

SPECIAL ARTICLE

Electronic Health Records and Quality of Diabetes Care

Randall D. Cebul, M.D., Thomas E. Love, Ph.D., Anil K. Jain, M.D.,
and Christopher J. Hebert, M.D.

ABSTRACT

BACKGROUND

Available studies have shown few quality-related advantages of electronic health records (EHRs) over traditional paper records. We compared achievement of and improvement in quality standards for diabetes at practices using EHRs with those at practices using paper records. All practices, including many safety-net primary care practices, belonged to a regional quality collaborative and publicly reported performance.

METHODS

We used generalized estimating equations to calculate the percentage-point difference between EHR-based and paper-based practices with respect to achievement of composite standards for diabetes care (including four component standards) and outcomes (five standards), after adjusting for covariates and accounting for clustering. In addition to insurance type (Medicare, commercial, Medicaid, or uninsured), patient-level covariates included race or ethnic group (white, black, Hispanic, or other), age, sex, estimated household income, and level of education. Analyses were conducted separately for the overall sample and for safety-net practices.

RESULTS

From July 2009 through June 2010, data were reported for 27,207 adults with diabetes seen at 46 practices; safety-net practices accounted for 38% of patients. After adjustment for covariates, achievement of composite standards for diabetes care was 35.1 percentage points higher at EHR sites than at paper-based sites ($P < 0.001$), and achievement of composite standards for outcomes was 15.2 percentage points higher ($P = 0.005$). EHR sites were associated with higher achievement on eight of nine component standards. Such sites were also associated with greater improvement in care (a difference of 10.2 percentage points in annual improvement, $P < 0.001$) and outcomes (a difference of 4.1 percentage points in annual improvement, $P = 0.02$). Across all insurance types, EHR sites were associated with significantly higher achievement of care and outcome standards and greater improvement in diabetes care. Results confined to safety-net practices were similar.

CONCLUSIONS

These findings support the premise that federal policies encouraging the meaningful use of EHRs may improve the quality of care across insurance types.

From the Departments of Medicine and Epidemiology and Biostatistics, and the Center for Health Care Research and Policy, Case Western Reserve University at MetroHealth Medical Center (R.D.C., T.E.L.); the Information Technology Division and Medicine Institute, Cleveland Clinic (A.K.J.); and the Department of Medicine, Ohio Permanente Medical Group (C.J.H.) — all in Cleveland. Address reprint requests to Dr. Cebul at the Center for Health Care Research and Policy, Rammelkamp Research and Education Bldg., MetroHealth Medical Center, 2500 MetroHealth Dr., Cleveland, OH 44109-1998, or at rdc@case.edu.

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INCENTIVES TO INCREASE ADOPTION AND meaningful use of electronic health records (EHRs) anticipate a quality-related financial return.^{1,2} However, empirical data showing either quality improvement or cost savings from EHR adoption are scarce. Available studies have shown few quality-related advantages of current EHR systems over traditional paper-based medical-record systems.¹⁻⁵ Projected cost savings are mostly based on models with largely unsupported assumptions about adherence to and the effect of fully functional EHR systems.^{6,7} Data are particularly scarce on EHR adoption by “priority primary care providers” — health care professionals practicing in small groups and those serving vulnerable populations, as such providers are defined in the Health Information Technology for Economic and Clinical Health (HITECH) Act.⁸ EHR adoption by such providers is supported by the national network of Health Information Technology Regional Extension Centers.

Innovations in care delivery as specified in the Affordable Care Act, such as accountable care organizations and patient-centered medical homes (PCMHs), also provide incentives for using information most easily obtained through EHR systems.^{9,10} Data regarding the benefits of PCMHs have come largely from reports by EHR-based organizations,¹¹⁻¹³ and these data support the posited links among EHR use, quality improvement, and cost savings. However, these reports did not compare EHR and paper-based systems.

Regional quality-improvement initiatives, such as those supported by the Robert Wood Johnson Foundation’s Aligning Forces for Quality (AF4Q) program,¹⁴ by Medicare and state Medicaid initiatives,^{15,16} and by multistakeholder collaboratives,¹⁷ provide an opportunity to evaluate the effectiveness of EHRs and refinements in national payment policy.^{15,18} In greater Cleveland, one of 16 AF4Q sites nationwide, diverse EHR-based and paper-based ambulatory practices publicly report on the quality and outcomes of care for patients with chronic medical conditions. Regional achievement of diabetes-related standards has been reported six times to date. The reported data come from practices with high concentrations of priority primary care providers and allow a comparison of quality standards for EHRs and paper records, after adjustment for important patient-level attributes. We examined the independent association of EHR use with achievement of quality standards for the care of patients with diabetes.

METHODS

STUDY DESIGN

We analyzed data from a retrospective cohort of primary care practices of seven diverse health care organizations that publicly reported achievement of quality standards for adults with diabetes between July 2007 and June 2010. Data reported here include the most recent yearlong cross section (July 2009 through June 2010) as well as practice-level trends across three years of reports.

SETTING AND SUBJECTS

The primary care practice partners of Better Health Greater Cleveland (hereafter referred to as Better Health) are responsible for the majority of medical care for people with chronic disease in Cuyahoga County, an urban area in northeastern Ohio with 1.3 million residents; the county includes Cleveland, one of the nation’s poorest large cities, and its affluent suburbs. Participating practices include 21 sites of large not-for-profit health care organizations, 1 of which serves many vulnerable (“safety net”) patients; 12 sites of a large safety-net public hospital system; 1 safety-net practice of a university hospital; and the safety-net practices of all 3 of the county’s federally qualified health centers. Since the program’s inception in 2007, reporting primary care providers have included physicians in general internal medicine, family practice, and medicine–pediatrics. In July 2009, nurse practitioners and other health care professionals with prescription-writing privileges were added to the list of reporting providers. Patients include all adults (18 to 75 years of age) with diabetes who made at least two visits to the same primary care practice during each yearlong measurement interval.

CARE AND OUTCOME STANDARDS

Better Health’s Clinical Advisory Committee approved nine quality standards for diabetes, including four standards of care and five standards of intermediate outcomes. Care standards are reported by standard and as an all-or-none composite¹⁹; outcome standards are reported by standard and as a composite indicating achievement of at least four of the five standards. Care standards include receipt of a glycosylated hemoglobin value, testing for urinary microalbumin or prescription of an angiotensin-converting–enzyme inhibitor or an angiotensin-receptor blocker, an eye examination to screen for diabetic retinopathy, and ad-

ministration of a pneumococcal vaccination. Intermediate-outcome standards include a glycated hemoglobin value below 8%, a blood pressure below 140/80 mm Hg, a low-density lipoprotein (LDL) cholesterol value below 100 mg per deciliter or documented prescription for a statin medication, a body-mass index (the weight in kilograms divided by the square of the height in meters) below 30, and nonsmoking status. All care and outcome standards pertain to the most recent result documented in the measurement interval, except pneumococcal vaccination (administration at any time is sufficient for meeting this standard).

COVARIATES

Patient information was collected regarding several sociodemographic variables, including insurance type (Medicare, commercial, Medicaid, or uninsured), race or ethnic group (white, black, Hispanic, or other), age, sex, estimated household income, and educational level, all prespecified for our analyses. Insurance type is the primary insurance reported during the most recent doctor's visit. Data on race or ethnic group were primarily obtained through self-report. Household income and educational level were estimated by linking each patient's home address to Census 2000 summaries.

DATA COLLECTION AND STUDY OVERSIGHT

Clinical practices or health care organizations submitted a unique study code for each patient and health care provider to Better Health's Data Management Center. EHR-based organizations provided data on all eligible patients. Data from paper-based organizations were gathered by centrally trained chart abstractors for a random sample of patients selected by the Data Management Center. More than 95% of patients in the sample had charts available for review. Each site reviewed summary results for accuracy before publicly reporting data. The MetroHealth System's Human Privacy Board approved data collection and submission protocols.

QUALITY-IMPROVEMENT ASSISTANCE

The collaborative supports three types of quality-improvement assistance. First, partner sites receive comparisons with other practices in their organization and regionwide for case mix, achievement of Better Health's standards, and quality improvement. Practice directors can identify data regarding specific providers. Public reports highlight the

top 10% of practice sites with respect to achievement of standards or improvement, by insurance category and overall. Second, Better Health sponsors semiannual daylong summits featuring national speakers and sharing of best practices in quality improvement and management of reported chronic conditions. Third, since mid-2009, all practices have had the opportunity to receive program-sponsored practice coaching. Coaching has principally focused on culture change, workflow redesign, and quality-improvement projects related to specific metrics.

STATISTICAL ANALYSIS

Our primary analyses examined cross-sectional practice-level achievement for the period from July 2009 through June 2010 and longitudinal changes since the July 2007–June 2008 period regarding each participating practice (in EHR-based organizations) or paper-based organization. Unadjusted comparisons of EHR-based organizations with paper-based organizations were made with the use of the weighted least-squares method and practice-level data. For multivariate modeling, practice data were disaggregated into four insurance types (Medicare, commercial, Medicaid, and uninsured). We used generalized estimating equations, weighted for population size in each practice–insurance combination, to calculate the cross-sectional effect of EHRs on the percentage of patients for whom the care provided met composite and component standards, adjusting for prespecified covariates and accounting for clustering within individual EHR practices and paper-based organizations. Interactions between type of medical-record system (electronic or paper-based) and type of insurance were added to the main models to obtain insurance-specific estimates for EHR sites versus paper-based sites. We also used weighted generalized estimating equations for analogous trend models, adding the baseline level of the composite as a covariate. The trend models predict the difference between EHRs and paper records on annualized slopes measured across three nonoverlapping, repeated cross sections (July 2007 through June 2008, July 2008 through June 2009, and July 2009 through June 2010). In post hoc analyses, these same cross-sectional and longitudinal comparisons were restricted to safety-net practices. All analyses were performed with the use of the geepack library and R statistical software, version 2.12.2 (R Foundation for Statistical Computing).^{20,21} Further de-

Table 1. Characteristics of Care Organizations, Practices, and Patients with Diabetes, July 2009–June 2010.*

Characteristic	All Practices	EHR Practices			Paper-Based Practices†	P Value‡
		All	Non–Safety Net	Safety Net		
Care organizations (no.)	7	3	2§	2§	4	
Practices (no.)	46	33	20	13	13	
Providers (no.)	569	516	285	231	53	
Patients (no.)	27,207	24,547	16,927	7620	2660	
Mean age (yr)	57.8	58.3	59.6	55.5	53.2	.007
Female sex (%)	52.4	52.0	49.0	58.7	56.6	0.20
Nonwhite race (%)¶	47.9	43.9	34.8	64.1	84.8	<0.001
Non-English language (%)	5.2	5.3	2.3	11.9	4.2	0.72
Primary insurance (%)						<0.001
Medicare	35.1	36.7	38.5	32.6	20.2	
Commercial	43.9	47.6	59.3	21.7	9.9	
Medicaid	8.6	7.1	0.6	21.5	22.5	
Uninsured	12.5	8.7	1.7	24.2	47.4	
Estimated median income (\$1,000s)	40.8	42.1	46.6	32.2	28.3	<0.001
High-school graduate (%)	79.2	80.0	83.7	71.7	72.2	<0.001

* EHR denotes electronic health record. Percentages may not add up to 100 because of rounding.

† All sites with paper-based records were safety-net practices.

‡ P values are for the comparison of EHR sites with paper-based sites.

§ One health care organization (with electronic health records) included nine non–safety-net practices and one safety-net practice.

¶ Data on race were obtained primarily through self-report.

tails can be found in the Supplementary Appendix (available with the full text of this article at NEJM.org).

RESULTS

CHARACTERISTICS OF THE PATIENTS

From July 2009 through June 2010, a total of 27,207 adults with diabetes received care from 569 primary care providers in 46 practices of 7 care organizations. Table 1 summarizes the population overall and according to type of record (electronic or paper) and safety-net status (37.8% of all patients were in safety-net practices). Twelve practices in 1 safety-net organization and 1 safety-net practice in a non–safety-net organization used EHRs; all other safety-net practices were paper-based; and all non–safety-net organizations used EHRs. As compared with safety-net practices, non–safety-net practices had smaller proportions of minority patients, patients who preferred a language other than English, and patients who were uninsured or were insured by

Medicaid, and their patients had generally higher income and educational levels. EHR-based safety-net sites served patients who were more similar to those at paper-based safety-net sites than to those at non–safety-net EHR sites.

ACHIEVEMENT OF CARE AND OUTCOMES STANDARDS

Table 2 summarizes the collective achievement of all sites on composite and individual standards for diabetes care and outcomes, including results for non–safety-net EHR sites, safety-net EHR sites, and paper-based sites, with and without model adjustment.

In unadjusted analyses, between July 2009 and June 2010, 50.9% of patients at EHR sites, as compared with 6.6% of patients at paper-based sites, received care for diabetes that met all four standards, representing a difference of 44.3 percentage points. EHR sites showed higher achievement on all components of the composite standard for care. For diabetes outcomes, 43.7% of patients at EHR sites and 15.7% of those at paper-based sites had outcomes that met at least four of the five

Table 2. Achievement of Composite and Component Standards for Diabetes Care and Outcomes, July 2009–June 2010.*

Standard	All Practices	EHR Practices			Paper-Based Practices	Unadjusted Difference†	Adjusted Difference
		All	Non–Safety Net	Safety Net			
		<i>percentage of patients</i>				<i>percentage points (95% CI)</i>	
Care							
Composite	46.6	50.9	53.6	44.8	6.6	44.3 (37.2 to 51.4)	35.1 (28.3 to 41.9)
Components							
Measurement of glycated hemoglobin	93.7	94.6	94.6	94.7	85.6	9.1 (7.0 to 11.1)	7.2 (0.4 to 14.0)
Kidney management‡	91.9	93.4	94.0	92.0	78.2	15.2 (12.9 to 17.5)	13.3 (8.4 to 18.3)
Eye examination	59.5	62.6	66.4	54.1	30.8	31.8 (26.0 to 37.7)	25.0 (18.7 to 31.2)
Pneumococcal vaccination	76.4	83.0	81.4	86.5	15.0	68.0 (59.5 to 76.5)	57.1 (43.6 to 70.5)
Outcomes							
Composite	41.0	43.7	48.8	32.3	15.7	28.0 (21.5 to 34.6)	15.2 (4.5 to 25.9)
Components							
Glycated hemoglobin <8%	68.3	70.5	74.1	62.4	48.0	22.5 (17.0 to 27.9)	10.9 (–1.7 to 23.6)
Blood pressure <140/80 mm Hg	54.1	55.8	58.6	49.5	38.9	16.8 (11.4 to 22.2)	11.1 (–1.0 to 23.2)
LDL cholesterol <100 mg/dl or use of statin drug	85.0	87.0	88.4	83.8	66.1	20.8 (17.8 to 23.9)	18.1 (11.8 to 24.4)
BMI <30§	32.9	32.8	33.7	30.9	34.1	–1.2 (–5.0 to 2.5)	–2.9 (–8.0 to –2.1)
Nonsmoker	79.2	82.1	86.4	72.5	52.3	29.8 (23.6 to 36.0)	17.0 (5.3 to 28.6)

* CI denotes confidence interval, EHR electronic health record, and LDL low-density lipoprotein.

† Unadjusted differences are the values for all EHR practices minus the values for paper-based practices. Differences may not exactly match the data as shown owing to rounding.

‡ Kidney management is defined as testing for urinary microalbumin or prescription of an angiotensin-converting–enzyme inhibitor or an angiotensin-receptor blocker.

§ The body-mass index (BMI) is the weight in kilograms divided by the square of the height in meters.

standards, a difference of 28.0 percentage points. Achievement was higher for EHR sites on all but one outcome standard. These findings were similar but somewhat blunted in analyses that adjusted for insurance type, age, sex, race or ethnic group, language preference, estimated household income, and educational level.

Figure 1A shows adjusted differences in cross-sectional achievement between EHR and paper-based practice sites for care and outcomes across all patients and for safety-net practices. For diabetes care, the adjusted difference between EHR and paper-based sites was 35.1 percentage points

(95% confidence interval [CI], 28.3 to 41.9; $P < 0.001$) across all practices and 29.8 percentage points (95% CI, 24.0 to 35.7; $P < 0.001$) at safety-net sites. For diabetes outcomes at all sites, the adjusted difference between EHR and paper-based sites was 15.2 percentage points (95% CI, 4.5 to 25.9; $P = 0.005$); for safety-net sites, the difference was 9.7 percentage points (95% CI, 3.4 to 16.1; $P = 0.002$).

Figure 1B shows the adjusted differences in achievement of composite standards for diabetes care and outcomes according to insurance type for the period from July 2009 through June 2010. For diabetes care, significant differences between

EHR and paper-based sites were found across all insurance types for all patients. For outcomes, we also found significant differences between EHR and paper-based sites across insurance types (largest for Medicare). Results were similar in analyses confined to safety-net practices, as detailed in the Supplementary Appendix.

TRENDS IN CARE AND OUTCOME STANDARDS

We analyzed trends in achievement of composite standards according to type of medical-record system and insurance type. These analyses included 25,804, 25,196, and 26,694 patients in the July 2007–June 2008, July 2008–June 2009, and July 2009–June 2010 periods, respectively, representing 36 sites that consistently used either electronic or paper records in all periods. Figure 1C shows annualized differences in improvement between EHR and paper-based sites, with adjustment for covariates. The differences in trends in care were significant across all insurance types (overall, a difference of 10.2 percentage points in annual improvement; 95% CI, 6.4 to 13.9; $P < 0.001$). Somewhat larger differences were observed overall in analyses of safety-net sites (15.9 percentage points; 95% CI, 13.0 to 18.7; $P < 0.001$) (see the Supplementary Appendix). Smaller but still significant differences were observed in trends in outcomes (overall, a difference of 4.1 percentage points in annual improvement; 95% CI, 0.5 to 7.7; $P = 0.02$), although differences among Medicaid patients were not significant in analyses of the total sample, and differences among the commercially insured patients were not significant in analyses of the safety-net sites (see the Supplementary Appendix).

DISCUSSION

We compared EHRs with paper-based records in a long-term regional collaborative that seeks to improve care and outcomes for patients with chronic conditions. EHR sites were associated with higher levels of achievement of and improvement in regionally vetted standards for diabetes care and outcomes. Our findings focus on composite standards, although the results were similar for virtually all component standards. Because the study was observational, it may be subject to selection bias, although our results were similar after adjustment for the more favorable socioeconomic profiles of patients cared for in organizations with EHRs. The association of

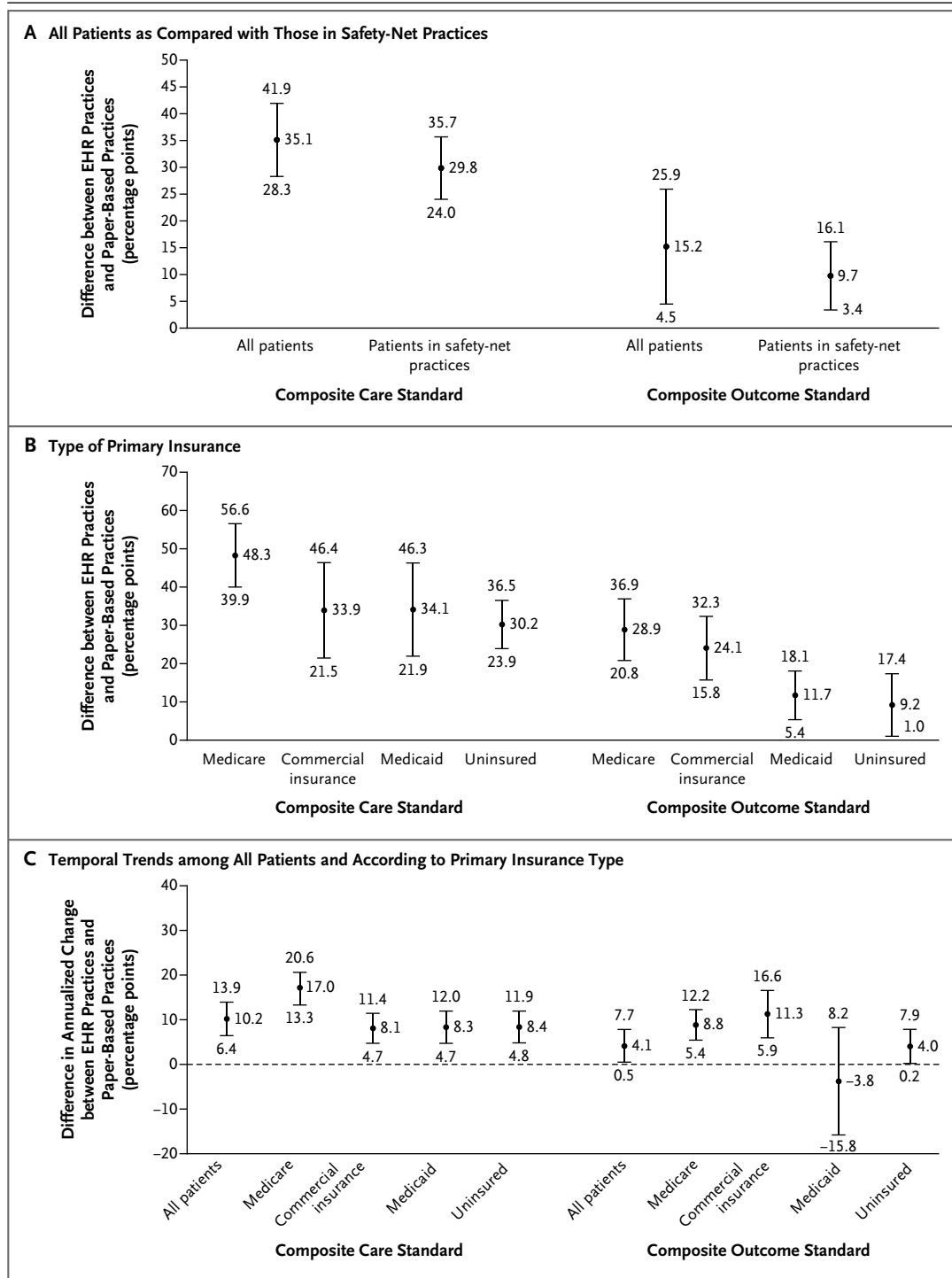
Figure 1 (facing page). Differences in Achievement of Composite Standards for Diabetes Care and Outcomes at Practices with Electronic Health Records (EHRs) and Those with Paper Records.

Shown are the estimated differences between EHR practices and paper-based practices in the percentage of patients for whom composite standards of diabetes care and outcomes were met. For the period from July 2009 through June 2010, Panel A shows the results for all patients and for those in safety-net practices, and Panel B shows the results according to the type of primary insurance. Panel C shows the estimated differences between EHR sites and paper-based sites with respect to annualized changes from the baseline measurement interval (July 2007 through June 2008) to the most recent interval (July 2009 through June 2010) in the percentage of patients for whom composite standards of diabetes care and outcomes were met, both overall and according to primary insurance type. In all three panels, the black circles indicate median differences, and the I bars 95% confidence intervals. For Panels A and B, results account for clustering within practices and have been adjusted for age, sex, race or ethnic group, preferred language, type of insurance, income, and educational level. Results for Panel C do not include preferred language among the covariates.

type of medical record with quality standards was significant across all insurance types. As in other studies,^{22,23} the association was stronger for care — which is largely under the direction of providers — than for outcomes, which also require supportive home and neighborhood environments, active patient engagement, and other resources that foster adherence to prescribed regimens. The association was generally weakest for the uninsured, a vulnerable group that is underrepresented in other studies of EHRs and quality of care.

Our results contrast sharply with those of a widely cited investigation by Linder et al.¹ and of more recent studies^{4,5} that showed no association of EHR use with quality of care, even when the EHRs were associated with electronic clinical decision support tools.⁴ We believe that there are at least three contributing factors that help explain our more favorable results.

First, two of the most prominent reports that showed no effect^{1,4} used older data from the National Ambulatory Medical Care Survey (NAMCS). In the more recent study focusing on clinical decision support,⁴ there was no determination of the quality of clinical decision support or whether clinical decision support tools were designed to improve care coordination^{24,25} or the heterogeneous standards evaluated. In contrast, the cur-



rent investigation includes EHR-based health care organizations using clinical decision support targeted to improve regionally endorsed standards and programs for cross-organizational sharing of EHR-catalyzed care coordination and teamwork. The region's relatively high level of achievement

is supported by comparisons with national benchmarks,^{26,27} including a recent report on diabetes standards and the widely respected EHR system of the Veterans Affairs health system.²³

Second, the NAMCS involves the review of a random sample of patient visits to providers with-

out determining continuity or mutual commitment to longitudinal care,²⁸ possibly resulting in less attention to EHR-based guidelines for the care of chronic disease when a patient sees a provider for the first time or when a patient and provider are in a discontinuous relationship. In the current investigation, the diagnosis and attribution of provider accountability were confirmed by each health care organization, and patients had to visit the same practice at least twice during the measurement period. As described by Tang et al.,²⁹ this requirement for multiple visits increases the likelihood of meeting endorsed guidelines.

Third, we compared sites that had sophisticated EHR systems with paper-based organizations that, as safety-net practices, care for a vulnerable patient population and may have fewer quality-related resources than other paper-based practices. To address this concern, we performed an analysis that was restricted to safety-net practices, which had similar results, and we included statistical adjustments to account for several important patient characteristics, such as estimated income and educational level. One of the paper-based sites was a university-based academic practice, a practice type usually associated with a higher quality of care.³⁰ Nonetheless, inferring that EHRs fully account for the observed differences in quality is not warranted, in part because of the participation of exceptional EHR-based organizations, a nonrepresentative sample of paper-based organizations, and inadequate adjustment for patient characteristics.

We also examined trends in quality associated with EHR use. Our results, showing accelerated improvement in care and outcomes, should encourage those concerned that the quality of ambulatory care may fail to improve with increased adoption of EHRs.⁴ Nonetheless, our study did not determine changes in achievement after the conversion from paper to electronic records, which would provide more compelling evidence of the

benefits of EHRs. Such evidence will appear only as Better Health's paper-based practices, and other practices nationwide, convert to EHRs and report their results. The stimulus for such conversion among priority primary care providers, including those who serve Medicaid beneficiaries and other vulnerable patient populations, includes both financial incentives for the meaningful use of EHRs and federal resources for EHR adoption through Regional Extension Centers funded by the HITECH Act.⁸

Finally, the differences in quality between EHR sites and paper-based sites that we report were observed in the context of a regional quality-improvement collaborative. Although the clinical partners in Better Health provide care to the majority of people with chronic illness in greater Cleveland, their willingness to publicly report their results distinguishes them from clinical practices that do not yet participate. Whether the large difference in achievement associated with EHR use is representative of other primary care practices or other regions is unknown. Also, the smaller difference in trends between EHR sites and paper-based sites may have resulted from a disproportionate use of Better Health–provided practice coaching by safety-net and paper-based practices (9 of 13 sites as of June 2010), improving quality in ways unrelated to the type of medical record. Although other researchers have reported favorable results of practice coaching,^{31,32} more needs to be learned about its effect on patient care and outcomes, especially in the context of quality-improvement networks. As Clancy et al. highlight,¹⁵ the recent proliferation of such networks provides rich opportunities to evaluate comparative effectiveness and refinements in national payment policy.

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Disclosure forms provided by the authors are available with the full text of this article at NEJM.org.

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