provider with prescribing authority in the 50 states and the District of Columbia; there were 2,420,212 physician-year observations for the period from 2010 to 2013. We averaged the quarterly data for each physician respondent in each year (adding the number of "yes" responses for a given physician over each quarter of a year and dividing by four) and then calculated the percentage of physician respondents each year in each HRR who report using an EHR in ambulatory care settings. While this measure captures a very basic level of EHR use, it has the advantage of being from a census of ambulatory health care sites and of covering the period before HITECH as well as during the early years of the program.[1]

The hospital EHR measure was based on AHA IT survey data.[2] Approximately 3,900 short-term acute care hospitals responded to the AHA General Survey and the IT Supplement in at least 1 year during the period from 2010 through 2013. In any year, hospitals that did not respond to both the AHA General Survey and the IT supplement were dropped from our sample and were not included in the calculation of the HRR-level measure. This resulted in dropping 40 percent of the initial set of possible hospital

observations. The final sample used in our HRR-level measure included 10,880 hospital-year observations from the AHA General Survey that also had responses from the IT Supplement survey. The AHA measure was based on whether a hospital was MU-ready, that is, whether it had implemented all eight core EHR applications included in the Stage 1 MU criteria that are reported in the AHA IT Supplement—patient demographics, patient problem lists, patient medication lists, discharge summaries, computerized provider order entry for medications, drug–allergy alerts, drug–drug interaction alerts, and any one of four clinical decision support rules (ONC 2015). We then calculated the percentage of Medicare discharges in each HRR from hospitals that reported MU readiness.

Regression Analysis

We constructed a balanced panel dataset of 1,224 HRR-year observations (306 HRRs over 4 years) for the ACSC admissions analysis and the HRR-level readmissions analysis and an unbalanced panel of 3,918 hospitals over 4 years for a total of 10,880 hospital-year observations for the hospital-level readmissions analysis. We estimated the correlation between outcomes and EHR penetration using ordinary least squares with HRR fixed effects to mitigate bias due to unobserved confounding variables among HRRs. We include controls for beneficiary characteristics such as race (the percentage of nonwhite beneficiaries); age (four categories specifying percentages of beneficiaries ages 71–75, 76–80, 80–85, and 86 or older); percentage who reside in a rural area (fewer than 1,000 people per square mile); and in a Micropolitan Statistical Area (areas centered on an urban cluster with a population of 10,000 to 49,999 people). We also include the average Hierarchical Condition Category score, which is a risk score calculated by CMS based on beneficiary characteristics such as age, gender, eligibility for Medicaid, and diagnoses from the previous calendar year. Furthermore, we control for relevant market characteristics that fluctuate over time—hospital market concentration (Herfindahl-Hirschman Index); the percentage of Medicare beneficiaries discharged from nonprofit, for-profit, and government-owned hospitals; and the percentages of Medicare beneficiaries discharged from critical access hospitals, members of multihospital systems, hospitals that belong to the Council of Teaching Hospitals, and those with residency training programs. The standard errors of the coefficients of all independent variables were adjusted for clustering by HRR.

STUDY RESULTS

Ambulatory Care Sensitive Conditions Admissions

There were small decreases in the average rate of ACSC admissions per 10,000 beneficiaries from 2010 to 2013 for four of the five types of admissions examined in our study, including the overall composite admissions rate (Table 1). Over the study time period, the composite ACSC admission rate decreased a total of 3.6 percent from its 2010 baseline level. Only the COPD/asthma-related ACSC admission rate increased over this time period—by 2.6 percent relative to its baseline level.

From 2010 to 2013, the hospital-level average readmission rate decreased by about 10 percent from 16.2 to 14.6 percent of admissions, and the HRR-level readmission rate decreased by about 15 percent from 892 to 762 per 10,000 beneficiaries in our sample (Table 1). Over this same period, there was an increase in both physician and hospital EHR penetration measures (Table 2). Physician EHR penetration rose from 50 to 72 percent over this period, while the percentage of Medicare discharges from MU-ready hospitals rose from 14 to 41 percent. Although, on average, both physician and hospital EHR indicators increased during the study period, the correlation between them at the HRR level was low at 0.31.

We find a statistically significant negative correlation between composite ACSC admissions per 10,000 beneficiaries with the four chronic conditions and the physician EHR penetration measure—a decrease in 1.06 in the composite admission rate per percentage-point increase in the physician EHR adoption rate (Table 3). Given the observed change in physician EHR adoption and the number of Medicare beneficiaries in the sample, the results translate into 26,689 fewer ACSC admissions in the study population during 2010 to 2013 than if physician ambulatory EHR use had remained at its 2010 level. This represents 3.2 percent fewer ACSC admissions relative to the total number of such admissions in our study population in 2010. This result appears to be driven primarily by a decrease in 1.62 admissions per 10,000 beneficiaries with CHF for each percentage-point increase in physician EHR penetration. While the correlations between physician EHR penetration and three of the condition-specific ACSC admission rates (diabetes, IHD, and CHF) are all negative as hypothesized, only the correlation with the CHF-related admission rate is statistically significant. The association between hospital MU readiness and ACSC admissions is negative for the composite rate as well as the subgroup rates; however, none of these correlations are statistically significant.

Table 1: Summary Statistics for ACSC Admissions: 306 HRRS, 2010 and 2013

	Overall Composite ACSC Admission Rate		*Diabetes Related Composite ACSC Admission Rate*		*Ischemic Heart Disease ACSC Admission Rate*		*Congestive Heart Failure Admission Rate*		*Admission Rate for COPD or Asthma in Older Adults*		*30-Day Readmissions—Hospital Level*		*30-Day Readmissions—HRR Level*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
2010	571.8	3,126.8	131.7	1,363.1	45.5	710.1	889.3	3,731.6	886.8	3,755.8	16.2%	4.9	892.3	187.7
2013	551.3	3,004.7	115.6	1,303.6	36.1	629.5	878.1	3,610.3	910.0	3,699.3	14.6%	5.0	762.4	145.1

Notes. ACSC admission rates given above are per 10,000 beneficiaries among those who had at least one of four chronic conditions and were aged 65 and older and enrolled in fee-for-service Medicare for all months during which the beneficiary was alive in a year. ACSC admission rates are adjusted for age, gender, and race differences across HRRs.

HRR readmission rates given above are per 10,000 beneficiaries, among those who had at least one of four chronic conditions and were aged 65 and older and enrolled in fee-for-service Medicare for all months during which the beneficiary was alive in a year.

ACSC, ambulatory care–sensitive condition; COPD, chronic obstructive pulmonary disease.

Table 2: Summary Statistics for EHR Penetration

	Physician EHR		*AHA MU Ready*	
	Mean	*SD*	*Mean*	*SD*
2010	50%	9	14%	35
2013	72%	7	41%	49

Notes. We calculated the physician EHR measure as annual national averages over physician-level data and the hospital EHR measure as annual national averages over hospital-level data, weighted by the number of Medicare discharges.
AHA, American Hospital Association; EHR, electronic health record; MU, meaningful use.

During the period of this study there was a significant temporal trend of a decrease in the composite ACSC admission rate relative to the baseline rate in 2010 (Table 3). The regression-adjusted average composite ACSC admission rate declined in 2011 and 2012 relative to the 2010 rate and continued to fall in 2013 when the regression-adjusted average was 61.9 per 10,000 below the 2010 level—a decrease in 10.8 percent relative to the 2010 ACSC admission rate in this study population.

Hospital Readmissions

We find no statistically significant correlations between the physician and hospital EHR penetration rates and the 30-day unplanned readmission rates at either level of measurement (Table 4). There is, however, an interesting pattern to contrast in the time trends—that is, the trend is statistically significantly negative for readmissions at the HRR level, whereas at the hospital level, the temporal trend in the regression-adjusted average readmission rate showed little movement between 2010 and 2013. Although there was a statistically significant increase of 1.45 percentage points in the hospital-level readmission rate from 2010 to 2011, the 2012 and 2013 regression-adjusted averages were not statistically different from the 2010 rate (Table 4). However, at the HRR level, the regression-adjusted average number of 30-day readmissions per 10,000 beneficiaries exhibited a trend similar to that of the composite ACSC admission rate. The HRR-level regression-adjusted average in our analysis fell steadily in each of the 3 years after 2010, and it was statistically significantly lower than the 2010 average in each of those years. In 2013, the regression-adjusted average number of readmissions was lower than the 2010 regression-adjusted average by 92 per 10,000 beneficiaries (a 10.3 percent decrease relative to the baseline level).

Table 3: EHR Penetration and ACSC Admission Rates, 2010–2013

	Composite ACSC Admission Rate	*Diabetes-Related ACSC Admission Rate*	*IHD ACSC Admission Rate*	*CHF Admission Rate*	*Admission Rate for COPD or Asthma in Older Adults*
Physician EHR measure	−1.06** (0.50)	−0.05 (0.20)	−0.15 (0.14)	−1.62* (0.96)	1.03 (1.19)
Hospital meaningful use ready measures	−0.07 (0.06)	−0.02 (0.02)	−0.01 (0.02)	−0.11 (0.10)	−0.12 (0.12)
Year fixed effects (relative to 2010)					
2011	−15.5*** (3.9)	−1.8 (1.7)	−2.4** (1.1)	−27.7*** (7.5)	−34.7*** (9.6)
2012	−50.4*** (8.3)	−15.7*** (3.3)	−3.0 (2.5)	−47.4*** (17.8)	−108.9*** (19.9)
2013	−61.9*** (13.4)	−17.3*** (5.4)	−7.7** (3.7)	−30.5 (27.3)	−163.3*** (32.3)

Notes. Each column represents a separate regression. Marginal effects per 10,000 beneficiaries are presented. Standard errors clustered by HRR are given in parentheses.

Each regression includes controls for the percentage of nonwhite beneficiaries; percentages of beneficiaries ages 71–75, 76–80, 80–85, and 86 or older; percentages who reside in a rural area and in Micropolitan Statistical Areas; average Hierarchical Condition Category score; hospital Herfindahl-Hirschman Index; the percentages of Medicare beneficiaries discharged from for-profit and government-owned hospitals; and the percentages of Medicare beneficiaries discharged from critical access hospitals, members of multihospital systems, hospitals that belong to the Council of Teaching Hospitals, and hospitals with residency training programs.

***$p < .01$, **$p < .05$, *$p < .10$.

ACSC, ambulatory care sensitive condition; CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; eHR, electronic health record; IHD, ischemic heart disease.

Table 4: EHR Adoption and 30-Day Readmissions at the Hospital and HRR Levels

	Hospital Readmissions	*HRR-Wide Readmissions*
Physician EHR measure	−0.00026 (0.00077)	−0.79 (0.68)
Hospital meaningful use ready measures	0.0009 (0.0044)	−0.100 (0.088)
Year fixed effects (relative to 2010)		
2011	0.0145*** (0.0046)	−11.46** (4.80)
2012	0.0088 (0.0089)	−49.32*** (10.62)
2013	0.017 (0.015)	−92.11*** (17.02)

Notes. Each column represents a separate regression. The hospital-level regression has a sample of 3,918 hospitals and controls for hospital fixed effects. Standard errors, clustered by hospital, are given in parentheses. Marginal effects in the hospital-level regressions are changes in the percentage of admissions resulting in 30-day readmissions. The HRR-level regression has 306 HRRs, controls for HRR fixed effects, and the results above present marginal effects per 10,000 beneficiaries. Standard errors, clustered by HRR, are given in parentheses.
Each regression included controls for the percentage of nonwhite beneficiaries; percentages of beneficiaries ages 71–75, 76–80, 80–85, and 86 or older; percentages who reside in a rural area and in a Micropolitan Statistical Area; average Hierarchical Condition Category score. The hospital-level regression additionally controlled for total annual hospital admissions. The HRR-level regression had additional controls for market-level hospital Herfindahl-Hirschman Index; the percentages of Medicare beneficiaries discharged from for-profit and government-owned hospitals; the percentages of Medicare beneficiaries discharged from critical access hospitals, members of multihospital systems, hospitals that belong to the Council of Teaching Hospitals, and hospitals with residency training programs.
***$p < .01$, **$p < .05$.
EHR, electronic health records; HRR, hospital referral region.

DISCUSSION

Both ACSC admissions and readmissions had a secular decline over the study period, 2010–2013, perhaps due to the impact of myriad federal and private interventions aimed at decreasing potentially avoidable hospitalizations. The recent national trend of declining hospitalization rates among Medicare fee-for-service beneficiaries has been documented in at least one other recent study (Krumholz et al. 2015). Although other unobserved factors are contributing to a decline in admissions, our findings show that increasing HRR-level adoption of physician EHR is significantly correlated with the observed decline in ACSC admissions, controlling for the average trend nationwide and other market characteristics. A comparison of the magnitudes of the EHR-associated decrease in the ACSC admission rate (a 3.2 percent decrease between 2010 and 2013) and the temporal trend (a 10.8 percent decrease between 2010 and 2013) indicates that the aggregate change in ACSC admissions associated with physician EHR was one-third the size of the temporal

change in ACSC admissions due to other unobserved factors. Our results suggest an impact on ACSC admissions that is consistent with the intended goals of the HITECH Act—reducing inefficient care and improving the quality of ambulatory care for patients with chronic conditions. We do not find, however, statistically significant correlations between hospital MU readiness and ACSC admissions. This finding is not too surprising since hospital adoption and use of EHRs may have only an indirect effect through improved quality of outpatient services and in some cases the ability to exchange information with ambulatory care providers (although the prevalence of such capability was limited during the period of this study).

Furthermore, we find no evidence of a significant negative correlation between ambulatory care physician or hospital EHR penetration and readmission rates when we use either hospital-level or HRR-level measures. Readmission rates within 30 days of a hospital discharge among all Medicare beneficiaries have historically persisted at around 19 percent of hospital discharges (James 2013)—somewhat greater than the 16 percent rate at baseline that we found in our sample of chronically ill beneficiaries. Modest reductions that have taken place during the first couple of years (2012–2013) of the Medicare Hospital Readmission Reduction Program (HRRP) have been concentrated among patients with acute myocardial infarction, heart failure, and pneumonia—the three conditions focused on by the HRRP (James 2013), only one of which overlaps with the conditions in this study. The high baseline rate of 50 percent physician EHR adoption in 2010 that we found occurred within a context in which the 30-day hospital readmission rate was near its historically persistent level. Our null findings for a relationship between physician and hospital EHR use and 30-day readmissions suggest that reducing readmissions may require a level of interoperability between EHRs in ambulatory care settings and hospital settings that is not yet present in most markets.

Our finding that the time trends are significantly negative for both ACSC admissions and readmissions at the HRR level, whereas the trend in hospital-level readmission rates is essentially flat, is consistent with the critique by Lynn et al. (Brock et al. 2013; Lynn 2014). That is, if market forces and policy interventions, including EHR growth and other quality improvement interventions, are leading to reductions in potentially preventable hospital admissions, using hospital-level readmission rates ignores the impact of these forces on the number and composition of admissions (the denominator). Analyzing the rate of readmissions per total beneficiaries in a given population, such as all beneficiaries in an HRR, eliminates this problem and may be the preferred marker of quality in these situations.

The national health IT landscape has undergone a significant transformation over the past decade. Use of health IT by both hospitals and ambulatory care providers has increased substantially. Forty-six percent of eligible professionals, including 54 percent of eligible physicians, and 95 percent of eligible hospitals (as of April 2015) have attested to meeting the Stage 1 MU criteria (ONC 2015). Through the HITECH Act, the federal government committed $27 billion in incentive payments to eligible providers for meeting MU objectives over a 10-year period (Blumenthal and Tavenner 2010), and through 2013, the Medicare incentive program made payments of just over $4 billion to eligible professionals and nearly $7.9 billion to eligible hospitals (Centers for Medicare and Medicaid Services 2015). Our results show that the growth in adoption and use of EHRs by physicians in ambulatory care settings has a modest negative association with ACSC admissions among chronically ill Medicare patients that is consistent with policy goals. For further context, we note that in a separate analysis reported elsewhere we estimated approximately $1.6 billion in reductions for Medicare Part A acute care expenditures among the same population of patients as in this study that was associated with the increase in physician ambulatory care EHR use during 2010–2013 (Lammers and McLaughlin 2016). It is likely that these expenditure reductions are due in large part to the reduction in ACSC admissions found in this study. While this represents savings that are only about 13 percent of the size of the incentive payments during the same period, it is important to keep in mind that this study narrowly examines a particular population of Medicare patients. In addition to the associations we observed between Medicare hospitalizations and expansion of EHR use, policy makers will also want to know if growth in EHR use among Medicaid providers is associated with decreased ACSC admissions and readmissions among Medicaid patients since the EHR Incentive Program also rewards Medicaid providers for achieving MU. Although there have been few studies of ACSC admissions or readmissions in the Medicaid population, one recent study based on 2010 data found that Medicaid readmissions were both prevalent and costly, with five major diagnostic categories accounting for the majority of admissions and readmissions (Trudnak et al. 2014).

Our study has a number of limitations that should be kept in mind. The measure of EHR use by physicians in ambulatory care settings is very blunt; that is, it does not capture variation in the use of specific EHR features. While our use of an HRR fixed effects regression model mitigates some sources of bias in estimating the relationship between EHR penetration and admission and readmission rates, we cannot be sure that growth in EHR use caused the

decline in admissions. Unobserved HRR characteristics that changed over the same time, such as other quality improvement efforts, including medical homes and ACOs, may confound the relationship between EHR use and admissions and readmissions. While it is possible that these other changes account for some of the correlations we find, it is also possible that adoption of EHRs enhanced, if not enabled, other innovations to have those effects (Hsiao et al. 2015). Furthermore, it is important to recognize that the observed correlations between EHR adoption and hospital admissions and readmissions are at the market level. Therefore, we cannot say that any individual patient will have a decreased likelihood of hospital admission if her ambulatory care physician uses an EHR.

Conclusion

This study extends the research about EHR's impacts on quality of care and utilization by examining a recent period beginning immediately before the launch of the HITECH programs and extending through the early years of their implementation. We shed new light on the relationship between physician use of EHR in ambulatory settings, as well as hospital use of EHR, and hospital admissions and readmissions. Our findings support a market-level association between recent increases in EHR penetration among ambulatory care physicians and declining ACSC admission rates in an elderly population with four common chronic conditions, but we find no such correlation between EHR penetration and readmission rates. This latter result may support the need for improving interoperability between EHRs in ambulatory care settings and hospital settings to realize improvements in readmission rates. A useful extension of this research would be to explore this relationship in other vulnerable populations, including Medicaid patients.

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NOTES

1. Medicare EHR Incentive Program Eligible Professionals Public Use data provides a potential alternative measure of physician EHR use; however, it does not encompass a time period prior to HITECH programs as the SK&A data does. We chose to use the SK&A data because we wanted to account for changes over time in provider adoption relative to a baseline level of use prior to the CMS EHR Incentive Programs.
2. We also conducted a sensitivity analysis using an alternative measure of hospital EHR penetration with another widely used data source, the Health Information Management Systems Society (HIMSS) Analytics annual survey. In particular, we used a measure of Stage 4 or greater of the HIMSS Electronic Medical Record Adoption Model, which is generally regarded as reflecting EHR capabilities equivalent to those of Stage 1 MU. All findings of this alternative analysis were quantitatively similar to and qualitatively the same in terms of statistical significance as the results using AHA-based measures of EHR adoption and use.

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SUPPORTING INFORMATION

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

Appendix SA1: Author Matrix.