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The Patient-Centered Medical Home and Associations With Health Care Quality and Utilization

A 5-Year Cohort Study

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Background: Effects of the patient-centered medical home (PCMH) are unclear. Previous studies had relatively short follow-up and may not have distinguished effects of the PCMH (which involves electronic health records [EHRs] plus organizational changes) from those of EHRs alone.

Objective: To determine effects of the PCMH on health care quality and utilization compared with paper records alone and EHRs alone, with extended follow-up.

Design: Prospective cohort study (2008 to 2012), including 3 years after PCMH implementation. (ClinicalTrials.gov: NCT00793065)

Setting: The Hudson Valley, a multipayer, multiprovider region in New York.

Participants: 438 primary care physicians in 226 practices, with 136 480 patients across 5 health plans.

Intervention: Level III PCMH, as defined by the National Committee for Quality Assurance.

Measurements: Claims-based outcomes included 8 quality and 7 utilization measures. Generalized estimating equations were used to compare adjusted differences in rates of change across study groups.

Results: Patterns of quality were fairly similar across groups. Utilization patterns were similar across groups from 2008 to 2011 but showed modest differences between the PCMH and control groups on most measures in 2012. For example, hospitalizations were relatively stable from 2008 to 2011 (approximately 3.9 to 5.2 per 100 patients per year) but decreased in the PCMH group in 2012 (incidence rate ratio, 0.79 [95% CI, 0.69 to 0.90] compared with paper records). Emergency department visits were highest for the PCMH group (16.7 per 100 patients at baseline and 15.4 per 100 patients at the end of the study period) and lowest for the paper group (14.3 per 100 patients at baseline and 12.2 per 100 patients at the end of the study period), but the rate of change did not differ across groups.

Limitation: Possible unmeasured confounding.

Conclusion: The PCMH was associated with modest changes in most utilization measures and provided similar quality compared with EHRs and paper records.

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The patient-centered medical home (PCMH) attempts to shift the medical paradigm from care for individual patients to care for populations, from care by physicians to care by a team of providers, from a focus on acute illness to an emphasis on chronic disease management, and from care at a single site to coordinated care across providers and settings (1). This model has been disseminated widely and leveraged to change physician reimbursement (2, 3).

However, the effects of the PCMH are unclear. Several systematic reviews have found insufficient evidence to determine its effectiveness (4–6). Some studies have found associations between the PCMH and modest improvements in health care quality (7), but others have found no association with quality (8–10). Recent studies have also found either no effect on health care utilization (9) or isolated effects on some utilization outcomes but not others (8, 10).

Previous studies may have been limited by their duration of follow-up, typically 1.5 to 2 years after PCMH implementation (8, 10). The PCMH is a complex intervention that usually involves implementation of electronic health records (EHRs) plus organizational changes, including changes to clinical workflow and responsibilities of providers and staff. These changes take time, and studies with relatively short follow-up may have underestimated the effects of the intervention. Another limitation of previous studies is that they have not consistently accounted for the effects of EHRs (9), which may independently influence quality and utilization (7).

Our objective was to evaluate the effects of the PCMH on health care quality and utilization, using extended follow-up (3 years after implementation). We also sought to distinguish the effects of the PCMH from those of EHRs alone.

Methods

Overview

We conducted a longitudinal cohort study of primary care physicians over a 5-year period (2008 to 2012) that included 3 years after PCMH implementation (2010 to 2012). This study builds on our previous evaluations, which included 1 year after transformation to the PCMH model (7, 11). The Institutional Review Boards at Weill Cornell Medical College and Kingston

See also:

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EDITORS' NOTES

Context

Long-term effects of the patient-centered medical home (PCMH) are unclear.

Contribution

This longitudinal study compared performance on health care quality and utilization measures for practices using paper records, those using electronic health records, and PCMH practices during a 5-year period (including 3 years after PCMH implementation). Performance on quality measures was similar across groups, but modest differences in utilization were observed.

Caution

Unexplained large changes that occurred in the final year may have driven the observed differences in utilization.

Implication

Long-term studies may be necessary to understand the effects of the PCMH on health care utilization.

Hospital approved the protocol. The study was registered at ClinicalTrials.gov (NCT00793065).

Setting and Context

This study took place in the Hudson Valley, a 7-county, multipayer, multiprovider region north of New York City. The Taconic Health Information Network and Community (THINC), a coalition-building organization, convened 6 health plans (Aetna, UnitedHealthcare, Empire Blue Cross Blue Shield, Capital District Physicians' Health Plan, MVP Health Care, and Hudson Health Plan), which covered 70% of the community's commercially insured patients (12, 13). These plans provided incentives totaling $2 to $10 per patient per month to practices that achieved level III PCMH (the highest level), as defined by the 2008 standards of the National Committee for Quality Assurance (NCQA) (1). THINC worked in conjunction with the Taconic Independent Practice Association (IPA) and MedAllies on this initiative and a previous initiative to promote adoption of EHRs in this community (13–15).

Participants

We included all primary care physicians for adults (general internists and family medicine physicians) who were members of the Taconic IPA or who volunteered for the PCMH initiative. We included all adult patients (aged ≥18 years) who were attributed to the primary care physicians and were eligible for at least 1 quality measure (described in the Statistical Analysis section).

Practice Transformation

As described previously, some practices volunteered for the PCMH initiative, and 2 external consulting groups assisted with PCMH transformation (7). Needs assessments took place in January 2009, and transformation began in March 2009. Practices systematically implemented components of the PCMH not already in place (**Appendix 1**, available at www.annals.org). The external consulting groups reported that transformation was shaped by 3 themes: changing culture toward population management, building a team by clearly defining roles and responsibilities, and becoming accountable for performance. Practices submitted applications to the NCQA between August 2009 and January 2010, and all achieved level III recognition.

Data Sources

The Taconic IPA provided data on which practices were using EHRs and which were participating in the PCMH initiative. The IPA provided baseline (2008) physician characteristics (age, sex, degree [MD vs. DO], specialty, and county) and the number of primary care physicians in each practice each year as a proxy for practice size.

Five of the health plans, representing 60% of the community's commercially insured patients, contributed claims for each year. A third-party data aggregator applied attribution logic yearly to assign patients to primary care physicians (7). All of a patient's health care utilization was attributed to the primary care physician, regardless of the ordering provider. The aggregator provided the number of patients attributed to each primary care physician (panel size), as well as several patient-level variables: age; sex; codes from the International Classification of Diseases, Ninth Revision; deidentified health plan identifier; and quality and utilization outcomes (described in the Statistical Analysis section).

We obtained data on which physicians received payments through the federal EHR Incentive (Meaningful Use) Program for 2011 (the first year of the program) and 2012 from the Centers for Medicare & Medicaid Services Web site (for Medicare beneficiaries) and the New York State Department of Health (for Medicaid beneficiaries) (16, 17).

Statistical Analysis

We included primary care physicians who had attributed patients in each of the 5 years of the study. We then included all patients attributed to those physicians and allowed the patients to vary over time. We created 3 study groups: physicians who implemented the PCMH (all of whom used EHRs), those who used EHRs but did not implement the PCMH, and those who used paper records without the PCMH. We fixed the study groups at the physicians' 2010 status to isolate the longer-term effects of the PCMHs we studied previously (7, 11).

We used claims to capture 8 ambulatory quality measures: eye examinations, hemoglobin A_{1c} testing, low-density lipoprotein cholesterol testing, and nephropathy screening for patients with diabetes; breast cancer screening and chlamydia screening for women; colorectal cancer screening; and appropriate medications for patients with asthma. These measures had been selected from the Healthcare Effectiveness Data

Table 1. Characteristics of Physicians and Their Patients, Overall and by Study Group*

Characteristic	Total	PCMH	EHRs Alone	Paper Records	*P* Value†
Physicians, *n*	438	125	87	226	
Mean age (SD), *y*	50 (10)	46 (9)	51 (9)	53 (10)	<0.001
Female, *n (%)*	146 (33)	47 (38)	27 (31)	72 (32)	0.48
MD degree (vs. DO), *n (%)*	392 (90)	110 (88)	71 (82)	211 (93)	0.008
Specialty, *n (%)*					
General internal medicine	260 (59)	88 (70)	43 (49)	129 (57)	0.006
Family medicine	178 (41)	37 (30)	44 (51)	97 (43)	
Panel size, *n (%)*‡					
<200	128 (29)	28 (22)	19 (22)	81 (36)	0.049
200–299	80 (18)	21 (17)	18 (21)	41 (18)	
300–499	111 (25)	36 (29)	21 (24)	54 (24)	
≥500	119 (27)	40 (32)	29 (33)	50 (22)	
Taconic IPA membership, *n (%)*	401 (92)	91 (73)	87 (100)	223 (99)	<0.001
Attested to Meaningful Use, *n (%)*					
2011	115 (26)	60 (48)	27 (31)	28 (12)	<0.001
2012	239 (55)	102 (82)	54 (62)	83 (37)	<0.001
Rural county, *n (%)*	82 (19)	19 (15)	11 (13)	52 (23)	0.053
Mean primary care physicians per practice (SD)	15 (21)	41 (21)	7 (9)	4 (5)	<0.001
Patients, *n*	75 769	23 430	17 071	35 268	
Mean age (SD), *y*	56 (12)	55 (12)	56 (12)	57 (12)	<0.001
Female, *n (%)*	48 287 (64)	15 236 (65)	10 885 (64)	22 166 (63)	<0.001
Mean case-mix index (SD)§	1.1 (1.2)	1.0 (1.2)	1.1 (1.2)	1.2 (1.3)	<0.001
Health plan, *n (%)*					
A	17 901 (24)	7344 (31)	3675 (22)	6882 (20)	<0.001
B	31 390 (41)	7623 (33)	7343 (43)	16 424 (47)	
C	1640 (2)	427 (2)	380 (2)	833 (2)	
D	1778 (2)	922 (4)	333 (2)	523 (1)	
E	23 060 (30)	7114 (30)	5340 (31)	10 606 (30)	

EHR = electronic health record; IPA = Independent Practice Association; PCMH = patient-centered medical home.
* Data are from the baseline year (2008), except for the Meaningful Use variables, which apply only to 2011 and 2012. Panel and practice size, county, and case mix change over time (data not shown) and were treated in the regression models as time-dependent variables. Data on sex were missing for 193 patients (<1%). Percentages may not sum to 100 due to rounding.
† Calculated using analysis of variance for continuous variables and chi-square tests for categorical variables.
‡ Continuous variable; log-transformed for modeling because of skewness.
§ Calculated using the number of major aggregated diagnostic groups in the Johns Hopkins Adjusted Clinical Groups System.

and Information Set by the participating health plans for this initiative.

We also used claims for 7 health care utilization outcomes: primary care visits, specialist visits, laboratory tests, radiology and other diagnostic tests, emergency department (ED) visits, hospitalizations, and 30-day all-cause rehospitalizations.

We considered 7 potential physician-level confounders (age, sex, degree, specialty, panel size, IPA membership, and receipt of Meaningful Use payments from Medicare or Medicaid), 2 potential practice-level confounders (county and practice size), and 4 potential patient-level confounders (age, sex, case-mix index [18], and health plan).

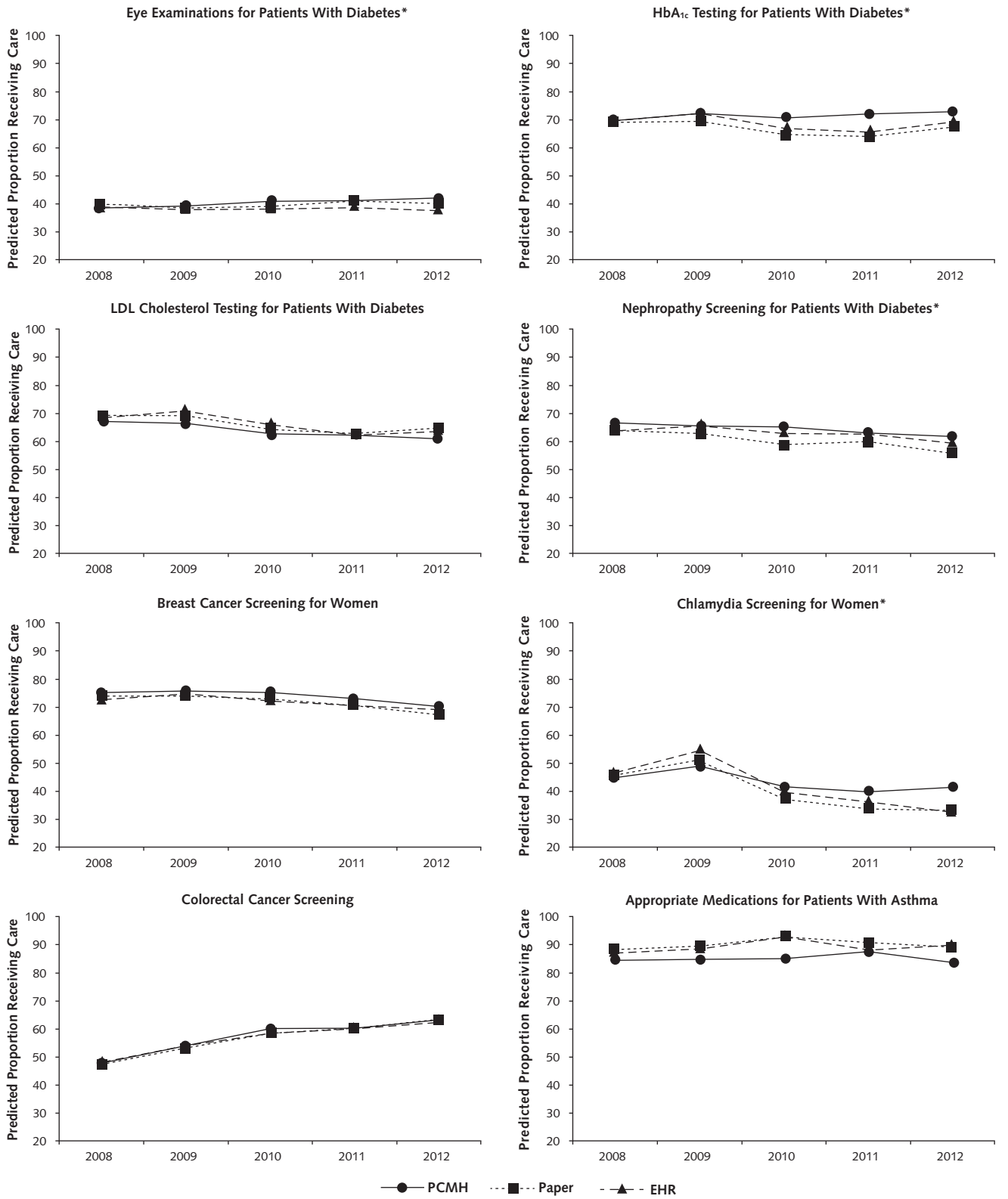
Descriptive statistics were used to characterize physicians and patients. We compared characteristics across study groups by using analysis of variance for continuous variables and chi-square tests for categorical variables.

We modeled quality as a binary dependent variable indicating whether an eligible patient had received recommended care. Patients were allowed to contribute to multiple quality measures. The models considered each patient–measure combination as a separate "trial," yielding the overall likelihood of receiving care. To determine adjusted rates of absolute performance and the adjusted relative association between study group and quality, we used generalized linear models with a Poisson probability distribution and log-link function, fit with generalized estimating equations (19).

The full model used all 5 years of data and included the following independent variables: study group and year (each as a dummy variable), interaction between study group and year, patient characteristics, and physician characteristics (except for IPA membership because of too few nonmembers). Panel size, practice size, county (in case physicians moved their practices during the study), Meaningful Use status, and patient case-mix indices were time-dependent; all other characteristics were fixed. We used an independent working correlation structure with robust SEs to account for clusters of measures within patients. These clusters were nested within physician, and physicians were nested within practice. We had complete data on 97.9% of patients.

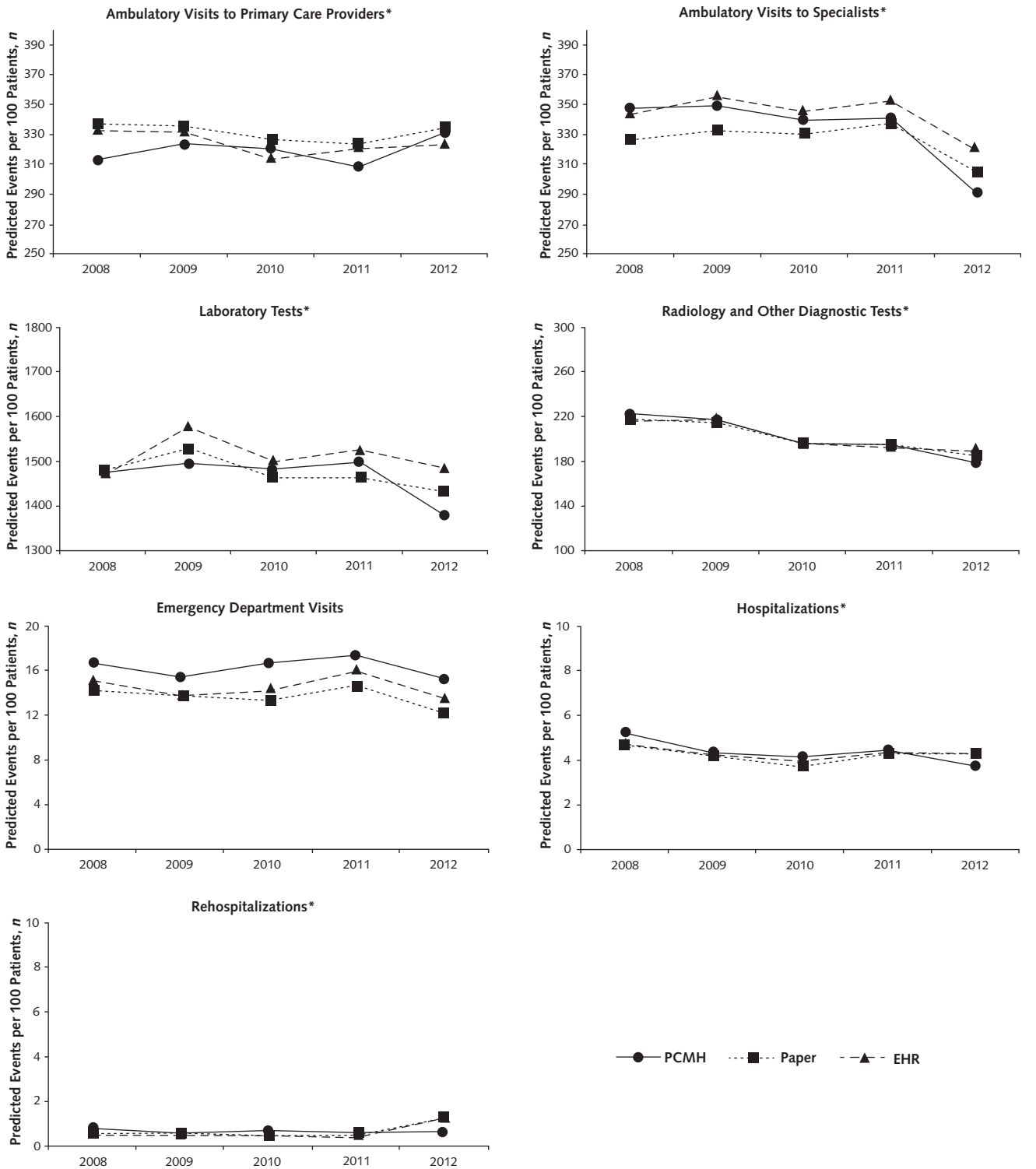
We report absolute adjusted rates of receipt of recommended care, estimated using marginal standardization under a balanced design and stratified by quality measure, study group, and year. We also report group relative risks (RRs) with 95% CIs using the marginal differences from 2008 to 2012. In addition, we

Figure 1. Adjusted probability of receiving recommended care, by quality measure and by study group over time.



EHR = electronic health record; HbA_{1c} = hemoglobin A_{1c}; LDL = low-density lipoprotein; PCMH = patient-centered medical home.
* $P < 0.05$ for ≥1 pairwise difference-in-differences over time (see also **Appendix Table 1** for details).

Figure 2. Adjusted rates of health care utilization, by type of utilization and by study group over time.



EHR = electronic health record; PCMH = patient-centered medical home.
* $P < 0.05$ for ≥1 pairwise difference-in-differences over time (see also **Appendix Table 1** for details).

exponentiated the model coefficients to obtain the RRs and 95% CIs that reflect the relative difference-in-differences for quality over time for pairwise comparisons of study groups.

For health care utilization, we counted the number of services per patient in each of the categories listed earlier. To determine adjusted rates of utilization and the adjusted relative association between study group

Table 2. Adjusted Absolute and Relative Associations Between Study Group and Quality and Utilization Outcomes*

Study Group, by Measure	Patients Receiving Recommended Care, %		Absolute Change, *percentage points*		
	2008	2012	2012 vs. 2008	PCMH or EHRs Alone vs. Paper Records	PCMH vs. EHRs Alone
Quality					
Eye examinations for patients with diabetes					
PCMH	38.5	41.5	3.0	2.8	4.5
EHRs alone	38.8	37.3	−1.5	−1.7	Reference
Paper records	39.8	40.0	0.2	Reference	-
HbA_{1c} testing for patients with diabetes					
PCMH	69.7	72.9	3.2	4.6	3.3
EHRs alone	69.6	69.5	−0.1	1.3	Reference
Paper records	68.9	67.5	−1.4	Reference	-
LDL cholesterol testing for patients with diabetes					
PCMH	67.4	61.2	−6.2	−1.6	−1.5
EHRs alone	68.5	63.8	−4.7	−0.1	Reference
Paper records	69.2	64.6	−4.6	Reference	-
Nephropathy screening for patients with diabetes					
PCMH	66.5	61.9	−4.6	3.4	0.1
EHRs alone	64.1	59.4	−4.7	3.3	Reference
Paper records	63.8	55.8	−8.0	Reference	-
Breast cancer screening for women					
PCMH	74.8	70.3	−4.6	1.1	−1.0
EHRs alone	72.4	68.9	−3.6	2.1	Reference
Paper records	73.4	67.7	−5.7	Reference	-
Chlamydia screening for women					
PCMH	44.8	41.0	−3.8	8.3	10.5
EHRs alone	46.7	32.3	−14.4	−2.2	Reference
Paper records	45.1	32.9	−12.1	Reference	-
Colorectal cancer screening					
PCMH	47.9	63.0	15.1	−0.8	1.2
EHRs alone	48.3	62.2	13.9	−2.0	Reference
Paper records	47.6	63.5	15.9	Reference	-
Appropriate medications for patients with asthma					
PCMH	84.7	83.6	−1.1	−1.8	−3.6
EHRs alone	87.1	89.6	2.5	1.8	Reference
Paper records	88.2	88.9	0.7	Reference	-
	Services per 100 Patients, *n*		**Absolute Change per 100 Patients, *n***		
	2008	**2012**	**2012 vs. 2008**	**PCMH or EHRs Alone vs. Paper Records**	**PCMH vs. EHRs Alone**
Utilization					
Ambulatory visits to primary care providers					
PCMH	312.9	331.3	18.4	21.2	27.8
EHRs alone	333.6	324.2	−9.4	−6.6	Reference
Paper records	337.4	334.5	−2.8	Reference	-
Ambulatory visits to specialists					
PCMH	348.4	291.2	−57.2	−34.5	−32.9
EHRs alone	344.2	319.8	−24.3	−1.6	Reference
Paper records	327.2	304.5	−22.7	Reference	-
Laboratory tests					
PCMH	1475.3	1379.6	−95.7	−50.8	−113.4
EHRs alone	1468.1	1485.8	17.7	62.6	Reference
Paper records	1479.2	1434.2	−45.0	Reference	-
Radiology and other diagnostic tests					
PCMH	223.6	181.0	−42.6	−8.1	−16.4
EHRs alone	215.8	189.6	−26.2	8.2	Reference
Paper records	219.1	184.7	−34.4	Reference	-
Emergency department visits					
PCMH	16.7	15.4	−1.3	0.8	0.1
EHRs alone	15.0	13.6	−1.4	0.7	Reference
Paper records	14.3	12.2	−2.1	Reference	-

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Table 2–Continued

Relative Change					
2012 vs. 2008		PCMH or EHRs Alone vs. Paper Records		PCMH vs. EHRs Alone	
Relative Risk (95% CI)	*P* Value	Relative Risk (95% CI)	*P* Value	Relative Risk (95% CI)	*P* Value
1.08 (1.01 to 1.15)	0.025	1.07 (1.00 to 1.15)	0.059	1.12 (1.03 to 1.22)	0.011
0.96 (0.89 to 1.03)	0.29	0.96 (0.88 to 1.04)	0.28	Reference	
1.01 (0.96 to 1.05)	0.82	Reference		–	
1.05 (1.02 to 1.08)	0.002	1.07 (1.03 to 1.10)	<0.001	1.05 (1.01 to 1.09)	0.017
1.00 (0.97 to 1.03)	0.95	1.02 (0.98 to 1.06)	0.32	Reference	
0.98 (0.96 to 1.00)	0.084	Reference		–	
0.91 (0.88 to 0.94)	<0.001	0.97 (0.94 to 1.01)	0.135	0.98 (0.94 to 1.02)	0.26
0.93 (0.90 to 0.97)	<0.001	1.00 (0.96 to 1.04)	0.87	Reference	
0.93 (0.91 to 0.96)	<0.001	Reference		–	
0.93 (0.89 to 0.97)	0.001	1.07 (1.01 to 1.12)	0.014	1.00 (0.95 to 1.07)	0.89
0.93 (0.88 to 0.98)	0.005	1.06 (1.00 to 1.13)	0.051	Reference	
0.87 (0.84 to 0.91)	<0.001	Reference		–	
0.94 (0.92 to 0.96)	<0.001	1.02 (1.00 to 1.04)	0.113	0.99 (0.96 to 1.01)	0.35
0.95 (0.93 to 0.97)	<0.001	1.03 (1.00 to 1.06)	0.021	Reference	
0.92 (0.91 to 0.94)	<0.001	Reference		–	
0.91 (0.83 to 1.01)	0.072	1.25 (1.10 to 1.42)	<0.001	1.32 (1.14 to 1.53)	<0.001
0.69 (0.61 to 0.79)	<0.001	0.95 (0.81 to 1.11)	0.49	Reference	
0.73 (0.66 to 0.81)	<0.001	Reference		–	
1.31 (1.28 to 1.35)	<0.001	0.99 (0.96 to 1.01)	0.32	1.02 (0.99 to 1.05)	0.195
1.29 (1.25 to 1.32)	<0.001	0.97 (0.94 to 1.00)	0.022	Reference	
1.33 (1.31 to 1.36)	<0.001	Reference		–	
0.99 (0.91 to 1.07)	0.76	0.98 (0.88 to 1.09)	0.71	0.96 (0.86 to 1.08)	0.48
1.03 (0.93 to 1.13)	0.56	1.02 (0.91 to 1.15)	0.72	Reference	
1.01 (0.93 to 1.09)	0.85	Reference		–	

Relative Change					
2012 vs. 2008		PCMH or EHRs Alone vs. Paper Records		PCMH vs. EHRs Alone	
Incidence Rate Ratio (95% CI)	*P* Value	Incidence Rate Ratio (95% CI)	*P* Value	Incidence Rate Ratio (95% CI)	*P* Value
1.06 (1.04 to 1.08)	<0.001	1.07 (1.05 to 1.09)	<0.001	1.09 (1.07 to 1.11)	<0.001
0.97 (0.95 to 0.99)	0.003	0.98 (0.96 to 1.00)	0.059	Reference	
0.99 (0.98 to 1.00)	0.21	Reference		–	
0.84 (0.82 to 0.86)	<0.001	0.90 (0.87 to 0.92)	<0.001	0.90 (0.87 to 0.93)	<0.001
0.93 (0.90 to 0.96)	<0.001	1.00 (0.97 to 1.03)	0.94	Reference	
0.93 (0.91 to 0.95)	<0.001	Reference		–	
0.94 (0.91 to 0.96)	<0.001	0.96 (0.94 to 0.99)	0.007	0.92 (0.90 to 0.95)	<0.001
1.01 (0.99 to 1.04)	0.36	1.04 (1.01 to 1.07)	0.004	Reference	
0.97 (0.95 to 0.99)	0.001	Reference		–	
0.81 (0.79 to 0.83)	<0.001	0.96 (0.93 to 0.99)	0.020	0.92 (0.89 to 0.96)	<0.001
0.88 (0.85 to 0.91)	<0.001	1.04 (1.00 to 1.08)	0.027	Reference	
0.84 (0.82 to 0.86)	<0.001	Reference		–	
0.92 (0.85 to 1.01)	0.068	1.08 (0.98 to 1.20)	0.122	1.02 (0.91 to 1.14)	0.76
0.91 (0.82 to 1.00)	0.050	1.06 (0.95 to 1.19)	0.29	Reference	
0.85 (0.79 to 0.91)	<0.001	Reference		–	

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Table 2–Continued

	Services per 100 Patients, *n*		Absolute Change per 100 Patients, *n*		
	2008	2012	2012 vs. 2008	PCMH or EHRs Alone vs. Paper Records	PCMH vs. EHRs Alone
Hospitalizations					
PCMH	5.2	3.7	−1.5	−1.0	−1.1
EHRs alone	4.7	4.3	−0.3	0.1	Reference
Paper records	4.7	4.3	−0.4	Reference	–
Rehospitalizations					
PCMH	0.8	0.7	−0.1	−0.8	−0.8
EHRs alone	0.6	1.3	0.7	0	Reference
Paper records	0.6	1.3	0.7	Reference	–

EHR = electronic health record; HbA_{1c} = hemoglobin A_{1c}; LDL = low-density lipoprotein; PCMH = patient-centered medical home.
* The relative risks, incidence rate ratios, CIs, and *P* values are those for the interaction between study group and year and were generated from models that also included study group and year as main effects. The relative risks for quality represent the probability of patients receiving recommended care, and the incidence rate ratios for utilization represent the probability of the given health care service being utilized. Results were derived using generalized linear models with the Poisson distribution and log-link function for quality and negative binomial (or zero-inflated negative binomial) regression for utilization.

and each outcome, we used generalized linear models with a negative binomial or zero-inflated negative binomial probability distribution and log-link function, given that these methods are appropriate for nonnegative, positively skewed, and overdispersed data (20, 21). Potential confounders, adjustments for clustering, completeness of data, and calculations of absolute rates and relative differences were the same as for quality, except for the interpretation of the exponentiated coefficients, which were incidence rate ratios (IRRs) under a negative binomial distribution.

We conducted additional analyses exploring the stability of patient characteristics over time. We also conducted 3 sensitivity analyses: one with time modeled as a linear function instead of with dummy variables; one using generalized linear mixed models (GLMMs) with random intercepts for patients, providers, and practices; and one without the requirement that baseline providers have patients in all 5 years of the study.

We considered *P* values less than 0.05 to be statistically significant. We used SAS, version 9.3 (SAS Institute), and Stata, version 12 (StataCorp), for all analyses.

Role of the Funding Source

The funding sources (The Commonwealth Fund and the New York State Department of Health) had no role in the study's design, conduct, or reporting.

RESULTS

Study Sample

Our sample was comprised of 438 primary care physicians from 226 practices, who cared for 136 480 unique patients over the 5-year study period (**Appendix Figure 1**, available at www.annals.org). Of these, 125 physicians in 12 practices implemented the PCMH (with EHRs), 87 physicians in 45 practices used EHRs without the PCMH, and 226 physicians in 169 practices used paper records.

Physician Characteristics

Overall, the typical physician was aged 50 years, was male, had an MD degree, was an IPA member, practiced in an urban or suburban county, and was in a practice with 15 primary care physicians (**Table 1**). Approximately half were general internists, had panel sizes of 300 or more patients, and attested to Meaningful Use by 2012.

Physicians in the PCMH group were more likely to be younger, be a general internist, attest to Meaningful Use, and have a larger practice size (**Table 1**). They were also less likely to be an IPA member and practice in a rural county. Physicians in the paper group were more likely to have an MD degree and a smaller panel size.

Patient Characteristics

Overall, the typical patient was aged 56 years; was female; had 1 major diagnosis; and had insurance through plan A, B, or E (**Table 1**). Patients in the PCMH group were more likely to be younger, female, and slightly healthier than patients in other groups (**Table 1**). They were also more likely to be in plan A than other patients.

Quality

We found modest improvements in the rate of change over time for the PCMH group compared with at least 1 control group for 2 of the 8 quality measures: eye examinations and hemoglobin A_{1c} testing for patients with diabetes (**Figure 1**; **Table 2**; and **Appendix Table 1**, available at www.annals.org). For 2 other measures (nephropathy screening for patients with diabetes and chlamydia screening for women), the PCMH group outperformed the control groups over time; however, all groups decreased their rates of appropriate care over time. There were no significant differences between the PCMH group and the control groups for the 4 remaining measures (breast cancer screening for women, colorectal cancer screening, low-

Table 2–Continued

Relative Change					
2012 vs. 2008		PCMH or EHRs Alone vs. Paper Records		PCMH vs. EHRs Alone	
Incidence Rate Ratio (95% CI)	*P* Value	Incidence Rate Ratio (95% CI)	*P* Value	Incidence Rate Ratio (95% CI)	*P* Value
0.72 (0.64 to 0.80)	<0.001	0.79 (0.69 to 0.90)	<0.001	0.77 (0.66 to 0.90)	0.001
0.93 (0.81 to 1.06)	0.28	1.02 (0.88 to 1.19)	0.79	Reference	
0.91 (0.83 to 1.00)	0.049	Reference		–	
0.93 (0.71 to 1.23)	0.63	0.43 (0.32 to 0.60)	<0.001	0.40 (0.28 to 0.57)	<0.001
2.33 (1.68 to 3.22)	<0.001	1.08 (0.79 to 1.48)	0.62	Reference	
2.15 (1.64 to 2.82)	<0.001	Reference		–	

density lipoprotein cholesterol testing for patients with diabetes, and appropriate asthma medication).

Utilization

Utilization patterns were similar across groups from 2008 to 2011 but showed modest and statistically significant differences in the rate of change for the PCMH group compared with the control groups on 6 of 7 utilization measures in 2012 (**Figure 2**, **Table 2**, and **Appendix Table 1**). For example, hospitalizations were relatively stable from 2008 to 2011 (approximately 3.9 to 5.2 per 100 patients per year) but decreased in the PCMH group in 2012. The exact patterns of utilization across the groups were complex, with the rates in the PCMH group sometimes starting above and sometimes starting below the other groups at baseline (**Figure 2**). Detailed descriptions of the results by group and by year can be found in **Appendix 2** (available at www.annals.org).

Overall, the analyses of changes from 2008 to 2012 indicated that, compared with the paper group, the PCMH group had 21 (7%) more primary care visits, 35 (10%) fewer specialist visits, 51 (4%) fewer laboratory tests, 8 (4%) fewer radiologic tests, 1 (21%) fewer hospitalization, and 1 (57%) fewer rehospitalization for every 100 patients (adjusted $P < 0.05$ for each) (**Table 2**). Similarly, the PCMH group had 28 (9%) more primary care visits, 33 (10%) fewer specialist visits, 113 (8%) fewer laboratory tests, 16 (8%) fewer radiologic tests, 1 (23%) fewer hospitalization, and 1 (60%) fewer rehospitalization for every 100 patients over the study period compared with the EHR group (adjusted $P < 0.05$ for each).

The PCMH group had the highest number of ED vists (16.7 per 100 patients at baseline and 15.4 per 100 patients at the end of the study period) and the paper group had the lowest (14.3 per 100 patients at baseline and 12.2 per 100 patients at the end of the study period). Although the paper group had a statistically significant decrease in ED visits over time, the rates of change did not differ across study groups (**Table 2**).

Additional Analyses

In additional analyses, we found that although the proportion of patients from a given health plan may have changed over time, these changes did not disproportionally affect a particular study group, thus minimizing bias (**Appendix Tables 2** and **3** and **Appendix Figure 2**, available at www.annals.org). When we used a linear function to model time, the magnitude of the effects was smaller but most results had similar direction and significance (**Appendix Table 4**, available at www.annals.org). Results for quality and all utilization measures persisted in sensitivity analyses using GLMMs with random intercepts for patients (**Appendix Table 5**, available at www.annals.org). Results also persisted for quality, specialist visits, ED visits, hospitalizations, and rehospitalizations when we used GLMMs with random intercepts for providers and practices (**Appendix Table 6**, available at www.annals.org). When we removed the requirement for providers to have patients in all 5 study years, results were similar for quality and persisted in magnitude, direction, and statistical significance for nearly all utilization outcomes (**Appendix Table 7**, available at www.annals.org).

DISCUSSION

In this community-based, multipayer study, we found that the PCMH was associated with modest changes in rates of health care utilization over time and similar health care quality compared with the paper and EHR groups. The changes in utilization were seen mostly in the last year of our study (3 years after implementation of the PCMH).

Why certain quality measures improved while others did not is unclear, but this has previously been attributed to the complexity of clinical workflow because different types of decision support, disease management, and care coordination are needed to improve different measures (22). For measures that showed improvement, the magnitude was similar to that found in previous studies of the PCMH in integrated delivery systems and in single–health plan studies, with typical improvements of 2% to 7% on affected measures (8, 23, 24). Of note, the goals of the PCMH initiative we evaluated were much broader than the 8 quality measures selected by the health plans at baseline and, over time, these measures became less of a focus for the

community than the clinical transformation needed to achieve changes in health care utilization.

We found that the PCMH was associated with an increase in primary care visits and a decrease in specialist visits. A previous cross-sectional, single–health plan study found a decrease in both types of visits (25). The pattern we found suggests a relative increase in the intensity of primary care, which is a central goal of the PCMH model.

Our study is one of the few to show an association with fewer laboratory and radiologic tests. Our finding of fewer hospitalizations was similar to the 6% reduction observed in an integrated delivery system (23). Why we did not find a change in ED visits is unclear, given that a reduction in ED visits has been a common effect of the PCMH elsewhere (8, 10, 23). It is plausible that hospitalizations and rehospitalizations could have been averted, without a change in ED visits, through improved care coordination in the ambulatory setting. Of note, rates of hospitalizations and rehospitalizations increased in the control groups in the last year of the study, which contributed to the finding of a relative decrease in the PCMH group. Keeping utilization at constant levels or avoiding an increase can be important and has been described as "bending the cost curve" (26). What caused utilization to increase in the control groups is unclear, and whether this relative difference will persist over even longer periods is unknown. The study's findings suggest that the effects of the PCMH take several years to unfold. If the NCQA standards are used as a road map for practice infrastructure, it takes time to put that infrastructure into place, learn how to use it, and then deliver care consistently to enough patients to make a difference—clinically and statistically—in the outcomes.

That there were few differences between the EHR and paper groups is striking. This finding is consistent with our earlier work, which had shorter follow-up (7, 11). We did find that EHRs alone were associated with more laboratory and radiologic tests compared with paper records, suggesting an increase in test utilization because EHRs may have made ordering easier (27). Thus, technology alone seems to be insufficient to decrease utilization. This interpretation is consistent with feedback we received from the PCMH practice leaders, who described building custom reports within their EHRs to guide, enable, and iteratively refine clinical transformation. These practice leaders noted that they needed the population-based data that the EHRs provided and paper records lacked, but they also stated that the EHR itself, if treated as a static repository of data, was not enough. This cohort of PCMH practices came to view the PCMH model as a starting point for additional transformation, and almost all of them went on to enter into accountable care organizations or other similar payment models at the end of the study period. The practice leaders regarded their experience with the PCMH as the source of their readiness for accountable care.

This study has several strengths. It took place in a multipayer, multiprovider community, which increases the generalizability of the results. The 3-group design and 5-year time frame allowed us to distinguish the long-term effects of the PCMH from the effects of EHRs alone. The study combined data from multiple sources, including 5 commercial health plans, an independent practice association, and the Meaningful Use program (28). We also had a large sample, with more than 400 primary care physicians, more than 200 practices, and more than 100 000 patients. We used patient-level data, with hierarchical modeling to account for clustering. The detailed figures we generated offer a view of the complex changes that occur over time and underscore the importance of the concurrent control groups we used.

This study also has several limitations. First, we cannot rule out confounding by unmeasured covariates. Two randomized, controlled trials (with <40 practices each) of the PCMH have been done, but others are unlikely to occur because of the complexity of using that study design for health care delivery (8, 29). Second, many of the results were influenced by changes in utilization in the last year of the study period. We cannot determine from this study whether 2012 was an outlier or whether rates of utilization that year reflected the cumulative effects of the PCMH intervention. Longer-term studies would be desirable but may be difficult given the emergence of accountable care organizations, as described earlier. Third, this study considered the effects of the 2008 NCQA standards. The NCQA has since released subsequent iterations of its standards, which have been viewed as more difficult to achieve. All PCMH practices in this study achieved the highest level of the 2008 standards (level III), which is most similar to the subsequent versions. Future studies will be needed to explore the effects of the newer standards. Fourth, this study considered a small subset of process-oriented quality measures, which reflect a small subset of the construct of quality. Fifth, this study did not address potential changes in cost; however, the substantial reductions observed in expensive forms of utilization, including hospitalizations, would be expected to be associated with significant reductions in cost. Sixth, this study did not explore potential differences between health plans, although our supplemental analyses suggest that this was not a substantial source of bias. Finally, this study did not capture PCMH capabilities in non-PCMH groups or PCMH transformation that might have occurred in 2011 and 2012 among physicians in the control groups. If the non-PCMH groups had considerable PCMH capabilities, this would bias the study toward the null.

In conclusion, the PCMH was associated with similar quality of care and modest changes in utilization (more primary care visits and fewer specialist visits, laboratory tests, radiologic tests, hospitalizations, and rehospitalizations) over time compared with EHRs or paper records alone. These results support ongoing efforts to build on the PCMH model, using information technology to inform population health management, payment reform, and health system change.

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Appendix 1: A Brief, Qualitative, Community-Based Description of the Hudson Valley Community Transformation Program

The intervention for practices seeking to implement the PCMH was comprised of 2 components: organizational support for practice leadership and individual practice–level support. Support for the initiative was led by 6 clinical nurses and practice coaches with experience in continuous quality improvement, EHR implementation, care management, workflow redesign, and general medical practice operations. Participating practices included small and large practices, as well as private practices and federally qualified health centers.

Organizational Support

The Taconic IPA Medical Council met monthly and included key members of the physician and operational leadership of the participating practices. This forum was used to inform and educate all members on the goals of the initiative and to garner support for the intervention and agree on the chronic conditions and preventive care measures that the initiative would focus on. The monthly Medical Council provided a platform for council members to collaborate, share best practices, and facilitate solutions for practice- and project-level issues. The project also included facilitated collaborative sessions to enhance practice and staff development, highlight best practices, provide educational support, and stimulate collaboration and learning across practices. These sessions were attended by practice leadership and care team members involved in the practice-level implementation and adoption of medical home concepts.

Practice-Level Support

A comprehensive assessment of each practice's PCMH capabilities was conducted and was used to create individualized practice gap analysis and work plans to achieve PCMH recognition. The assessment included a site visit and administration of a standardized medical home capability assessment tool. The tool was completed by at least 1 physician as well as by other key team members (including nurses, medical assistants, and staff). The results were aggregated to provide benchmarking, determine which practices had greater support needs, and assign appropriate coaching support.

The assessment results were presented to each practice, and a practice-specific plan for transformation was developed in conjunction with each practice. A schedule of monthly on-site and weekly or biweekly telephone intervention support was created based on progress made between meetings. In practices where significant gaps were identified, a 2-hour PCMH kickoff session was conducted for the entire staff. Each practice was provided with tools, templates, and policies to support the practice redesign as well as specific guidance to facilitate the NCQA recognition process requirements. Coaches worked with practice leadership to redesign workflow emphasizing a team-based approach to care, with new processes focusing on coordination of care, quality, safety, and preventive care, which were supported by the use of health information technology tools, such as EHRs, electronic prescribing, an electronic patient registry, and clinical decision support.

Appendix 2: Detailed Description of Quality and Utilization Results

Quality

We found modest but significant improvements in the rate of change over time for the PCMH group compared with at least 1 control group for 2 of the 8 quality measures: eye examinations and hemoglobin A_{1c} testing for patients with diabetes (**Figure 1**, **Table 2**, and **Appendix Table 1**). For eye examinations, the PCMH group improved on provision of appropriate care, from 38.5% of patients in 2008 to 41.5% in 2012 (absolute change, 3.0 percentage points), whereas the EHR group stayed at essentially the same rate over time; overall, the change in the PCMH group was 4.5 percentage points more than in the EHR group from 2008 to 2012 (RR, 1.12 [95% CI, 1.03 to 1.22]). For hemoglobin A_{1c} testing, the PCMH group improved from 69.7% of patients in 2008 to 72.9% in 2012 (absolute change, 3.2 percentage points), whereas both control groups decreased between 2008 and 2011 and then increased slightly in 2012; overall, patients in the PCMH group improved by 3.3 percentage points more than those in the EHR group (RR, 1.05 [CI, 1.01 to 1.09]) and 4.6 percentage points more than those in the paper group (RR, 1.07 [CI, 1.03 to 1.10]) over time. There were no

differences between the EHR and paper groups for these measures.

For 2 other measures (nephropathy screening for patients with diabetes and chlamydia screening for women), the PCMH group outperformed the control groups over time; however, all groups decreased their rates of appropriate care over time (**Figure 1**, **Table 2**, and **Appendix Table 1**). The PCMH group decreased its rate of nephropathy screening from 66.5% of patients in 2008 to 61.9% in 2012 (absolute change, −4.6 percentage points); overall, this was 3.4 percentage points less than the decrease in the paper group (RR, 1.07 [CI, 1.01 to 1.12]). For chlamydia screening, the rate in the PCMH group increased from 2008 to 2009 but then decreased, with an overall change from 44.8% in 2008 to 41.0% in 2012 (absolute change, −3.8 percentage points); overall, this was 10.5 percentage points less than the decrease in the EHR group (RR, 1.32 [CI, 1.14 to 1.53]) and 8.3 percentage points less than the decrease in the paper group (RR, 1.25 [CI, 1.10 to 1.42]). There were no significant differences between the EHR and paper groups for these measures.

For 2 measures (breast cancer screening for women and colorectal cancer screening), there were no differences between the PCMH group and the control groups, but there were differences between the EHR and paper groups (**Figure 1**, **Table 2**, and **Appendix Table 1**). All 3 groups decreased their rates of breast cancer screening slightly over time, with the EHR group decreasing less than the paper group (absolute changes, −3.6 vs. −5.7 percentage points). All 3 groups increased their rates of colorectal cancer screening over time, with the paper group increasing slightly more than the EHR group (absolute changes, 15.9 vs. 13.9 percentage points).

There were no significant differences across the study group in rates of low-density lipoprotein cholesterol testing for patients with diabetes or appropriate asthma medications over time (**Figure 1**, **Table 2**, and **Appendix Table 1**).

Utilization

When we considered the utilization outcomes, we found that the PCMH group significantly outperformed the control groups on 6 of the 7 measures (**Figure 2**, **Table 2**, and **Appendix Table 1**).

For primary care visits, patients of physicians in the PCMH group increased their utilization from 2008 to 2010, decreased it in 2011, and then increased it again in 2012, with an overall change from 312.9 visits per 100 patients in 2008 to 331.3 in 2012 (absolute change, 18.4 visits per 100 patients). The PCMH group began with lower rates of primary care visits than the other groups, and those groups decreased their rates slightly over time. The PCMH group thus saw a relative increase in primary care visits compared with the EHR group (IRR, 1.09 [CI, 1.07 to 1.11]) and the paper group (IRR, 1.07 [CI, 1.05 to 1.09]). There was no significant difference between the EHR and paper group for primary care visits.

For specialist visits, the PCMH group had relatively stable utilization from 2008 to 2011 followed by a sharp decrease in 2012. The other groups increased their utilization of specialist visits from 2008 to 2011 and then also decreased sharply in 2012. The PCMH group started at 348.4 specialist visits per 100 patients in 2008 and ended with 291.2 in 2012 (absolute change, −57.2 visits per 100 patients); overall, the PCMH group had a 10% relative decrease in specialist visits compared with the other groups (IRR, 0.90 [CI, 0.87 to 0.93] compared with the EHR group and 0.90 [CI, 0.87 to 0.92] compared with the paper group). There was no significant difference between the EHR group and the paper group for specialist visits.

For laboratory tests, all 3 groups increased their utilization initially, and the PCMH group then decreased its utilization, especially in 2012. The PCMH group started with 1475.3 laboratory tests per 100 patients in 2008 and ended with 1379.6 in 2012 (absolute change, −95.7 tests per 100 patients); overall, the PCMH group used fewer laboratory tests over time than the other groups (IRR, 0.92 [CI, 0.90 to 0.95] compared with the EHR group and 0.96 [CI, 0.94 to 0.99] compared with the paper group). The EHR group had a relative increase in laboratory tests compared with the paper group (IRR, 1.04 [CI, 1.01 to 1.07]).

For radiologic tests, all 3 groups decreased their utilization over time, although the PCMH group decreased the most. The PCMH group began with 223.6 radiologic tests per 100 patients and ended with 181.0 (absolute change, −42.6 tests per 100 patients; IRR, 0.92 [CI, 0.89 to 0.96] compared with the EHR group and 0.96 [CI, 0.93 to 0.99] compared with the paper group). The EHR group did not decrease as much as the paper group (IRR, 1.04 [CI, 1.00 to 1.08]).

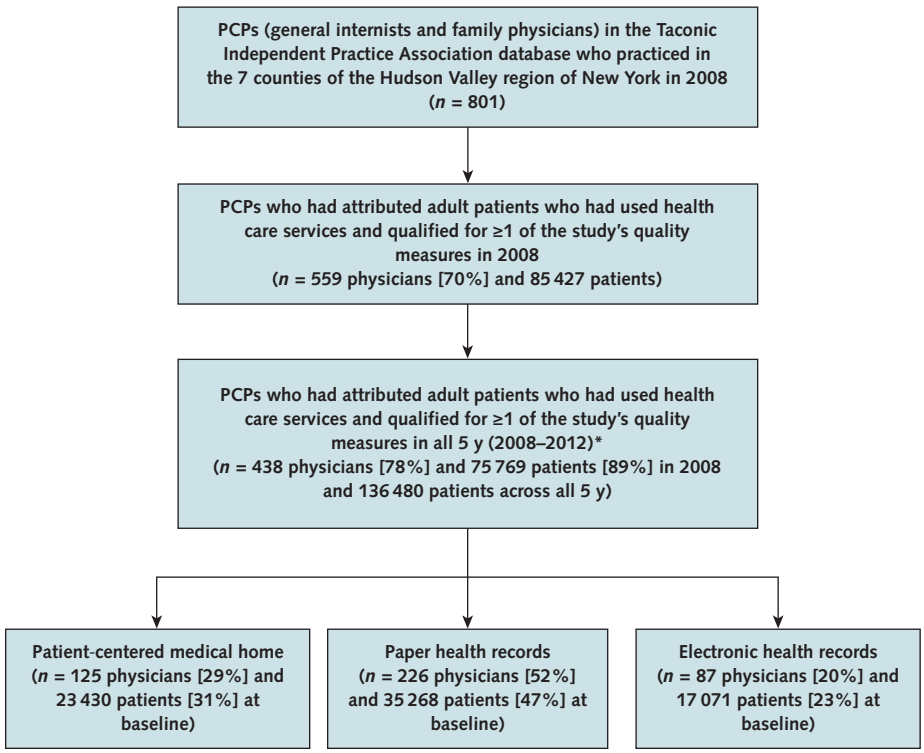
For ED visits, all groups followed a similar pattern, with between 12 and 17 visits per 100 patients and no significant differences in the rate of change over time across groups.

For hospitalizations, all groups decreased their utilization from 2008 to 2011, and the PCMH group continued to decrease while the other groups increased in 2012. The PCMH group began with 5.2 hospitalizations per 100 patients and decreased to 3.7 (absolute change, −1.5 hospitalizations per 100 patients; IRR, 0.77 [CI, 0.66 to 0.90] compared with the EHR group and 0.79 [CI, 0.69 to 0.90] compared with the paper group). The rate of change did not differ between the EHR and paper groups.

For rehospitalizations, all groups had a relatively constant rate of utilization from 2008 to 2011, but the PCMH group decreased slightly (absolute change,

−0.1 rehospitalization per 100 patients) while the other groups increased in 2012. The relative differences were significant (IRR, 0.40 [CI, 0.28 to 0.57] compared with the EHR group and 0.43 [CI, 0.32 to 0.60] compared with the paper group). There was no difference between the EHR and paper groups.

Appendix Figure 1. Study flow diagram.



PCP = primary care physician.
* The PCPs were required to have patients in all 5 y of the study, but they did not need to be the same patients across all 5 y.

Appendix Table 1. Adjusted Absolute Performance on Quality and Utilization Outcomes, by Measure and Study Group Over Time

Year, by Measure and Study Group	Total Eligible Patients, *n*	Patients Receiving Recommended Care (95% CI), %		
		PCMH	EHRs Alone	Paper Records
Quality				
Eye examinations for patients with diabetes				
2008	13 183	38.5 (36.6–40.6)	38.8 (36.8–40.9)	39.8 (38.1–41.6)
2009	12 963	39.1 (37.1–41.2)	37.6 (35.6–39.6)	38.5 (36.8–40.2)
2010	11 097	40.8 (38.7–43.1)	38.0 (35.9–40.2)	39.0 (37.2–40.8)
2011	11 792	41.2 (39.2–43.3)	38.4 (36.4–40.5)	40.3 (38.6–42.1)
2012	9794	41.5 (39.2–43.9)	37.3 (35.1–39.6)	40.0 (38.3–41.8)
HbA_{1c} testing for patients with diabetes				
2008	13 183	69.7 (68.0–71.5)	69.6 (67.8–71.4)	68.9 (67.4–70.4)
2009	12 963	72.3 (70.6–74.1)	72.3 (70.6–74.1)	69.6 (68.1–71.1)
2010	11 097	70.3 (68.6–72.1)	67.2 (65.4–69.1)	64.7 (63.2–66.3)
2011	11 792	71.9 (70.3–73.5)	65.5 (63.7–67.3)	64.1 (62.7–65.6)
2012	9794	72.9 (71.2–74.8)	69.5 (67.7–71.4)	67.5 (66.0–69.0)
LDL cholesterol testing for patients with diabetes				
2008	13 183	67.4 (65.6–69.2)	68.5 (66.6–70.4)	69.2 (67.6–70.8)
2009	12 963	66.4 (64.6–68.3)	70.6 (68.7–72.5)	69.3 (67.6–70.8)
2010	11 097	63.2 (61.4–65.1)	65.8 (63.9–67.8)	64.2 (62.6–65.9)
2011	11 792	62.4 (60.7–64.1)	62.6 (60.8–64.4)	62.8 (61.2–64.3)
2012	9794	61.2 (59.4–63.1)	63.8 (61.9–65.7)	64.6 (63.1–66.2)
Nephropathy screening for patients with diabetes				
2008	13 183	66.5 (64.3–68.8)	64.1 (61.9–66.4)	63.8 (62.0–65.7)
2009	12 963	65.8 (63.6–68.0)	65.3 (63.6–68.0)	63.0 (61.1–64.8)
2010	11 097	65.0 (62.8–67.4)	62.6 (60.1–65.2)	58.9 (57.0–60.9)
2011	11 792	63.2 (61.2–65.3)	62.4 (60.1–64.8)	59.7 (57.8–61.6)
2012	9794	61.9 (59.7–64.2)	59.4 (56.9–62.0)	55.8 (54.0–57.6)
Breast cancer screening for women				
2008	38 857	74.8 (73.7–76.0)	72.4 (71.2–73.7)	73.4 (72.4–74.5)
2009	35 701	75.6 (74.4–76.8)	74.7 (73.5–76.0)	74.2 (73.5–76.0)
2010	28 300	75.3 (74.1–76.6)	72.7 (71.4–74.1)	72.8 (71.7–74.0)
2011	30 047	72.9 (71.8–74.1)	70.6 (69.4–71.9)	70.5 (69.5–71.6)
2012	25 487	70.3 (69.0–71.5)	68.9 (67.5–70.2)	67.7 (66.6–68.8)
Chlamydia screening for women				
2008	3427	44.8 (41.8–48.1)	46.7 (43.0–50.8)	45.1 (41.8–48.6)
2009	3392	49.0 (45.9–52.4)	54.9 (50.9–59.3)	51.4 (47.9–55.1)
2010	2734	41.6 (38.7–44.7)	39.3 (35.8–43.2)	36.9 (34.0–40.2)
2011	3206	39.6 (37.2–42.2)	35.8 (32.8–39.1)	34.0 (31.5–36.7)
2012	2529	41.0 (38.0–44.2)	32.3 (29.0–36.1)	32.9 (30.2–36.0)
Colorectal cancer screening				
2008	53 410	47.9 (46.9–49.0)	48.3 (47.2–49.5)	47.6 (46.7–48.6)
2009	46 518	54.0 (52.8–55.3)	54.2 (53.1–55.5)	53.1 (52.1–54.1)
2010	38 251	59.6 (58.3–61.0)	57.9 (56.6–59.2)	58.5 (57.4–59.7)
2011	40 783	60.1 (58.8–61.4)	60.0 (58.8–61.2)	60.7 (59.6–61.9)
2012	34 892	63.0 (61.6–64.5)	62.2 (60.9–63.6)	63.5 (62.3–64.6
Appropriate medications for patients with asthma				
2008	873	84.7 (79.4–90.3)	87.1 (81.9–92.6)	88.2 (83.4–93.3)
2009	626	85.0 (79.4–90.9)	88.6 (82.9–94.7)	89.7 (84.6–95.1)
2010	456	84.9 (78.9–91.3)	92.4 (86.2–99.1)	92.8 (87.5–98.4)
2011	465	87.6 (82.5–93.0)	88.2 (80.7–96.4)	90.5 (85.0–96.4)
2012	386	83.6 (77.6–90.2)	89.6 (82.0–97.9)	88.9 (82.4–95.9)
		Rate per 100 Patients (95% CI)		
		PCMH	EHRs Alone	Paper Records
Utilization				
Ambulatory visits to primary care providers				
2008	75 576	312.9 (308.2–317.6)	333.6 (328.6–338.6)	337.4 (333.0–341.8)
2009	67 083	323.5 (318.5–328.6)	331.6 (326.6–336.6)	336.1 (331.7–340.5)
2010	54 763	320.6 (315.5–325.8)	312.9 (307.7–318.0)	326.8 (322.3–331.3)
2011	58 310	308.7 (304.1–313.2)	320.3 (315.5–325.1)	324.0 (319.7–328.3)
2012	49 522	331.3 (325.8–336.7)	324.2 (319.1–329.3)	334.5 (330.2–338.8)

Continued on following page

Appendix Table 1–Continued

Year, by Measure and Study Group	Total Eligible Patients, *n*	Rate per 100 Patients (95% CI)		
		PCMH	EHRs Alone	Paper Records
Ambulatory visits to specialists				
2008	75 576	348.4 (341.3–355.5)	344.2 (336.7–351.7)	327.2 (321.3–333.2)
2009	67 083	349.8 (342.4–357.2)	355.3 (347.8–362.9)	333.0 (326.8–339.2)
2010	54 763	340.0 (332.6–347.5)	346.1 (338.5–353.7)	330.1 (323.7–336.4)
2011	58 310	341.4 (334.6–348.1)	352.8 (345.4–360.3)	337.7 (331.5–344.0)
2012	49 522	291.2 (284.6–297.8)	319.8 (312.7–327.0)	304.5 (298.7–310.3)
Laboratory tests				
2008	75 576	1475.3 (1447.8–1502.9)	1468.1 (1439.8–1496.4)	1479.2 (1454.7–1503.7)
2009	67 083	1497.4 (1469.0–1525.9)	1580.8 (1550.8–1610.8)	1531.6 (1506.0–1557.2)
2010	54 763	1485.2 (1455.1–1515.2)	1499.7 (1468.4–1531.1)	1465.3 (1439.3–1491.3)
2011	58 310	1498.9 (1471.4–1526.4)	1526.7 (1497.1–1556.3)	1464.8 (1440.2–1489.4)
2012	49 522	1379.6 (1350.9–1408.2)	1485.8 (1454.2–1517.5)	1434.2 (1410.0–1458.5)
Radiology and other diagnostic tests				
2008	75 576	223.6 (218.5–228.7)	215.8 (210.7–220.9)	219.1 (214.7–223.6)
2009	67 083	217.4 (212.2–222.6)	218.3 (213.0–223.6)	215.4 (210.9–219.8)
2010	54 763	196.4 (191.6–201.2)	196.0 (191.0–200.9)	197.9 (193.5–202.2)
2011	58 310	195.8 (191.3–200.3)	192.8 (188.1–197.5)	195.5 (191.5–199.6)
2012	49 522	181.0 (176.4–185.7)	189.6 (184.5–194.7)	184.7 (180.6–188.7)
Emergency department visits				
2008	75 576	16.7 (15.1–18.2)	15.0 (13.6–16.5)	14.3 (13.0–15.6)
2009	67 083	15.4 (13.9–16.9)	13.8 (12.5–15.2)	13.7 (12.4–14.9)
2010	54 763	16.7 (15.1–18.4)	14.1 (12.7–15.5)	13.3 (12.0–14.5)
2011	58 310	17.4 (15.8–19.1)	16.0 (14.4–17.5)	14.7 (13.4–16.1)
2012	49 522	15.4 (13.9–16.9)	13.6 (12.2–15.1)	12.2 (11.0–13.3)
Hospitalizations				
2008	75 576	5.2 (4.7–5.7)	4.7 (4.2–5.1)	4.7 (4.3–5.2)
2009	67 083	4.3 (3.9–4.7)	4.2 (3.7–4.6)	4.2 (3.8–4.5)
2010	54 763	4.1 (3.7–4.5)	3.9 (3.4–4.3)	3.8 (3.5–4.2)
2011	58 310	4.4 (4.0–4.8)	4.3 (3.8–4.7)	4.3 (3.9–4.6)
2012	49 522	3.7 (3.4–4.1)	4.3 (3.8–4.8)	4.3 (3.9–4.7)
Rehospitalizations				
2008	75 576	0.8 (0.6–0.9)	0.6 (0.4–0.7)	0.6 (0.5–0.7)
2009	67 083	0.6 (0.5–0.8)	0.5 (0.4–0.7)	0.5 (0.4–0.6)
2010	54 763	0.7 (0.5–0.8)	0.5 (0.3–0.6)	0.5 (0.4–0.6)
2011	58 310	0.6 (0.5–0.8)	0.4 (0.3–0.5)	0.5 (0.4–0.6)
2012	49 522	0.7 (0.6–0.9)	1.3 (1.0–1.6)	1.3 (1.0–1.6)

EHR = electronic health record; HbA_{1c} = hemoglobin A_{1c}; LDL = low-density lipoprotein; PCMH = patient-centered medical home.

Appendix Table 2. Additional Analyses to Explore Stability of Patient Characteristics Over Time: Number of Years of Data Contributed by Patients in the Study (*n* = 136 480)*

Years of Data Contributed	Patients, *n* (%)
5 of 5	15 181 (11)
4 of 5	14 688 (11)
3 of 5	16 924 (12)
2 of 5	33 006 (24)
1 of 5	56 681 (42)

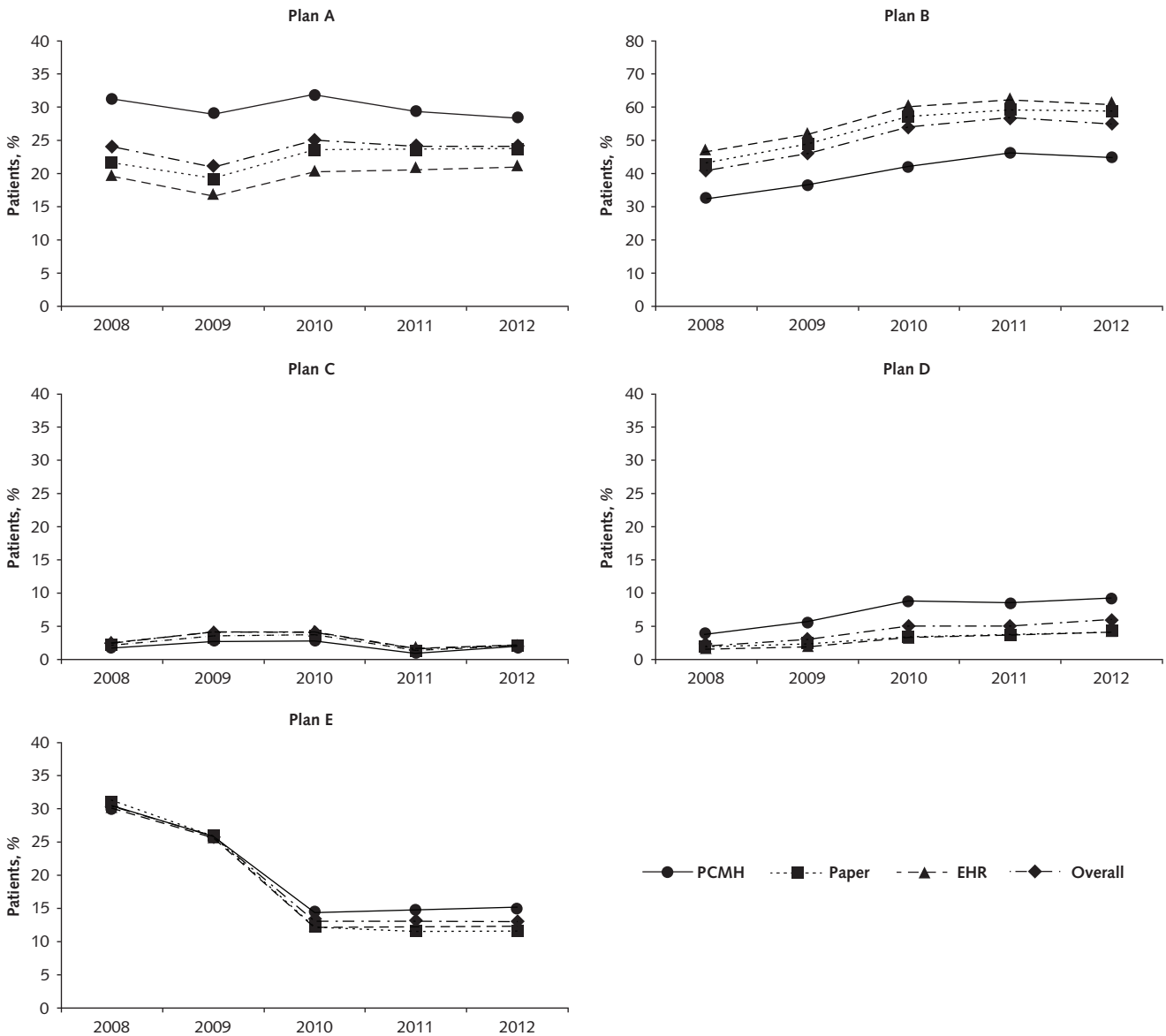
* As shown in this table, a majority of patients (58%) contributed ≥2 y of data over the 5-y study period.

Appendix Table 3. Additional Analyses to Explore Stability of Patient Characteristics Over Time: Characteristics of Patients Contributing Data in Each Year of the Study (n = 136 480)*

Year	Patients, *n*	Female, %	Health Plan, %					Mean Age (SD), *y*	Mean Case-Mix Index (SD)
			A	B	C	D	E		
2008	75 769	64	24	41	2	2	30	56 (12)	1.1 (1.2)
2009	67 088	64	21	46	4	3	26	54 (12)	1.1 (1.2)
2010	54 765	64	25	54	4	5	13	54 (12)	1.2 (1.2)
2011	58 312	64	24	57	1	5	13	53 (12)	1.1 (1.2)
2012	52 188	63	24	55	2	6	13	52 (12)	1.1 (1.2)

* As shown in this table, the overall number of patients per year decreased over time. The proportion of female patients decreased slightly, whereas case mix remained relatively constant over time. Plans A and C each accounted for a similar proportion of patients over time, whereas the proportions of patients from plans B and D increased and the proportion of patients from plan E decreased over time. The average patient age decreased over time. All of these variables were considered time-dependent in the multivariable model; thus, these changes over time were measured and controlled for in the model.

Appendix Figure 2. Proportions of patients from each of the participating health plans, by study group over time.



These figures show that any secular trends in the proportion of patients coming from each plan over time affected the study groups similarly. As a result, the likelihood of substantial bias from these secular trends is relatively low. EHR = electronic health record; PCMH = patient-centered medical home.

Appendix Table 4. Adjusted Absolute and Relative Associations Between Study Group and Quality and Utilization Outcomes, With Time Treated as a Linear Variable*

Study Group, by Measure	Patients Receiving Recommended Care, %		Absolute Change, *percentage points*			Relative Risk (95% CI); *P* Value		
	2008	2012	2012 vs. 2008	PCMH or EHRs Alone vs. Paper Records	PCMH vs. EHRs Alone	Within Group, per Year	PCMH or EHRs Alone vs. Paper Records	PCMH vs. EHRs Alone
Quality								
Eye examinations for patients with diabetes								
PCMH	38.6	41.8	3.3	2.4	4.1	1.02 (1.01 to 1.04); *P* = 0.007	1.02 (1.00 to 1.03); *P* = 0.076	1.03 (1.01 to 1.05); *P* = 0.012
EHRs alone	38.4	37.6	−0.8	−1.7	Reference	0.99 (0.98 to 1.01); *P* = 0.52	0.99 (0.97 to 1.01); *P* = 0.26	Reference
Paper records	39.1	39.9	0.8	Reference	–	1.01 (0.99 to 1.02); *P* = 0.32	Reference	–
HbA_{1c} testing for patients with diabetes								
PCMH	70.9	72.4	1.6	5.4	5.3	1.01 (1.00 to 1.01); *P* = 0.112	1.02 (1.01 to 1.03); *P* < 0.001	1.02 (1.01 to 1.03); *P* < 0.001
EHRs alone	71.0	67.3	−3.8	0.1	Reference	0.99 (0.98 to 0.99); *P* < 0.001	1.00 (0.99 to 1.01); *P* = 0.87	Reference
Paper records	69.4	65.5	−3.9	Reference	–	0.99 (0.98 to 0.99); *P* < 0.001	Reference	–
LDL cholesterol testing for patients with diabetes								
PCMH	67.8	60.8	−7.1	−0.4	0.4	0.97 (0.97 to 0.98); *P* < 0.001	1.00 (0.99 to 1.01); *P* = 0.60	1.00 (0.99 to 1.01); *P* = 0.90
EHRs alone	70.2	62.8	−7.5	−0.8	Reference	0.97 (0.96 to 0.98); *P* < 0.001	1.00 (0.99 to 1.01); *P* = 0.55	Reference
Paper records	69.8	63.1	−6.7	Reference	–	0.98 (0.97 to 0.98); *P* < 0.001	Reference	–
Nephropathy screening for patients with diabetes								
PCMH	66.4	62.2	−4.2	3.3	0.1	0.98 (0.97 to 0.99); *P* = 0.001	1.01 (1.00 to 1.03); *P* = 0.013	1.00 (0.99 to 1.01); *P* = 0.92
EHRs alone	64.8	60.6	−4.2	3.2	Reference	0.98 (0.97 to 0.99); *P* = 0.004	1.01 (1.00 to 1.03); *P* = 0.038	Reference
Paper records	63.9	56.4	−7.5	Reference	–	0.97 (0.96 to 0.98); *P* < 0.001	Reference	–
Breast cancer screening for women								
PCMH	75.1	72.0	−3.1	2.0	0.2	0.99 (0.99 to 0.99); *P* < 0.001	1.01 (1.00 to 1.01); *P* = 0.005	1.00 (0.99 to 1.01); *P* = 0.77
EHRs alone	73.2	69.9	−3.3	1.9	Reference	0.99 (0.98 to 0.99); *P* < 0.001	1.01 (1.00 to 1.01); *P* = 0.029	Reference
Paper records	73.8	68.7	−5.2	Reference	–	0.98 (0.98 to 0.99); *P* < 0.001	Reference	–
Chlamydia screening for women								
PCMH	46.4	39.8	−6.6	9.6	11.3	0.96 (0.94 to 0.98); *P* < 0.001	1.07 (1.04 to 1.09); *P* < 0.001	1.07 (1.04 to 1.11); *P* < 0.001
EHRs alone	51.3	33.4	−17.9	−1.7	Reference	0.90 (0.87 to 0.92); *P* < 0.001	0.99 (0.96 to 1.03); *P* = 0.73	Reference
Paper records	48.7	32.5	−16.3	Reference	–	0.90 (0.88 to 0.92); *P* < 0.001	Reference	–
Colorectal cancer screening								
PCMH	48.6	65.4	16.7	0.1	1.8	1.08 (1.07 to 1.08); *P* < 0.001	1.00 (0.99 to 1.01); *P* = 0.94	1.01 (1.00 to 1.01); *P* = 0.056
EHRs alone	48.9	63.9	15.0	−1.7	Reference	1.07 (1.06 to 1.08); *P* < 0.001	0.99 (0.99 to 1.00); *P* = 0.035	Reference
Paper records	48.1	64.7	16.6	Reference	–	1.08 (1.07 to 1.08); *P* < 0.001	Reference	–
Appropriate medications for patients with asthma								
PCMH	84.6	85.8	1.3	−0.9	−1.9	1.00 (0.99 to 1.02); *P* = 0.68	1.00 (0.98 to 1.02); *P* = 0.83	0.99 (0.97 to 1.02); *P* = 0.67
EHRs alone	87.4	90.6	3.2	1.0	Reference	1.01 (0.99 to 1.03); *P* = 0.41	1.00 (0.98 to 1.03); *P* = 0.83	Reference
Paper records	88.5	90.7	2.2	Reference	–	1.01 (0.99 to 1.02); *P* = 0.46	Reference	–

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Appendix Table 4–Continued

Study Group, by Measure	Services per 100 Patients, *n*		Absolute Change per 100 Patients, *n*			Incidence Rate Ratio (95% CI); *P* Value		
	2008	2012	2012 vs. 2008	PCMH or EHRs Alone vs. Paper Records	PCMH vs. EHRs Alone	Within Group, per Year	PCMH or EHRs Alone vs. Paper Records	PCMH vs. EHRs Alone
Utilization								
Ambulatory visits to primary care providers								
PCMH	316.4	322.1	5.7	14.8	20.6	1.00 (1.00 to 1.01); *P* = 0.043	1.01 (1.01 to 1.02); *P* < 0.001	1.02 (1.01 to 1.02); *P* < 0.001
EHRs alone	333.1	318.2	−14.9	−5.9	Reference	0.99 (0.98 to 0.99); *P* < 0.001	1.00 (0.99 to 1.00); *P* = 0.065	Reference
Paper records	337.7	328.7	−9.0	Reference	–	0.99 (0.99 to 1.00); *P* < 0.001	Reference	–
Ambulatory visits to specialists								
PCMH	351.5	313.8	−37.7	−27.2	−26.4	0.97 (0.97 to 0.98); *P* < 0.001	0.98 (0.97 to 0.99); *P* < 0.001	0.98 (0.97 to 0.99); *P* < 0.001
EHRs alone	346.5	335.2	−11.3	−0.8	Reference	0.99 (0.99 to 1.00); *P* = 0.009	1.00 (0.99 to 1.01); *P* = 0.97	Reference
Paper records	327.9	317.4	−10.5	Reference	–	0.99 (0.99 to 1.00); *P* < 0.001	Reference	–
Laboratory tests								
PCMH	1487.7	1440.5	−47.2	3.6	−63.0	0.99 (0.99 to 1.00); *P* = 0.004	1.00 (0.99 to 1.01); *P* = 0.85	0.99 (0.98 to 1.00); *P* = 0.003
EHRs alone	1499.6	1515.4	15.8	66.6	Reference	1.00 (1.00 to 1.01); *P* = 0.38	1.01 (1.00 to 1.02); *P* = 0.001	Reference
Paper records	1493.1	1442.3	−50.8	Reference	–	0.99 (0.99 to 1.00); *P* < 0.001	Reference	–
Radiology and other diagnostic tests								
PCMH	225.8	182.0	−43.8	−8.0	−11.6	0.95 (0.94 to 0.95); *P* < 0.001	0.99 (0.98 to 1.00); *P* = 0.012	0.99 (0.98 to 0.99); *P* = 0.001
EHRs alone	219.5	187.3	−32.2	3.6	Reference	0.96 (0.95 to 0.97); *P* < 0.001	1.00 (1.00 to 1.01); *P* = 0.30	Reference
Paper records	221.6	185.8	−35.8	Reference	–	0.96 (0.95 to 0.96); *P* < 0.001	Reference	–
Emergency department visits								
PCMH	16.3	16.3	0.0	1.2	0.2	1.00 (0.98 to 1.02); *P* = 0.99	1.02 (1.00 to 1.05); *P* = 0.064	1.00 (0.98 to 1.03); *P* = 0.82
EHRs alone	14.5	14.3	−0.2	1.0	Reference	1.00 (0.98 to 1.02); *P* = 0.77	1.02 (0.99 to 1.05); *P* = 0.147	Reference
Paper records	14.1	12.9	−1.2	Reference	–	0.98 (0.96 to 0.99); *P* = 0.006	Reference	–
Hospitalizations								
PCMH	5.2	3.7	−1.5	−1.0	−1.0	0.92 (0.90 to 0.95); *P* < 0.001	0.95 (0.92 to 0.98); *P* = 0.001	0.95 (0.92 to 0.98); *P* = 0.003
EHRs alone	4.6	4.1	−0.5	0.0	Reference	0.97 (0.94 to 1.00); *P* = 0.066	1.00 (0.97 to 1.04); *P* = 0.99	Reference
Paper records	4.6	4.1	−0.5	Reference	–	0.97 (0.95 to 0.99); *P* = 0.012	Reference	–
Rehospitalizations								
PCMH	0.8	0.6	−0.2	−0.5	−0.5	0.93 (0.87 to 1.00); *P* = 0.040	0.82 (0.76 to 0.89); *P* < 0.001	0.85 (0.78 to 0.92); *P* < 0.001
EHRs alone	0.5	0.8	0.3	0.0	Reference	1.10 (1.02 to 1.18); *P* = 0.009	0.97 (0.90 to 1.05); *P* = 0.46	Reference
Paper records	0.6	0.9	0.3	Reference	–	1.13 (1.07 to 1.20); *P* < 0.001	Reference	–

EHR = electronic health record; HbA_{1c} = hemoglobin A_{1c}; LDL = low-density lipoprotein; PCMH = patient-centered medical home.

* The relative risks, incidence rate ratios, CIs, and *P* values are those for the interaction between study group and year and were generated from models that also included study group and year as main effects. The relative risks for quality represent the probability of patients receiving recommended care, and the incidence rate ratios for utilization represent the probability of the given health care service being utilized. Results were derived using generalized linear models with the Poisson distribution and log-link function for quality and negative binomial (or zero-inflated negative binomial) regression for utilization.

Appendix Table 5. Adjusted Relative Associations Between Study Group and Quality and Utilization Outcomes: Random Intercepts for Unique Patients*

Change Over Time (2012 vs. 2008), by Study Group and Outcome Measure	Full Generalized Linear Mixed Model With Random Intercepts for Patients* (n = 133 617)	
	Risk Ratio (95% CI)	***P* Value**
Quality		
PCMH vs. paper records	1.01 (0.99–1.03)	0.41
PCMH vs. EHRs alone	1.01 (0.98–1.04)	0.37
EHRs vs. paper records	1.00 (0.97–1.02)	0.82
	Incidence Rate Ratio (95% CI)	***P* Value**
Utilization		
Ambulatory visits to primary care providers		
PCMH vs. paper records	1.04 (1.02–1.06)	<0.001
PCMH vs. EHRs alone	1.07 (1.05–1.09)	<0.001
EHRs vs. paper records	0.98 (0.96–0.99)	0.012
Ambulatory visits to specialists		
PCMH vs. paper records	0.91 (0.89–0.93)	<0.001
PCMH vs. EHRs alone	0.90 (0.88–0.93)	<0.001
EHRs vs. paper records	1.01 (0.99–1.04)	0.38
Laboratory tests		
PCMH vs. paper records	0.96 (0.93–0.98)	<0.001
PCMH vs. EHRs alone	0.92 (0.90–0.95)	<0.001
EHRs vs. paper records	1.03 (1.00–1.06)	0.051
Radiology and other diagnostic tests		
PCMH vs. paper records	0.96 (0.93–1.00)	0.026
PCMH vs. EHRs alone	0.93 (0.89–0.96)	<0.001
EHRs vs. paper records	1.04 (1.00–1.08)	0.026
Emergency department visits		
PCMH vs. paper records	1.03 (0.94–1.12)	0.57
PCMH vs. EHRs alone	1.00 (0.90–1.10)	0.94
EHRs vs. paper records	1.03 (0.93–1.14)	0.54
Hospitalizations		
PCMH vs. paper records	0.80 (0.71–0.91)	<0.001
PCMH vs. EHRs alone	0.79 (0.68–0.92)	0.003
EHRs vs. paper records	1.02 (0.88–1.17)	0.83
Rehospitalizations		
PCMH vs. paper records	0.45 (0.34–0.60)	<0.001
PCMH vs. EHRs alone	0.45 (0.32–0.63)	<0.001
EHRs vs. paper records	0.98 (0.73–1.32)	0.89

EHR = electronic health record; PCMH = patient-centered medical home.
* The risk ratios, incidence rate ratios, CIs, and *P* values are those for the interaction between study group and year and were generated from models that also included study group and year as main effects. The risk ratios for quality represent the probability of patients receiving recommended care, and the incidence rate ratios for utilization represent the probability of the given health care service being utilized. Results were derived using generalized linear mixed models with random intercepts for patients and using maximum likelihood estimation with Laplace approximation. The Poisson distribution and log-link function were used for quality, and negative binomial (or zero-inflated negative binomial) regression was used for utilization.

Appendix Table 6. Adjusted Relative Associations Between Study Group and Quality and Utilization Outcomes: Random Intercepts for Unique Providers and Practices*

Change Over Time (2012 vs. 2008), by Study Group and Outcome Measure	Level of Random Effects	Full Generalized Linear Mixed Model* (n = 133 617)	
		Risk Ratio (95% CI)	*P* Value
Quality			
PCMH vs. paper records	Provider and practice	1.05 (1.01–1.09)	0.023
PCMH vs. EHRs alone	Provider and practice	1.05 (1.00–1.09)	0.046
EHRs vs. paper records	Provider and practice	1.01 (0.97–1.05)	0.67
		Incidence Rate Ratio (95% CI)	***P* Value**
Utilization			
Ambulatory visits to primary care providers			
PCMH vs. paper records	Provider and practice	1.01 (0.97–1.04)	0.68
PCMH vs. EHRs alone	Provider and practice	1.00 (0.96–1.03)	0.86
EHRs vs. paper records	Provider and practice	1.01 (0.98–1.04)	0.52
Ambulatory visits to specialists			
PCMH vs. paper records	Provider and practice	0.95 (0.91–0.99)	0.028
PCMH vs. EHRs alone	Provider and practice	0.95 (0.91–1.00)	0.050
EHRs vs. paper records	Provider and practice	0.99 (0.95–1.04)	0.64
Laboratory tests			
PCMH vs. paper records	Provider and practice	0.99 (0.94–1.03)	0.45
PCMH vs. EHRs alone	Provider and practice	0.93 (0.88–0.97)	0.012
EHRs vs. paper records	Provider and practice	1.06 (1.01–1.11)	0.026
Radiology and other diagnostic tests			
PCMH vs. paper records	Provider and practice	0.96 (0.91–1.01)	0.076
PCMH vs. EHRs alone	Provider and practice	0.93 (0.88–0.98)	0.022
EHRs vs. paper records	Provider and practice	1.03 (0.98–1.09)	0.166
Emergency department visits			
PCMH vs. paper records	Practice	0.98 (0.89–1.07)	0.62
	Provider	1.00 (0.92–1.10)	0.92
PCMH vs. EHRs alone	Practice	0.94 (0.84–1.05)	0.26
	Provider	0.98 (0.88–1.09)	0.68
EHRs vs. paper records	Practice	1.05 (0.94–1.16)	0.40
	Provider	1.03 (0.93–1.14)	0.60
Hospitalizations			
PCMH vs. paper records	Practice	0.78 (0.68–0.89)	<0.001
	Provider	0.79 (0.70–0.90)	<0.001
PCMH vs. EHRs alone	Practice	0.78 (0.67–0.91)	0.001
	Provider	0.80 (0.68–0.93)	0.003
EHRs vs. paper records	Practice	1.00 (0.86–1.16)	0.98
	Provider	0.99 (0.86–1.15)	0.90
Rehospitalizations			
PCMH vs. paper records	Practice	0.42 (0.31–0.56)	<0.001
	Provider	0.44 (0.33–0.59)	<0.001
PCMH vs. EHRs alone	Practice	0.39 (0.28–0.56)	<0.001
	Provider	0.41 (0.29–0.58)	<0.001
EHRs vs. paper records	Practice	1.05 (0.77–1.43)	0.77
	Provider	1.06 (0.78–1.45)	0.70

EHR = electronic health record; PCMH = patient-centered medical home.
* The risk ratios, incidence rate ratios, CIs, and *P* values are those for the interaction between study group and year and were generated from models that also included study group and year as main effects. The risk ratios for quality represent the probability of patients receiving recommended care, and the incidence rate ratios for utilization represent the probability of the given health care service being utilized. Results were derived using generalized linear mixed models with random intercepts for providers and/or practices and using maximum likelihood estimation with Laplace approximation. The Poisson distribution and log-link function were used for quality, and negative binomial (or zero-inflated negative binomial) regression was used for utilization.

Appendix Table 7. Sensitivity Analysis of Providers With Baseline Data (*n* = 559): Adjusted Relative Associations Between Study Group and Quality and Utilization Outcomes*

Change Over Time (2012 vs. 2008), by Study Group and Outcome Measure	Full Multivariate Models (*n* = 144 015)	
	Risk Ratio (95% CI)	***P* Value**
Quality		
PCMH vs. paper records	1.01 (0.99–1.02)	0.43
PCMH vs. EHRs alone	1.01 (0.99–1.02)	0.51
EHRs vs. paper records	1.00 (0.98–1.02)	0.98
	Incidence Rate Ratio (95% CI)	***P* Value**
Utilization		
Ambulatory visits to primary care providers		
PCMH vs. paper records	1.09 (1.07–1.11)	<0.001
PCMH vs. EHRs alone	1.09 (1.06–1.11)	<0.001
EHRs vs. paper records	1.01 (0.99–1.03)	0.55
Ambulatory visits to specialists		
PCMH vs. paper records	0.89 (0.86–0.91)	<0.001
PCMH vs. EHRs alone	0.90 (0.88–0.93)	<0.001
EHRs vs. paper records	0.98 (0.95–1.01)	0.189
Laboratory tests		
PCMH vs. paper records	0.96 (0.93–0.98)	0.001
PCMH vs. EHRs alone	0.92 (0.90–0.95)	<0.001
EHRs vs. paper records	1.04 (1.01–1.07)	0.009
Radiology and other diagnostic tests		
PCMH vs. paper records	0.97 (0.94–1.00)	0.069
PCMH vs. EHRs alone	0.93 (0.90–0.97)	<0.001
EHRs vs. paper records	1.04 (1.00–1.08)	0.027
Emergency department visits		
PCMH vs. paper records	1.06 (0.97–1.17)	0.22
PCMH vs. EHRs alone	1.01 (0.90–1.12)	0.93
EHRs vs. paper records	1.06 (0.95–1.18)	0.33
Hospitalizations		
PCMH vs. paper records	0.81 (0.71–0.91)	0.001
PCMH vs. EHRs alone	0.78 (0.68–0.91)	0.001
EHRs vs. paper records	1.03 (0.89–1.19)	0.71
Rehospitalizations		
PCMH vs. paper records	0.42 (0.31–0.58)	<0.001
PCMH vs. EHRs alone	0.39 (0.28–0.55)	<0.001
EHRs vs. paper records	1.08 (0.80–1.46)	0.60

EHR = electronic health record; PCMH = patient-centered medical home.
* The risk ratios, incidence rate ratios, CIs, and *P* values are those for the interaction between study group and year and were generated from models that also included study group and year as main effects. The risk ratios for quality represent the probability of patients receiving recommended care, and the incidence rate ratios for utilization represent the probability of the given health care service being utilized. Results were derived using generalized linear models with the Poisson distribution and log-link function for quality and negative binomial (or zero-inflated negative binomial) regression for utilization.