

# Using Electronic Health Record Clinical Decision Support Is Associated With Improved Quality of Care

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**T**he CMS Electronic Health Record Incentive Program, better known as “meaningful use,” provides initial monetary incentives for adoption of electronic health records (EHRs) and subsequently imposes monetary penalties if physician practices do not meet requirements. The meaningful use program has spurred a significant rise in the number of office-based physicians reporting EHR use, from 24% in 2005 to 48% in 2009 to 72% in 2012.<sup>1</sup>

The meaningful use goals and objectives are divided into 3 stages. Stage 1 requirements include using a certified EHR to capture and share patient data by 2015; stage 2, beginning in 2014, includes use of advanced care processes with clinical decision support (CDS); and stage 3, to begin in 2016, will require providers to demonstrate outcome improvements. The time frame for stages 2 and 3 was recently extended.<sup>2</sup> As of March 2013, 73% of eligible providers had registered to participate in the meaningful use incentive program and 44% of eligible providers had received incentive payment for meeting meaningful use objectives.<sup>3</sup>

Although the meaningful use requirements have already been established, the evidence is inconsistent regarding improvement in healthcare processes or patient outcomes as a result of the implementation of general and individual EHR components. Prior studies have shown that EHR-based CDS is associated with improved prescribing safety,<sup>4</sup> preventive care measures,<sup>5</sup> and diabetes testing and control.<sup>6</sup> CDS has also been associated with some improvements in quality indicators,<sup>7</sup> but results have been variable.<sup>8-11</sup> Despite having EHRs, many physicians report being unable to complete basic panel management activities,<sup>12</sup> which affects their ability to deliver high-quality care for patients with chronic conditions.

Notwithstanding the mandate to use certified EHRs, use of an EHR in the outpatient setting has not yet been shown unequivocally to improve quality indicators across a broad

## ABSTRACT

### Objectives

To determine whether clinical decision support (CDS) is associated with improved quality indicators and whether disabling CDS negatively affects these.

### Study Design/Methods

Using the 2006-2009 National Ambulatory and National Hospital Ambulatory Medical Care Surveys, we performed logistic regression to analyze adult primary care visits for the association between the use of CDS (problem lists, preventive care reminders, lab results, lab range notifications, and drug-drug interaction warnings) and quality measures (blood pressure control, cancer screening, health education, influenza vaccination, and visits related to adverse drug events).

### Results

There were an estimated 900 million outpatient primary care visits to clinics with EHRs from 2006-2009; 97% involved CDS, 77% were missing at least 1 CDS, and 15% had at least 1 CDS disabled. The presence of CDS was associated with improved blood pressure control (86% vs 82%; OR 1.3; 95% CI, 1.1-1.5) and more visits not related to adverse drug events (99.9% vs 99.8%; OR 3.0; 95% CI, 1.3-7.3); these associations were also present when comparing practices with CDS against practices that had disabled CDS. Electronic problem lists were associated with increased odds of having a visit with controlled blood pressure (86% vs 80%; OR 1.4; 95% CI, 1.3-1.6). Lab result notification was associated with increased odds of ordering cancer screening (15% vs 10%; OR 1.5; 95% CI, 1.03-2.2).

### Conclusions

The use of CDS was associated with improvement in some quality indicators. Not having at least 1 CDS was common; disabling CDS was infrequent. This suggests that meaningful use standards may improve national quality indicators and health outcomes, once fully implemented.

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**Take-Away Points**

- The use of some electronic health record clinical decision support (CDS) was associated with improved quality of care among national primary care outpatient visits from 2006 to 2009.
- Most practices were missing at least 1 CDS module considered essential by meaningful use standards.
- Meaningful use standards may have a significant impact on national quality of care and health outcomes once fully implemented.

range of practices and EHRs, especially because there is substantial variability among the 1600 certified EHR platforms.<sup>13</sup> In addition to the large number of EHRs, they also can be customized to each practice's needs and resource availability, so results will vary between practices in terms of impact on care even with the use of a single vendor's practice. Certain types of practices, such as smaller community-based practices, may be less able to fully implement a complete EHR with clinical decision support, which is the kind postulated to have the greatest potential to improve quality.<sup>14,15</sup> Decisions about choices around the CDS functions implemented may affect the quality of care delivered by that practice. To further inform the potential effect of meaningful use stages 2 and 3, we examined the association between having CDS, not having CDS, and disabling CDS, and quality of care indicators using nationally representative data just prior to the start of the meaningful use incentive program.

**METHODS**

We performed a retrospective, cross-sectional analysis of adult primary care ambulatory clinic visits in the National Ambulatory Medical Care Survey (NAMCS) and National Hospital Ambulatory Medical Care Survey (NHAMCS) outpatient department records from 2006-2009 in order to analyze data with little impact from current meaningful use incentive payments. We examined a number of patient and practice characteristics to determine any differences in access to practices with EHRs based on prior work showing associations between these characteristics and EHR availability.<sup>8,14,16</sup> On the premise that most preventive care takes place through a primary care practice, we limited our sample to just those practices.

**Data Source**

The NAMCS and NHAMCS are conducted by the Ambulatory Care Statistics Branch of the National Center for Health Statistics (NCHS) of the CDC. These surveys focus on outpatient visits to non-federally funded US medical practices.

The NCHS uses a complex multistage probability sampling design based first on geography, then physician specialty, and finally patient visits to individual practices. Information is collected at ambulatory visits by participating practices or US Census Bureau representatives. The NCHS assigned weights to each visit record to allow for estimation of national statistics. The NCHS institutional review board approves the protocols for the NAMCS and NHAMCS, including a waiver of informed consent for patients.

The NAMCS collects information at a visit level from community-based physician practices; from 2006 to 2009, approximately 30,000 community-based office visits were recorded annually. The NHAMCS collects information at a visit level from hospital-based physician practices; from 2006 to 2009, approximately 34,000 hospital-based office visits were recorded annually.

In all years included in the analysis, both the NAMCS and NHAMCS included questions in their intake surveys that asked whether the practice had an electronic medical record (for other than billing purposes), a computerized patient problem list, computerized warnings of drug interactions or contraindications, a computerized system to view lab results, a computerized system that highlights out-of-range lab values, and a computerized system for reminders for guideline-based interventions and/or screening tests. Response variables indicated that a practice had a function ("yes"), did not have a function ("no"), had the function but disabled it ("turned off"), or was unsure if the practice had the function ("don't know" or "blank").

The NAMCS and NHAMCS record health information for each visit sampled. The respondent indicates the top 3 reasons for the visit, which are then coded by NCHS; the patient's vital signs, including blood pressure; whether any health education was ordered or provided during the visit; and whether an influenza vaccination was ordered or administered during the visit. The respondent also indicates any screening services ordered or performed during the visit. The respondent can record mammography, Pap smears, and scope procedures (NCHS records and codifiers, free text scope procedures, 1 of which is sigmoidoscopy/colonoscopy), among others.

The NAMCS and NHAMCS collect patient and practice demographic information: patient age, patient race, patient income category (imputed based on patient zip code by NCHS), primary reason for the visit, region of the country, practice ownership, and number of physicians in the practice (solo or non-solo). Race data are col-

■ **Table 1.** Potential Association Between Electronic Health Record Functions and Clinical Quality Outcomes Evaluated

		Electronic Health Record Functions					Composite of All Functions
		Preventive Care Reminders	Problem Lists	Lab Results	Out of Range Lab Notification	Drug-Drug Interaction Warnings	
Clinical Quality Outcomes	Controlled blood pressure	✓	✓				✓
	No adverse drug events			✓	✓	✓	✓
	Preventive care (composite of below)	✓	✓				✓
	Health education	✓	✓				✓
	Cancer screening	✓	✓	✓	✓		✓
	Influenza vaccine, Oct-Mar	✓					✓

lected in the manner already in use by the practice. Due to high nonresponse rates for race (24% to 33% in NAMCS, and 12% to 15% in NHAMCS for the years included), the NCHS also provides a race variable imputed based first on the patient's location, then on physician specialty and *International Classification of Diseases, Ninth Revision, Clinical Modification* code for primary diagnosis, and finally on a random basis.

### Data Analysis

Our predictors of interest were EHR CDS modules mandated by stage 1 of meaningful use: electronic problem lists, preventive care reminders, lab result reporting, out-of-range lab notification, and drug-drug interaction warnings. We performed analyses with each predictor separately, and performed analyses combining them into a composite group of key EHR features. Based on prior work that examined associations between certain EHR features and clinical outcomes,<sup>4,5,9,11,17,18</sup> we developed a matrix between CDS functions and the clinical outcomes of interest and performed analyses accordingly (Table 1).

Our main outcomes of interest were based on national quality metrics related to adult primary care: blood pressure control (defined as a systolic blood pressure less than 140 mm Hg), age- and gender-appropriate cancer screening (mammography, Pap smear, and sigmoidoscopy or colonoscopy), health education for particular conditions, influenza vaccination during the months of October through March, and adverse drug events (as measured by visits coded to be related to an adverse drug event). We also combined the receipt of cancer screening, health education, and influenza vaccination into a composite "preventive care" outcome measure.

We were interested in the difference in outcomes based on whether a practice had a CDS function or not. Specifically, we examined whether there were significant differences in the rates of the clinical outcomes depending on whether a visit was to a practice with the CDS or without the CDS.

We categorized practices into 3 groups: all CDS tools active; without 1 or more CDS function; or any disabled CDS. We considered the practice to have all CDS active if they answered "yes" to having all 5 of the individual CDS. We considered the practice to be without 1 or more CDS functions if they answered "no," "turned off," "don't know," or "blank" to any of the CDS functions. We considered the practice to have "disabled CDS" if they answered "turned off" for any of the CDS functions.

We collapsed practice ownership into 5 categories: physician or physician group, community health center, health maintenance organization, medical or academic health center, and other. All other covariates were used as provided by NCHS.

### Statistical Analysis

The unit of analysis was the patient visit. We followed NCHS guidelines based on the hierarchical sampling design. We performed all statistical tests on data with less than a 30% relative standard error (the standard error divided by the estimate itself) and more than 30 sample records.

We used multivariable logistic regression modeling to control for a number of patient and practice level covariates. We modeled age as a continuous variable, and all other covariates as categorical variables. We evaluated categorical variables with the  $\chi^2$  test and continuous variables with the *t* test. We performed multivariable logistic

regression modeling for each quality measure individually. The main predictors of interest were the status of the EHR CDS function. We considered *P* values of less than .05 to be significant.

We used SAS statistical software (version 9.3; SAS Institute, Cary, North Carolina) for all analyses.

## RESULTS

From 2006-2009, the NAMCS/NHAMCS databases included 104,102 adult primary care visits, representing 2 billion adult primary care visits in the United States. Of these, 45% of visits were to practices with EHRs. Of those visits, 97% also had at least 1 of the 5 CDS functions of interest. Of visits using EHRs with at least 1 CDS function, 77% did not have (for any reason), and 15% had disabled (actively turned off), at least 1 of the 5 CDS functions of interest.

We compared patient and practice demographics for visits to clinics with all the CDS functions versus visits to clinics with at least 1 CDS function missing (Table 2). Patients were of similar age (50.9 years vs 51.1 years, *P* = 0.84). Rates of visits for flares of chronic problems (7%) and pre- or post surgery (2%) were similar between the 2 groups; rates of visits for new problems (39% vs 41%) and follow-up of chronic problems (32% vs 33%) were less common and visits for preventive care (17% vs 16%) were more common at clinics without at least 1 of the CDS functions versus clinics with all the CDS functions (*P* <.0001). Of visits to practices with at least 1 CDS function missing versus those to practices with all the CDS functions, rates of visits to health maintenance organizations (3% vs 7%) were lower, and to physician groups (60% vs 50%), community health centers (5% vs 3%), or medical/academic health centers (18% vs 12%) were higher (*P* <.0001). There were no differences in the distribution of visits to clinics without at least 1 of the CDS functions versus visits to clinics with all the CDS functions by gender, race, or region of the country.

Most patients who made visits (81%) had controlled blood pressure. Of eligible visits, there were low documented rates of age-appropriate cancer screening (13%) and influenza vaccination (4%). Approximately 0.2% of visits were related to an adverse drug event. Patients who made visits to clinics with all the CDS functions present versus those who visited clinics that were missing at least 1 of the CDS functions were more likely to have controlled blood pressure (86% vs 82%; OR 1.3; 95% CI, 1.1-1.5) and more likely to not have adverse drug event visits (99.9% vs 99.8%; OR 3.0; 95% CI, 1.3-7.3) (Table 3).

We found similar results when specifically analyzing visits to clinics with all the CDS functions versus visits to clinics with any of the CDS functions disabled. Patients were more likely to have controlled blood pressure (86% vs 83%; OR 1.5; 95% CI, 1.02-2.3) and more likely to not have adverse drug event visits (99.9% vs 99.8%; OR 5.2; 95% CI, 1.4-19.0) (Table 4).

We next examined only those CDS functions directly related to each clinical outcome. There were higher odds of receiving cancer screening if the visit was to a clinic with electronic lab results (15% vs 10%; OR 1.5; 95% CI, 1.03-2.2) or notification of acceptable lab ranges (16% vs 11%; OR 1.4; 95% CI, 1.03-1.8) than if the visit was to a clinic without these CDS functions. There were higher odds of having controlled blood pressure (86% vs 80%; OR 1.4; 95% CI, 1.3-1.6) if the visit was to a clinic with electronic problem lists rather than to a clinic without this EHR function (Table 5).

Because of extremely small numbers and/or absence of outcomes in certain subgroups, we were unable to analyze the association of disabling particular CDS functions with specific clinical outcomes.

## DISCUSSION

Using national surveys of ambulatory visits to primary care clinics, we found significant associations between the use of CDS and some, but not all, clinical quality measures before the enactment of meaningful use. Physicians reporting use of CDS had patients with better blood pressure control and fewer visits related to adverse drug events; these associations were present regardless of whether the physicians with CDS were compared with physicians without CDS or with physicians with disabled CDS. Physicians who reported having electronic problem lists had better rates of blood pressure control of their patients. Physicians with electronic lab results or notification of lab ranges were more likely to provide age-appropriate cancer screening. As we enter stages 2 and 3 of meaningful use in which clinicians must use CDS and then provide data about their performance with respect to patient outcomes, hopefully performance will continue to improve, though this remains to be demonstrated.

The incidence of not having at least 1 of the CDS functions was common, which is likely because the meaningful use mandate was not yet in place at the time of these national surveys. However, despite not having this mandate, the incidence of disabling any CDS was infrequent. Keeping decision support active is a "best practice" in clinical decision support,<sup>19</sup> but prior experience has demonstrated

**Table 2.** Characteristics of Adult Primary Care Ambulatory Clinic Visits to Primary Care Clinics With EHRs—With All CDS versus Without at Least 1 CDS, 2006-2009

	All Primary Care Visits N <sup>a</sup> = 104,102	With EHRs N <sup>b</sup> = 51,054	With All CDS N <sup>c</sup> = 10,466	Without at Least 1 CDS N <sup>d</sup> = 40,588	P
	%	%	%	%	
<b>Age, y (mean +/- SD)</b>	50.8 ± 0.4	51.1 ± 0.5	50.9 ± 0.9	51.1 ± 0.6	.84
<b>Male %</b>	42	42	42	42	.77
<b>Race</b>					.88
White	83	83	84	83	
Black	12	11	10	11	
Other	5	6	6	6	
<b>Annual income</b>					<b>&lt;.0001</b>
<\$32,794	23	21	14	24	
\$32,794-40,626	24	23	28	22	
\$40,627-52,387	22	22	22	22	
>\$52,387	25	25	27	25	
<b>Reason for visit</b>					<b>&lt;.0001</b>
New problem	40	39	41	39	
Chronic problem, follow-up	32	32	33	32	
Chronic problem, flare	7	7	7	7	
Pre-/post surgery	22	22	2	2	
Preventive care	16	17	15	17	
<b>Region</b>					.82
Northeast	18	18	20	17	
Midwest	24	24	25	24	
South	38	33	30	34	
West	20	25	25	24	
<b>Practice ownership</b>					<b>&lt;.0001</b>
Physician or physician group	70	60	50	60	
HMO	2	4	7	3	
CHC	4	4	3	5	
Medical/academic health center	13	16	12	18	
Other	11	14	18	14	
<b>Practice size</b>					<b>&lt;.0001</b>
Solo	30	21	20	22	
Non-solo	70	79	80	78	

<sup>a</sup>Reported N is sampled records representing 2 billion visits in the United States between 2006 and 2009.

<sup>b</sup>Reported N is sampled records representing 900 million visits in the United States between 2006 and 2009.

<sup>c</sup>Reported N is sampled records representing 200 million visits in the United States between 2006 and 2009.

<sup>d</sup>Reported N is sampled records representing 700 million visits in the United States between 2006 and 2009.

Boldface indicates  $P < .05$ . CDS indicates clinical decision support; CHC, community health center; EHR, electronic health record; HMO, health maintenance organization; y, years.

that many practices elected to disable specific types of decision support before meaningful use. These decisions can sometimes be indicated if the EHR is generating too many false positive warnings, which can create alert fatigue, although there typically are better solutions. The low rate of disabling CDS is reassuring and may indicate that the performance characteristics of CDS are improving. Notably, the odds of having controlled blood pressure and

avoiding adverse drug events were higher at clinics with active CDS compared with those who had disabled it.

Prior studies of EHR use and clinical quality outcomes have been inconsistent in their findings. One study using earlier data from the same surveys used here found almost no associations between CDS use and clinical quality measures.<sup>16</sup> A more recent study found a significant, although small, improvement in blood pressure control of patients

**Table 3.** Odds of Receiving High-Quality Care When Attending a Clinic With All Versus Without at Least 1 CDS Function

Quality Measure	Unadjusted Sample N (% total visits)	% Visits With All CDS	% Visits Without at Least 1 CDS	aOR <sup>a</sup>	95% CI
Controlled BP	41,365 (81%)	86%	82%	<b>1.3</b>	<b>1.1-1.5</b>
No adverse drug event visit	50,954 (99.8%)	99.9%	99.8%	<b>3.0</b>	<b>1.3-7.3</b>
Preventive care—composite	22,773 (43%)	46%	42%	1.2	0.9-1.5
Health education	21,481 (43%)	44%	40%	1.2	0.9-1.5
Cancer screening	1979 (13%)	15%	14%	1.2	0.9-1.6
Influenza vaccine, Oct-Mar	722 (4%)	5%	3%	1.8	0.8-3.8

<sup>a</sup>Odds ratio adjusted for patient age, gender, race, income, reason for visit, region of country, practice ownership, practice size. Boldface indicates  $P < .05$ . aOR indicates adjusted odds ratio; BP, blood pressure.

**Table 4.** Odds of Receiving High-Quality Care When Attending a Clinic With All CDS Active versus With Any CDS Disabled

Quality Measure	Unadjusted Sample N (% total visits)	% With All CDS	% With Any CDS Disabled	aOR <sup>a</sup>	95% CI
Controlled BP	9736 (84%)	86%	83%	<b>1.5</b>	<b>1.02-2.3</b>
No adverse drug event visit	11,502 (99.9%)	99.9%	99.8%	<b>5.2</b>	<b>1.4-19.0</b>
Preventive care—composite	4914 (46%)	46%	46%	0.96	0.6-1.6
Health education	4636 (41%)	44%	39%	1.04	0.6-1.7
Cancer screening	521 (15%)	15%	12%	2.0	0.9-4.4
Influenza vaccine, Oct-Mar	151 (6%)	5%	12%	0.6	0.3-1.4

<sup>a</sup>Odds ratio adjusted for patient age, gender, race, income, reason for visit, region of country, practice ownership, practice size. Boldface indicates  $P < .05$ . aOR indicates adjusted odds ratio; BP, blood pressure.

visiting physicians with CDS functions in their EHR versus patients visiting physicians without EHRs or CDS.<sup>8</sup> In our study, we found an association between general CDS use and blood pressure control, and more consistent associations between quality indicators and CDS functions that were clinically related to these measures. These associations may be present because EHRs and CDS are evolving in a positive direction, spurred in part by the requirements of certification and also those of meaningful use.

Despite the positive findings, we have also found a lack of association between general CDS use and cancer screening, influenza vaccination, or health education, just as many previously have shown a lack of association between general EHR use and certain health outcomes.<sup>5,9,14</sup> These findings may be because it is harder to change outcomes than quality processes. Some diseases, such as diabetes and hypertension, may be more amenable to clinical decision support than others, in part because there are clear guidelines and metrics.

This study has several limitations. We could not directly measure actual use of CDS during a visit, as the survey

consisted of self-reported metrics. Even when physician practices have EHR features at their disposal, clinicians find ways to bypass or ignore them.<sup>20,21</sup> Of the small number of practices that chose to disable CDS functionality, we do not know the reasoning behind their decisions, which may, in some cases, have been justified. In addition, the distinction between not having CDS functions and having turned off CDS may be sufficiently nuanced as to lead survey respondents to misclassify their EHR, although this would not affect our analysis of the difference between visits to clinics with all 5 of the CDS functions versus those without CDS. In addition, there were low rates of cancer screening and influenza vaccination captured in this visit-based incident data. There were also low rates of adverse drug event outcomes.

## CONCLUSIONS

In contrast with some other studies, we found that the use of CDS functions was associated with improvements in measures of health quality at a national level. In addition,

■ **Table 5.** Odds of Receiving High-Quality Care When Attending a Clinic With Versus Without the Associated CDS Functions

Quality Measure	Preventive Care Reminder				Problem List				Lab Results				Lab Ranges Noted				Drug-Drug Interaction Warning			
	% With CDS	% Without CDS	aOR <sup>a</sup>	95% CI	% With CDS	% Without CDS	aOR <sup>a</sup>	95% CI	% With CDS	% Without CDS	aOR <sup>a</sup>	95% CI	% With CDS	% Without CDS	aOR <sup>a</sup>	95% CI	% With CDS	% Without CDS	aOR <sup>a</sup>	95% CI
Controlled BP	84	82	1.04	0.9-1.2	86	80	<b>1.4</b>	<b>1.3-1.6</b>												
No adverse drug event visit									99.8	99.9	0.3	0.1-1.3	99.8	99.9	0.7	0.3-1.5	99.8	99.8	0.8	0.4-1.6
Preventive care	44	40	1.2	0.98-1.4																
Health education	42	38	1.2	0.99-1.5	42	39	1.2	0.98-1.4												
Cancer screening	15	12	1.1	0.8-1.6	14	14	1.1	0.9-1.4	15	10	<b>1.5</b>	<b>1.03-2.2</b>	16	11	<b>1.4</b>	<b>1.03-1.8</b>				
Influenza vaccine (Oct-Mar)	4	4	1.2	0.7-2.0																

<sup>a</sup>Odds ratio adjusted for patient age, gender, race, income, reason for visit; region of country; practice ownership, practice size. Boldface indicates  $P < .05$ .

aOR indicates adjusted odds ratio; BP, blood pressure.

tion, decisions to disable these CDS functions, although infrequent, negated these increases in care quality. With the continued implementation of meaningful use, there should be a further decline in practices without EHRs or that choose not to implement or to disable CDS. Overall, meaningful use standards that include CDS appear to have a significant positive effect on some national quality-of-care indicators and health outcomes. It will be important to evaluate the evolving impact of meaningful use as the stages continue to be more widely implemented and better integrated with care processes; we anticipate further gains in healthcare quality indicators and outcomes as a result.

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### REFERENCES

- Hsiao C-J, Hing E. Use and Characteristics of Electronic Health Record Systems Among Office-based Physician Practices: United States, 2001-2012; NCHS Data Brief, No 111, December 2012. Hyattsville, MD: HHS, CDC, National Center for Health Statistics; 2012.
- Reider J, Tagalicod R. Progress on adoption of electronic health records. HealthITBuzz website. <http://www.healthit.gov/buzz-blog/electronic-health-and-medical-records/progress-adoption-electronic-health-records/>. Updated December 6, 2013. Accessed December 10, 2013.
- A record of progress on health information technology. CMS Website. <http://www.cms.gov/Newsroom/MediaReleaseDatabase/Fact-Sheets/2013-Fact-Sheets-Items/2013-04-23.html>. Published April 23, 2013. Accessed June 17, 2013.
- Abramson EL, Malhotra S, Osorio SN, et al. A long-term follow-up evaluation of electronic health record prescribing safety. *J Am Med Inform Assoc*. 2013;20(e1):e52-e58.
- Jaspers MW, Smeulers M, Vermeulen H, Peute LW. Effects of clinical decision-support systems on practitioner performance and patient outcomes: a synthesis of high-quality systematic review findings. *J Am Med Inform Assoc*. 2011;18(3):327-334.
- Reed M, Huang J, Graetz I, et al. Outpatient electronic health records and the clinical care and outcomes of patients with diabetes mellitus. *Ann Intern Med*. 2012;157(7):482-489.

7. Kern LM, Barron Y, Dhopeswarkar RV, Edwards A, Kaushal R; HITEC Investigators. Electronic health records and ambulatory quality of care. *J Gen Intern Med.* 2013;28(4):496-503.
8. Samal L, Linder JA, Lipsitz SR, Hicks LS. Electronic health records, clinical decision support, and blood pressure control. *Am J Manag Care.* 2011;17(9):626-632.
9. Keyhani S, Hebert PL, Ross JS, Federman A, Zhu CW, Siu AL. Electronic health record components and the quality of care. *Med Care.* 2008;46(12):1267-1272.
10. Zhou L, Soran CS, Jenter CA, et al. The relationship between electronic health record use and quality of care over time. *J Am Med Inform Assoc.* 2009;16(4):457-464.
11. Poon EG, Wright A, Simon SR, et al. Relationship between use of electronic health record features and health care quality: results of a statewide survey. *Med Care.* 2010;48(3):203-209.
12. DesRoches CM, Audet AM, Painter M, Donelan K. Meeting meaningful use criteria and managing patient populations: a national survey of practicing physicians. *Ann Intern Med.* 2013;158(11):791-799.
13. The Office of the National Coordinator for Health Information Technology. Certified Complete Ambulatory EHR Products. <http://onchpl.force.com/ehrcert/ehrproductsearch>. Published 2013. Accessed June 17, 2013.
14. Linder JA, Ma J, Bates DW, Middleton B, Stafford RS. Electronic health record use and the quality of ambulatory care in the United States. *Arch Intern Med.* 2007;167(13):1400-1405.
15. Rittenhouse DR, Casalino LP, Shortell SM, et al. Small and medium-size physician practices use few patient-centered medical home processes. *Health Aff (Millwood).* 2011;30(8):1575-1584.
16. Romano MJ, Stafford RS. Electronic health records and clinical decision support systems: impact on national ambulatory care quality. *Arch Intern Med.* 2011;171(10):897-903.
17. Wolfstadt JI, Gurwitz JH, Field TS, et al. The effect of computerized physician order entry with clinical decision support on the rates of adverse drug events: a systematic review. *J Gen Intern Med.* 2008;23(4):451-458.
18. Chaudhry B, Wang J, Wu S, et al. Systematic review: impact of health information technology on quality, efficiency, and costs of medical care. *Ann Intern Med.* 2006;144(10):742-752.
19. Bates DW, Kuperman GJ, Wang S, et al. Ten commandments for effective clinical decision support: making the practice of evidence-based medicine a reality. *J Am Med Inform Assoc.* 2003;10(6):523-530.
20. Flanagan ME, Saleem JJ, Millitello LG, Russ AL, Doebbeling BN. Paper- and computer-based workarounds to electronic health record use at three benchmark institutions. *J Am Med Inform Assoc.* 2013; 20(e1):e59-e66.
21. Zheng K, Hanauer DA, Padman R, et al. Handling anticipated exceptions in clinical care: investigating clinician use of "exit strategies" in an electronic health records system. *J Am Med Inform Assoc.* 2011; 18(6):883-889. ■

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