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Association Between Patient-Centered Medical Homes and Adherence to Chronic Disease Medications

A Cohort Study

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Background: Despite the widespread adoption of patient-centered medical homes into primary care practice, the evidence supporting their effect on health care outcomes has come primarily from geographically localized and well-integrated health systems.

Objective: To assess the association between medication adherence and medical homes in a national patient and provider population, given the strong ties between adherence to chronic disease medications and health care quality and spending.

Design: Retrospective cohort study.

Setting: Claims from a large national health insurer.

Patients: Patients initiating therapy with common medications for chronic diseases (diabetes, hypertension, and hyperlipidemia) between 2011 and 2013.

Measurements: Medication adherence in the 12 months after treatment initiation was compared among patients cared for by providers practicing in National Committee for Quality Assurance–recognized patient-centered medical homes and propensity score–matched control practices in the same Primary Care Service Areas. Linear mixed models were used to examine the association between medical homes and adherence.

Results: Of 313 765 patients meeting study criteria, 18 611 (5.9%) received care in patient-centered medical homes. Mean rates of adherence were 64% among medical home patients and 59% among control patients. Among 4660 matched control and medical home practices, medication adherence was significantly higher in medical homes (2.2% [95% CI, 1.5% to 2.9%]). The association between medical homes and better adherence did not differ significantly by disease state (diabetes, 3.0% [CI, 1.5% to 4.6%]; hypertension, 3.2% [CI, 2.2% to 4.2%]; hyperlipidemia, 1.5% [CI, 0.6% to 2.5%]).

Limitation: Clinical outcomes related to medication adherence were not assessed.

Conclusion: Receipt of care in a patient-centered medical home is associated with better adherence, a vital measure of health care quality, among patients initiating treatment with medications for common high-cost chronic diseases.

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More than 10% of U.S. primary care practices meet the standards necessary to be recognized as patient-centered medical homes, a population-based model of practice that aims to improve health care quality and patient engagement through improved technology and enhanced care coordination (1–3). Enthusiasm for this model has been buoyed by evidence (largely from geographically localized integrated delivery systems) that suggests that it is associated with improved patient satisfaction, higher quality, and lower costs (4–7).

Although patient-centered medical homes are believed to improve care processes and interactions with patients, they have been evaluated on only a few health care quality measures (8, 9). Patient-centered medical home recognition requires infrastructure to coordinate care and provide support and outreach to patients with chronic conditions (1, 10). Despite widespread adoption, the mechanism by which medical homes affect health care quality or chronic disease management and the extent to which they do so require further elucidation (11–13). In chronic conditions, such as hypertension, diabetes, and hyperlipidemia, medication adherence (the extent to which patients take their medications as prescribed) has become a growing concern for clinicians and payers. Poor adherence is strongly associated with worse patient outcomes and high health care spending (14–16). Consequently, medication adherence is viewed as a key measure of quality of care by major organizations, such as the Centers for Medicare & Medicaid Services and the National Quality Forum, and is used to determine financial performance incentives for providers. However, it has not been evaluated in medical homes (17, 18). Accordingly, we sought to assess the association between medical homes and adherence using National Committee for Quality Assurance (NCQA) recognition criteria among a national cohort of patients initiating therapy with oral hypoglycemic, antihypertensive, and cholesterol-lowering medications.

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METHODS

Data Sources

We used administrative claims data from Aetna, a large national health insurer. This limited data set (according to Health Insurance Portability and Accountability Act provisions) included patient-level claims for medical inpatient and outpatient procedures, hospitalizations, office visits, emergency department visits, and outpatient pharmacy prescription drug claims. Patients in this database are fully insured beneficiaries enrolled in plans provided by Aetna. These data were also linked to enrollment data that included age, sex, and ZIP code of residence, with use of a scrambled identifier for each patient. Aggregate data on socioeconomic status, race, and educational attainment were obtained by linking the ZIP code of residence with data from the 2010 United States Census. The Institutional Review Board of Brigham and Women's Hospital approved the study.

We also used the NCQA practice roster (as of February 2014) to identify patients using medical homes. This source provides a full listing of more than 37 000 medical home providers, consisting of a provider identifier, the National Provider Identifier, practice name, level of recognition (1, 2, or 3), recognition version (2008 or 2011), and start and end dates of recognition for different levels and versions. Criteria for recognition include access and communication, patient tracking, care management, self-management, electronic prescribing, and performance reporting and improvement (Appendix Table 1, available at www.annals.org) (19).

The National Plan and Provider Enumeration System (NPPES) downloadable file (as of 15 April 2016) was also used to identify providers and practices. This publicly available database includes all health providers with a provider identifier in the United States and provides their office addresses, specialties, and credentialing information. The database is updated on a quarterly basis; because these data are used for enumeration, provider organizations are incentivized to update their information regularly.

Practice Identification

We used the NPPES file to identify providers with prescribing authority (for example, MD, physician assistant, nurse practitioner, or DO) and then aggregated providers into distinct practices based on their practice address information. Using the listed provider information, we measured practice characteristics, including number of providers and specialists. Because we were interested in studying adherence to chronic disease medications, we identified practices with at least 1 patient in the Aetna administrative claims database who initiated therapy with an oral hypoglycemic, antihypertensive, or cholesterol-lowering statin medication between 2011 and 2013. We measured additional practice-level characteristics from these patients, including number of patients per practice and average patient age. Finally, we restricted to practices within a U.S. Health Resources and Services Administration Primary Care Service Area (PCSA). These service areas are geographic markets of primary care, consisting of 6542 areas defined by aggregated ZIP code areas that reflect travel by Medicare patients to primary care providers. We linked this practice cohort with the NCQA practice roster to identify recognized practices and providers.

Patient Identification

Using the Aetna administrative claims data, we identified patients initiating therapy with an oral hypoglycemic, antihypertensive, or cholesterol-lowering statin medication between 1 January 2011 and 31 December 2013. Each patient's date of initiation of therapy was considered to be the "index date," and new initiation was defined as not having filled a prescription for a medication for the disease state of interest during the previous 180 days. Patients who were aged 18 years or older and had at least 1 drug claim, at least 1 health care claim, and continuous enrollment in the 180 days before initiating treatment with the study medication were included in the analysis. Patients who were missing a provider identifier on their index prescription fill were excluded.

Medication Adherence

The outcome of interest was adherence to medications for 1 of 3 therapeutic conditions during the 12 months after initiation. For each eligible index medication, we created a drug supply diary linking all observed fills after initiation based on dispensing date and days' supply. The supply for overlapping fills could accumulate an excess of up to 180 days and was adjusted for any hospitalizations during the study period by allowing days in the hospital to contribute to the supply diary. Different drugs in the same chemically related therapeutic class (for example, β-blockers) were considered to be interchangeable.

From these supply diaries, we calculated the proportion of days that patients had medications available to them (that is, the proportion of days covered) by dividing the number of days with medication available by the number of days during follow-up for each month in a 12-month follow-up period or until the patient was censored (20). If a patient lost continuous eligibility during the year after the index date, they were censored on that date, and the proportion of days covered was calculated based on the number of days available. For the overall calculation, we combined all treatment episodes and determined the rates of adherence at the patient level, with each eligible initiated medication as the unit of analysis. If a patient initiated treatment with multiple medications for the same disease state on the same day, the average proportion of days covered was used as the outcome measure. Medications for each disease state were considered separately. For chronic disease medications like these, patients are usually considered "fully adherent" if they have at least 80% of days covered, conforming to the level of medication adherence believed to be necessary to achieve clinically important effects (21, 22).

Baseline Characteristics

We considered many patient factors that could have confounded the relationship between medical home recognition and adherence. Demographic characteristics, such as age and sex, were obtained from the enrollment files at the time of therapy initiation. Median household income, race/ethnicity, and educational attainment of the population within each 5-digit ZIP code area were obtained from the linked 2010 United States Census data. Clinical diagnoses, including coronary artery disease, chronic obstructive pulmonary disease or asthma, hypertension, congestive heart failure, stroke, major depression, diabetes, liver disease, chronic kidney disease, hyperlipidemia, cancer, Alzheimer disease or dementia, and peripheral vascular disease, were assessed in the 180 days before medication initiation by using codes from the International Classification of Diseases, 9th Revision. Patient utilization characteristics, such as the number of unique prescriptions filled (by generic name), number of outpatient office visits, number of days spent in the hospital, combined comorbidity score, and baseline cardiovascular disease medication use, were also measured in the 180 days before medication initiation (23). Characteristics of the initiated medication, including copayment and brand-name status, were also obtained from the outpatient prescription claims files.

Statistical Analysis

We performed descriptive statistical analysis using absolute standardized differences to compare the baseline characteristics between medical home and control practices and patients. Significant imbalance between groups is usually characterized by an absolute standardized difference greater than 0.1 (24).

Because several practices had an extremely large number of providers and thus were probably not primary care practices, we excluded practices in the top fifth percentile of providers per practice. To construct a matched control group, we used logistic regression to estimate each practice's probability of being a recognized medical home, using the practice characteristics listed in Table 1. Before matching, we trimmed nonoverlapping propensity scores. Each medical home practice was then matched to a control practice within the same service area using propensity scores, with use of a greedy matching algorithm (5:1 digit matching) and 1:1 sampling without replacement (25–27). This propensity score–matching method provided the average treatment effect among medical homes. Matching within service areas allowed the practices to be balanced on unmeasured geographic characteristics. As a result, medical homes without a similar control practice within the same service area were not included in the study.

Linear mixed models were used to estimate the effect of medical home recognition on adherence in the 12 months after initiation, with random-effects intercepts incorporated for each level of potential clustering (for example, within service area, practice, or the matched set) (SAS procedure PROC MIXED). These models also adjusted for the 37 measured patient baseline characteristics as fixed effects. We repeated the response model estimations for the absolute differences in adherence within patient subgroups by each cardiometabolic condition and year of medication initiation (2011, 2012, or 2013). All analyses were conducted using SAS, version 9.4 (SAS Institute). Additional details are provided in the Appendix (available at www.annals.org).

We also conducted sensitivity analyses to examine the robustness of the findings. First, we explored the use of random intercepts for service area, the matched set, and practice separately and adjusted for any remaining unbalanced practice characteristics. We also modeled how a hypothetical unmeasured confounder might have influenced our estimates in the primary analysis by using the methods of Lin and colleagues (28). Further details are provided in the Appendix.

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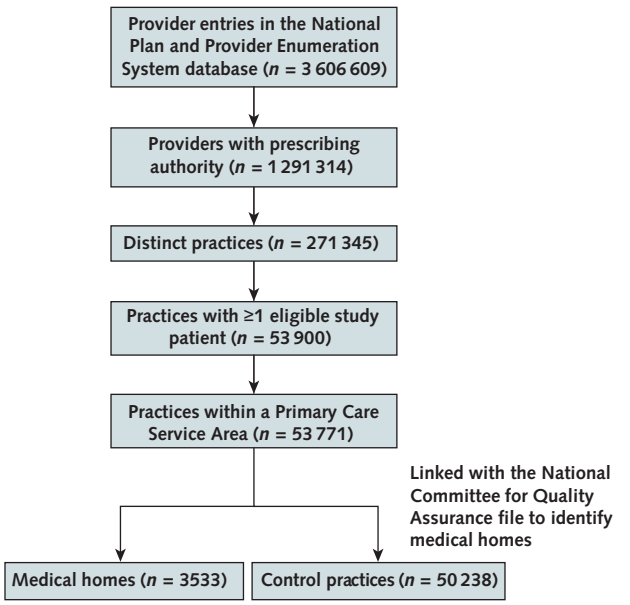
Table 1. Practice Characteristics

Characteristic	Before Matching		After Matching*	
	Patient-Centered Medical Home (n = 3533)	Control Practice (n = 50 238)	Patient-Centered Medical Home (n = 2330)	Control Practice (n = 2330)
Patients, n†				
Mean	12.3	6.1	5.4	5.3
Median (IQR)	5 (11)	3 (6)	4 (7)	4 (6)
Patient age, y†				
Mean	51.4	50.5	51.3	51.8
Median (IQR)	52 (7.0)	51.8 (10.3)	51.9 (8.5)	51.8 (8.8)
Providers, n				
Mean	23.4	13.4	8.7	8.4
Median (IQR)	9 (17)	4 (8)	6 (9)	5 (8)
Geriatricians, n				
Mean	0.1	0.1	0.1	0.1
Median (IQR)	0 (0)	0 (0)	0 (0)	0 (0)
Pediatricians, n				
Mean	1.9	0.6	0.5	0.4
Median (IQR)	0 (1)	0 (0)	1 (2)	0 (1)
Internists, n				
Mean	4.6	1.8	1.4	1.3
Median (IQR)	1 (4)	0 (1)	0 (0)	0 (0)

IQR = interquartile range.
* The absolute standardized differences were <0.1 for number of patients, number of geriatricians, number of pediatricians, and patient age; 0.11 for number of providers; and 0.12 for number of internists.
† Among patients eligible for cohort inclusion.

Figure 1. Identification of practices.



RESULTS

Among the 3 606 609 providers in the NPPES database, we identified 271 345 distinct practices based on address and office location. Of these, 53 771 study practices were within a service area and had at least 1 study patient (Figure 1). After linking with the NCQA file, we identified 3533 medical homes (6.6%) and 50 238 control practices. We evaluated this method of aggregating practices by using the NCQA practice file as the gold standard and found good agreement between the data sets.

The practice characteristics are shown in Table 1. After propensity score matching of practices within service areas, 2330 medical homes and 2330 control practices were included in the cohort. The medical home and control practices had a median of 6 and 5 providers per practice, respectively. These 4660 practices were distributed over 1047 service areas. After matching, the practice characteristics were relatively well-balanced—almost all absolute standardized differences were less than 0.1. However, the mean number of providers (8.7 for medical homes vs. 8.4 for control practices) and internists (1.4 for medical homes vs. 1.3 for control practices) per practice differed slightly.

Overall, 313 765 patients met the inclusion criteria for the study (Appendix Table 2, available at www.annals.org). The baseline characteristics of medical home patients and control patients are shown in Table 2 and are presented by drug class in Appendix Table 3 (available at www.annals.org). Before propensity score matching, the mean ages of medical home and control patients were 52.7 and 51.6 years, respectively. Patients using medical homes had lower rates of coronary artery disease, cancer, congestive heart failure, and baseline use of cardiovascular disease medication and were also less likely to initiate treatment with a brand-name medication. After practice matching, the patient characteristics were still fairly well-balanced, even before covariate adjustment in the mixed models.

Medication Adherence

In the year after initiating treatment, patients seen at medical homes had higher levels of medication adherence than control patients. In total, 43.9% of the medical home patients were optimally adherent (proportion of days covered ≥80%) compared with 37.6% of the control patients (Appendix Table 4, available at www.annals.org). The unadjusted mean proportion of days covered was 64% among medical home patients and 59% among control patients. Rates of adherence were similar across all 3 disease states by medical home use. Monthly mean adherence patterns over the 12-month follow-up within the matched practice cohort are shown in Figure 2. Patients using medical homes were more adherent throughout the entire follow-up than those using control practices, with the sharpest decrease in adherence beginning in month 4.

Absolute rates of adherence were 2.2% (95% CI, 1.5% to 2.9%) higher among patients using medical homes than control patients (Table 3). The association between medical homes and adherence was similar across medication classes and initiation years, although the effect on adherence was slightly higher among patients initiating medications for diabetes (3.0% [CI, 1.5% to 4.6%]) and hypertension (3.2% [CI, 2.2% to 4.2%]) than among those initiating medications for hyperlipidemia (1.5% [CI, 0.6% to 2.5%]).

Sensitivity Analysis

The results of our sensitivity analyses are presented in Appendix Table 5 (available at www.annals.org). Use of different random intercepts and adjustment for unbalanced practice characteristics did not materially change the results. Overall patient characteristics by disease state are shown in Appendix Table 3. The sensitivity analysis of a hypothetical confounder indicated that it would have to be strong and prevalent to materially change the results (Appendix Table 6, available at www.annals.org).

DISCUSSION

We evaluated whether the use of patient-centered medical homes influenced patients' adherence to evidence-based medications for hypertension, diabetes, and high cholesterol in a large nationwide sample of providers and practices. We estimated that patients using NCQA-recognized medical homes had levels of adherence that were, on average, 2% to 3% higher than among patients receiving care in other practices. These differences in adherence were slightly greater for patients initiating therapy with medications for diabetes and hypertension.

To earn NCQA recognition, practices and providers must meet rigorous standards for addressing patient needs in primary care practice, which requires substantial time. Depending on practices' capabilities,

this transformation process could begin 12 to 18 months before they receive (or even apply for) recognition, and practices differ in how long the transformation takes and the extent to which changes occur (19, 29). Patient-centered medical homes focus on enhancing and establishing patient–provider relationships, patient engagement, and quality of care, primarily through improved technology and care coordination (29). For recognition, medical homes are also encouraged to specifically focus on management of a set of chronic diseases, notably diabetes and hypertension. Thus, medical homes are hypothesized to have built capacities and tools to better manage chronic diseases.

In the management of chronic conditions, medication adherence has become a core measure of health care quality and patient outcomes for many large organizations (17). Despite widespread research and interventions with varying degrees of success, long-term adherence to medications has remained stubbornly low (14, 30–32). Other interventions, such as elimination of out-of-pocket copayments, case management, and intensive behavioral support and education, have some of the strongest evidence favoring their effectiveness on medication adherence of all studied interventions (33, 34). These approaches increased adherence by approximately 3% to 4%. The effect we observed was slightly smaller but may nevertheless be clinically meaningful (22).

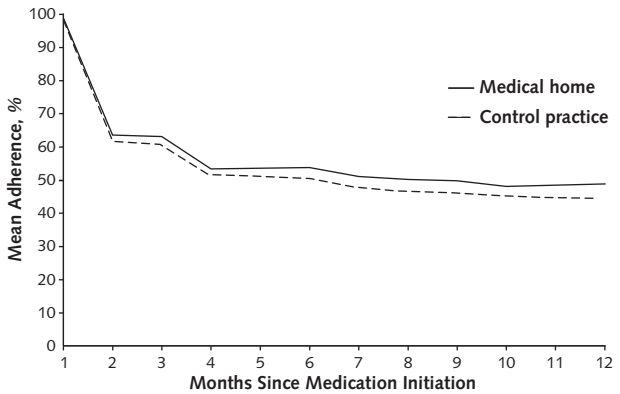
The evidence on health care quality in medical homes has been mixed depending on the patient population and setting (4, 6, 35). Previous studies have shown that patients cared for in medical homes have lower health care spending and emergency department use than those in more traditional care settings (4, 5, 36). Most of the positive evidence supporting patient-centered medical homes comes from larger,

Table 2. Patient Characteristics

Characteristic	Overall Cohort		Matched Cohort*	
	Patient-Centered Medical Home (*n* = 18 611)	Control Practice (*n* = 295 154)	Patient-Centered Medical Home (*n* = 11 636)	Control Practice (*n* = 10 117)
Demographic				
Mean age (SD), *y*	52.7 (10.4)	51.6 (11.2)	52.3 (10.4)	51.8 (10.9)
Male, %	49.2	49.6	48.9	49.3
Median by ZIP code (IQR)				
Household income, *$*	65 477 (30 057)	62 913 (29 956)	61 518 (28 956)	61 979 (28 322)
Black race, %	5.6 (12.3)	5.4 (11.7)	5.1 (12.2)	5.5 (11.5)
High school graduate, %	90.3 (8.4)	89.3 (10.6)	89.8 (8.4)	89.8 (9.6)
Clinical, %				
Alzheimer disease/dementia	0.3	0.5	0.2	0.3
Cancer	0.3	0.7	0.2	0.5
Chronic kidney disease	2.3	3.2	2.3	2.4
Congestive heart failure	0.3	0.7	0.2	0.5
Chronic obstructive pulmonary disease/asthma	8.6	8.9	8.2	9.1
Coronary artery disease	0.6	2.4	0.6	1.6
Depression	9.0	8.2	9.0	8.5
Diabetes	26.7	26.9	26.4	26.7
Hyperlipidemia	56.7	53.7	56.0	55.7
Hypertension	57.9	56.3	58.1	58.0
Liver disease	2.6	3.0	2.7	2.9
Peripheral vascular disease	0.3	0.5	0.3	0.5
Stroke/transient ischemic attack	0.4	0.8	0.4	0.6
Health service utilization				
Mean comorbidity score (SD)	−0.1 (0.9)	0 (1.1)	−0.1 (0.9)	0 (1.1)
Median duration of hospitalization (IQR), *d*	0 (0)	0 (0)	0 (0)	0 (0)
Median office visits (IQR), *n*	4 (5)	4 (6)	4 (5)	4 (5)
Median unique generic drugs (IQR), *n*	5 (4)	5 (5)	5 (4)	5 (4)
Prescription drug use				
Brand-name index prescription, %	10.9	15.0	11.2	13.9
Median index prescription copayment (IQR), *$*	10.0 (10.5)	10.0 (14.1)	10.0 (9.7)	10.0 (14.3)
Initiation year, %				
2011	26.4	41.7	40.4	39.7
2012	36.2	31.2	31.0	31.4
2013	37.4	27.1	28.6	28.9
Anticoagulant/antiplatelet, %	3.2	5.8	3.1	4.6
Digoxin, %	0.3	0.5	0.2	0.4
Diuretic, %	27.0	24.4	27.5	25.4
Nitrate, %	0.7	1.9	0.7	1.4

IQR = interquartile range.
* Absolute standardized differences were all <0.1.

Figure 2. Monthly adherence in the first year after medication initiation.



Results are among 2330 medical homes and 2330 matched control practices across 1047 service areas. Adherence was assessed by the proportion of days in the 12-mo follow-up covered by prescription claims for the same medication or another one in its molecularly related therapeutic class.

geographically localized, integrated health systems (4, 37, 38); smaller practices with less payment transformation have seen less positive results (35, 39, 40). Moreover, these previous studies generally have not included a full set of practices recognized by a national body, so the mixed evidence may have resulted from limited samples of practices, providers, and patients (7). One recent exception is a nationally representative study by van Hasselt and colleagues (4), which found that payments and emergency department visits decreased after practice transformation. However, to our knowledge, only 1 study has examined the association between medical home use and medication adherence. In this analysis, conducted among North Carolina Medicaid beneficiaries, patients using medical homes were slightly more likely to adhere to chronic disease medications, with differences in adherence of approximately 3% to 6% compared with control patients, depending on the disease state (41). Our study found slightly smaller absolute differences in adherence, which could be due to several factors, including variations in features of the medical homes, analytic approach, or geographic differences.

Our findings have implications for health plans, policymakers, and clinicians. Payment incentives to reward medical home recognition may substantially improve quality of care and patient engagement, ultimately decreasing costs. Although primary care practice transformation is one step, the vision for care coordination and delivery system transformation may not end with transforming primary care practices into patient-centered medical homes. Recent support for broader medical neighborhood capacities and improving data sharing to maximize care coordination across a wider system may lead to even greater improvements in medication adherence and quality of care. The Centers for Medicare & Medicaid Services is testing broader payment reform for primary care providers through many primary care payment and delivery reform programs (1). Programs that provide investment in primary care practices to encourage practice transformation and care coordination may be critical to meaningfully improving performance on quality measures that are based on altering patient behavior between visits to the provider.

Our findings should be considered in light of several limitations. First, this study was based on administrative data, which limited the number of measurable characteristics, and some bias is possible because of inadequately measured confounders, if they were differential between the groups. Given the nature of the data, medication adherence was measured indirectly using the days' supply, a validated method that has been shown to correlate well with electronic records and patient self-report. Although we had the full prac-

Table 3. Association Between Patient-Centered Medical Homes and Patient Adherence to Chronic Disease Medications

Outcome*	Patient Adherence†, %		Unadjusted Mean Difference in Adherence Between Groups, *percentage points*†	Adjusted Mean Difference in Adherence Between Groups (95% CI), *percentage points*†‡
	Patient-Centered Medical Home	Control Practice		
Primary outcome				
Adherence§	64.1	61.3	2.8	2.2 (1.5–2.9)
Secondary analyses				
By disease state				
Diabetes	65.0	61.2	3.8	3.0 (1.5–4.6)
Hypertension	63.3	59.3	4.0	3.2 (2.2–4.2)
Hyperlipidemia	64.5	62.6	1.9	1.5 (0.6–2.5)
By year of therapy initiation				
2011	62.8	60.7	2.1	2.3 (1.0–3.5)
2012	63.3	60.7	2.6	2.1 (0.9–3.2)
2013	65.5	61.8	3.7	3.2 (2.0–4.3)

* Reference group is control practices.
† Among 2330 patient-centered medical homes and 2330 matched control practices across 1047 service areas.
‡ From linear mixed models with adjustment for patient characteristics.
§ Assessed by the proportion of days in the 12-mo follow-up period "covered" by prescription claims for the same medication or another in its molecularly related therapeutic class.

tice and provider roster data set, administrative claims data cannot identify the exact practice in which a provider prescribed a medication for a patient. Due to limitations of claims data, a potential also exists for misclassification of practices using the data sets. However, we assumed that if patients visited a provider associated with a medical home, they received care there; thus, the study was conservative by design. Clinical outcomes were not assessed, and we also could not assess whether specific features of medical homes were associated with better adherence or the effect of transformation, an area of future research that may help guide practice transformation. The cohort was also limited to commercially insured patients and used a cross-sectional design.

In conclusion, patients using NCQA-recognized patient-centered medical homes seem to have better adherence to newly initiated chronic disease medications than patients using other practices. Medical homes were shown to lead to significantly better medication adherence, a vital measure of health care quality for chronic diseases. These findings have significant implications for providers, health plans, and policymakers who are considering the best potential practices for patients.

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Reproducible Research Statement: *Study protocol:* Available from Dr. Choudhry (e-mail, nkchoudhry@bwh.harvard.edu). *Statistical code:* Not available. *Data set:* Available to approved persons through written agreements with the authors and the data partner.

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Appendix: Additional Details About Methods

Identifying Practices

As described in the text, we identified providers by using the NPPES data set, which is a publicly available and downloadable file from the U.S. government (https://nppes.cms.hhs.gov/NPPES). We identified providers with prescribing authority from the data set and aggregated them into practices based on their listed office address, city, and state, cleaning the data as necessary to standardize address notations. This database does not specifically identify providers' primary practices by name. From this, we identified 271 345 distinct practices, of which 53 900 had at least 1 eligible study patient (one who initiated therapy with a study medication and was enrolled in a plan provided by Aetna). We then linked with the NCQA practice roster to identify whether these practices as identified in the NPPES were recognized practices. If the practices were not listed, they were deemed to be available control practices. We used the practice roster as a gold standard and tested the same address-aggregating mechanism in these data as in the NPPES data for potential misclassification. We found that 71.6% of providers in the NCQA file matched to the same practice as the NPPES and, conversely, that only 7.1% of providers were incorrectly assigned to a medical home when they should have been in control practices. Consequently, any misclassification would likely have biased toward the null of observing no effect of medical homes.

Geographic Considerations

We chose the PCSA as the geographic unit for identifying similar practices for several reasons. It is used by the U.S. Health Resources and Services Administration and was extensively developed at the Dartmouth Institute for Health Policy and Clinical Practice. It is considered to be an appropriate geographic market of primary care that is linkable with ZIP code data and reflects distances that patients would consider traveling to primary care providers within the 50 U.S. states and the District of Columbia. Of the 53 900 possible practices, we excluded 129 (0.2%) because they were in U.S. territories and were not assigned to service areas. Moreover, within each service area that contained a medical home in the study data, 81.5% of the medical homes had at least 3 potential control practices for matching.

Propensity Score Estimation for Individual Practices

We first excluded practices in the top fifth percentile of number of providers per practice to restrict to primary care practices because the NPPES database does not identify the provider's practice setting. We then calculated a propensity score by using a logistic regression model to estimate the probability of being a medical home (PROC LOGISTIC in SAS). This model included the practice covariates listed in Table 1 and practices with at least 1 eligible study patient. We selected these characteristics for the models based on the availability of the information. For the few continuous characteristics, we assessed whether their inclusion as a linear term was sufficient by examining other linear order terms. Linear terms seemed to be sufficient for the model estimation for these characteristics.

Only 136 of 53 771 potential practices had propensity scores that did not overlap with practices in the other group. The median propensity scores were 0.059 (range, 0.028 to 0.977) in the patient-centered medical home group and 0.044 (range, 0.027 to 0.976) in the control group. We excluded these nonoverlapping practices before matching to trim the distribution of propensity scores.

From the propensity scores, to conduct the matching, we used a published greedy matching algorithm (5:1 digit matching) and 1:1 sampling of practices without replacement in SAS. We used this matching algorithm within each service area to identify control prac-

tices that were similar to each medical home based on the propensity score. We performed exact matching within PCSAs to achieve balance on geography. This 1:1 propensity score–matching procedure provided estimates for the average effect in medical home practices by providing a counterfactual practice to compare differences in effects on adherence. The postmatching c-statistic was 0.589, indicating that very little ability to discriminate between medical home and control practices remained after matching (that is, we achieved very good balance after matching [42]). After performing the propensity score matching, we identified all of the eligible patients within these matched practices.

Response Model Estimation

We used a linear mixed model to estimate the mean difference in medication adherence for patients in medical homes and control practices over the 12 months after medication initiation. To conduct this analysis, we used PROC MIXED in SAS. The outcome for these models was patient-level adherence, a continuous variable that was fit using an identity link. The primary analysis used random-effects intercepts for the matched set, service area, and practice and included all of the measured patient characteristics listed in Table 2 as fixed effects to adjust for differences in patient characteristics within the matched sets. The incorporation of random intercepts accounted for the potential correlation of outcomes within service area and practice. Using a random intercept for each matched set ensured that the comparisons between medical homes and control practices were made only within matched sets, thereby controlling for differences across the matched sets. The sensitivity analyses shown in Appendix Table 5 tested the effects of using different random intercepts. The covariance parameter estimates for the level of service area, practice, and matched set were smaller than the residuals, suggesting that very little variation in the response model was explained by these levels of clustering.

Sensitivity Analysis of a Hypothetical Confounder

In a sensitivity analysis, we also modeled how a hypothetical unmeasured confounder might have influenced the estimates of the effectiveness of medical homes in our primary analysis by using the methods of Lin and colleagues (28). Although the measured characteristics were relatively well-balanced before matching (and were well-balanced after matching), patients using medical homes may differ in other ways that are unmeasurable in the data source. Some examples of possible unmeasured confounders are disease severity or functional status, although we examined new initiators of medications to help alleviate this concern. Consequently, we modeled our hypothetical confounder on the possibility that medical home patients may differ from control patients. On the basis of previous confounder knowledge, we estimated that a strong confounder might be when the risk for an outcome is doubled. This could occur when patients with the confounder (who might be sicker) would be half as likely to be adherent as patients with less severe disease and this variable is not otherwise accounted for by other variables in the propensity score. If examining relative risks, we believed that a confounder would have to be both strong and differentially prevalent to materially influence the results (Appendix Table 6). Moreover, hypothetical unmeasured confounders could move the effect estimates for an absolute or relative measure in either direction.

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Appendix Table 1. Criteria for National Committee for Quality Assurance Recognition

2008 Recognition (Physician Practice Connection–Patient-Centered Medical Home): 9 Standards and 30 Elements	2011 Recognition (Patient-Centered Medical Home): 6 Standards and 27 Elements
Access and communication	Enhance access and continuity
Access and communication processes (must pass*)	Access during office hours (must pass)
Access and communication results (must pass)	After-hours access
	Electronic access
	Continuity
	Medical home responsibilities
	Culturally and linguistically appropriate services
	The practice team
Patient tracking and registry	Identify and manage patient populations
Basic system for managing patient data	Patient information
Electronic system for clinical data	Clinical data
Use of electronic clinical data	Comprehensive health assessment
Organizing clinical data (must pass)	Use data for population management (must pass)
Identifying important conditions (must pass)	
Use of system for population management	
Care management	Plan and manage care
Guidelines for important condition (must pass)	Implement evidence-based guidelines
Preventive service clinician reminders	Identify high-risk patients
Practice organization	Care management (must pass)
Care management of important conditions	Medication management
Continuity of care	Use electronic prescribing
Patient self-management	Provide self-care support and community resources
Documenting communication needs	Support self-care process (must pass)
Self-management support (must pass)	Provide referrals to community resources
Electronic prescribing	Track and coordinate care
Electronic prescribing writing	Test tracking and follow-up
Prescribing decision support: safety	Referral tracking and follow-up (must pass)
Prescribing decision support: efficiency	Coordinate with facilities/care transitions
Test tracking	Measure and improve performance
Test tracking and follow-up (must pass)	Measure performance
Electronic system for managing tests	Measure patient/family experience
	Implement continuous quality improvement (must pass)
	Demonstrate continuous quality improvement
	Report performance
	Report data externally
	Use certified electronic health record technology
Referral tracking	–
Referral tracking and coordination	
Performance reporting and improvement	–
Measures of performance (must pass)	
Patient experience data	
Reporting to physicians (must pass)	
Setting goals and taking action	
Reporting standardized measures	
Electronic reporting: external entities	
Advanced electronic communication	–
Availability of interactive web	
Electronic patient identification	
Electronic care management support	

* Identifies a required aspect for recognition. Achievement of other elements is required to receive more than minimal recognition.

Appendix Table 2. Study Inclusion Criteria

Criterion	Patients Initiating Antidiabetic Medications, *n*	Patients Initiating Antihypertensive Medications, *n*	Patients Initiating Statins, *n*
Fill between 1/1/2011 and 12/31/2013	277 715	1 016 548	708 650
Aged ≥18 y on index date	276 497	1 012 822	708 352
Nonmissing provider identifier on index fill	257 877	945 519	660 149
Continuous enrollment for 180 d before index date	144 604	511 240	372 336
≥1 drug and health claim in 180 d before index date	116 206	388 461	304 210
New user	58 227	162 756	144 649
Unique patients (across medication types)	313 765		

Appendix Table 3. Baseline Characteristics of the Overall Cohort, by Drug Class

Characteristic	Antidiabetic (*n* = 58 227)		Antihypertensive (*n* = 162 756)		Statin (*n* = 144 649)	
	Patient-Centered Medical Home (*n* = 3139)	Control Practice (*n* = 55 088)	Patient-Centered Medical Home (*n* = 8718)	Control Practice (*n* = 154 038)	Patient-Centered Medical Home (*n* = 8968)	Control Practice (*n* = 135 681)
Demographic						
Mean age (SD), *y*	53.0 (10.9)	50.3 (12.1)	51.4 (11.0)	50.3 (11.8)	53.9 (9.4)	53.7 (9.6)
Male, %	49.6	45.0	47.9	48.1	50.4	53.0
Median by ZIP code						
Income, $	63 407	61 386	65.446	63 095	66 025	63 455
Black race, %	6.3	5.9	5.4	5.3	5.5	5.4
High school graduate, %	89.5	88.5	90.3	89.6	90.5	89.4
Region, %						
Midwest	9.4	8.1	9.0	8.1	8.9	7.5
Northeast	47.3	21.9	49.2	24.0	50.9	24.9
South	31.8	43.3	31.7	41.7	31.2	42.2
West	7.8	23.6	7.1	23.4	5.9	22.4
Clinical, %						
Alzheimer disease/dementia	0.3	0.4	0.3	0.5	0.3	0.6
Cancer	0.5	0.5	0.3	0.9	0.3	0.4
Chronic kidney disease	3.1	3.6	1.7	2.8	2.5	3.4
Congestive heart failure	0.5	0.5	0.2	0.7	0.3	0.8
Chronic obstructive pulmonary disease/asthma	9.1	9.0	8.4	9.1	8.6	8.7
Coronary artery disease	0.9	1.3	0.5	2.1	0.6	3.2
Depression	7.8	7.4	9.4	9.0	9.0	7.7
Diabetes	62.1	55.7	17.8	17.8	22.9	25.4
Hyperlipidemia	57.4	51.5	39.6	38.2	73.0	72.2
Liver disease	3.4	3.8	2.4	3.1	2.4	2.7
Hypertension	58.4	52.1	67.2	61.4	48.6	52.1
Peripheral vascular disease	0.4	0.3	0.3	0.4	0.4	0.7
Stroke/transient ischemic attack	0.3	0.4	0.4	0.5	0.4	1.2
Health services utilization						
Median office visits, *n*	4	4	4	4	4	4
Median duration of hospitalization, *d*	0	0	0	0	0	0
Median unique generic drugs, *n*	5	6	4	5	5	5
Mean comorbidity (SD), *n*	0.0 (1.1)	0.0 (1.1)	−0.1 (0.9)	0.1 (1.1)	0.0 (0.9)	0.0 (1.0)
Prescription drug use						
Brand-name index prescription, %	10.6	12.7	5.4	7.5	16.2	24.5
Median index copayment, $	10.0	10.0	10.0	10.0	13.8	15.0
Initiation year, %						
2011	24.7	40.2	25.5	40.9	27.9	43.3
2012	34.8	31.0	36.7	31.5	36.3	30.8
2013	40.6	28.8	37.8	27.6	35.8	25.9
Anticoagulant/platelet, %	4.9	5.3	2.3	5.1	3.5	6.9
Digoxin, %	0.6	0.5	0.2	0.5	0.3	0.5
Diuretic, %	30.3	25.9	29.8	25.0	23.2	23.1
Nitrate, %	1.3	1.4	0.6	1.7	0.7	2.5

Appendix Table 4. Patient Adherence to Chronic Disease Medications in 12 mo After Initiation

Patient Group	Medical Home Patients		Control Patients	
	Mean Adherence*	Optimally Adherent, %†	Mean Adherence*	Optimally Adherent, %†
All patients	0.64	43.9	0.59	37.6
By disease state				
Diabetes (*n* = 58 277)	0.63	42.0	0.57	33.9
Hypertension (*n* = 162 756)	0.64	45.2	0.58	38.1
Hyperlipidemia (*n* = 144 649)	0.64	43.2	0.61	38.5

* Represents the proportion of days in the 12-mo follow-up period "covered" by prescription claims for the same medication or another in its molecularly related therapeutic class.
† Proportion of days covered with medication ≥0.80.

Appendix Table 5. Sensitivity Analyses

Cohort Group*	Adherence, %		Mean Difference in Adherence (95% CI), *percentage points*†
	Medical Home Patients	Control Patients	
Original results: random intercepts for service area, matched set, and practice, including all baseline patient characteristics	63.3	61.1	2.2 (1.5–2.9)
Random intercept for matched set, including all baseline patient characteristics	63.3	61.1	2.2 (1.2–3.1)
Random intercept for service area and matched set, including all baseline patient characteristics	63.4	61.0	2.4 (1.8–3.1)
Random intercepts for service area, matched set, and practice, including all baseline patient characteristics and any unbalanced practice characteristics	63.3	61.2	2.1 (1.4–2.8)
Random intercepts for service area, matched set, and practice, without any baseline patient characteristics	63.5	61.0	2.5 (1.5–3.5)

* Reference group is control practices.
† Adherence is assessed and shown by the percentage of days in the 12-mo follow-up period "covered" by prescription claims for the same medication or another in its molecularly related therapeutic class.

Appendix Table 6. Influence of Hypothetical Unmeasured Confounder*

Variable	Hypothetical Association Between Unmeasured Confounder and Outcome (Relative Risk of 2.0)	Prevalence of Confounder in Control Group (P_0)		
		0.0	0.2	0.4
Prevalence of confounder in medical home group (P_1)	0.0	1.10 (1.08–1.13)	1.32 (1.30–1.36)	1.54 (1.51–1.58)
	0.2	0.92 (0.90–0.94)	1.10 (1.08–1.13)	1.28 (1.28–1.32)
	0.4	0.79 (0.77–0.81)	0.94 (0.93–0.97)	1.10 (1.08–1.13)

* Values are relative risks (95% CIs) for an association between the unmeasured confounder and the outcome.