Medication Adherence as a Measure of the Quality of Care Provided by Physicians

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ABSTRACT

OBJECTIVES: To assess the extent to which medication adherence in congestive heart failure (CHF) and diabetes may serve as a measure of physician-level quality.

STUDY DESIGN: A retrospective analysis of Medicare data from 2007 to 2009, including parts A (inpatient), B (outpatient), and D (pharmacy).

METHODS: For each disease, we assessed the correlation between medication adherence and health outcomes at the physician level. We controlled for selection bias by first regressing patient-level outcomes on a set of covariates including comorbid conditions, demographic attributes, and physician fixed effects. We then classified physicians into 3 levels of average patient medication adherence—low, medium, and high—and compared health outcomes across these groups.

RESULTS: There is a clear relationship between average medication adherence and patient health outcomes as measured at the physician level. Within the diabetes sample, among physicians with high average adherence and controlling for patient characteristics, 26.3 per 1000 patients had uncontrolled diabetes compared with 45.9 per 1000 patients among physicians with low average adherence. Within the CHF sample, also controlling for patient characteristics, the average rate of CHF emergency care usage among patients seen by physicians with low average adherence was 16.3% compared with 13.5% for doctors with high average adherence.

CONCLUSIONS: This study's results establish a physician-level correlation between improved medication adherence and improved health outcomes in the Medicare population. Our findings suggest that medication adherence could be a useful measure of physician quality, at least for chronic conditions for which prescription medications are an important component of treatment.

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Measuring the quality of care offered by healthcare providers is an important tool for effectively promoting value in the US healthcare system. New quality metrics are constantly being developed and refined, and they are increasingly used in performance-based contracting. From the standpoint of providing incentives to increase the value of care, ideally these measures would directly observe the incremental value of care—in economic terms, the "marginal product of care"—and link reimbursement to the difference between incremental value and incremental cost. However, this direct effect is not easy to measure. Quality metrics sometimes attempt to do so by capturing various elements of healthcare delivery, including process, outcomes, and patient satisfaction.[1]

More recently, quality measures have been developed to evaluate the prescribing patterns, use, and consequences of prescription medications. Some of this growth reflects the increasing availability of medications to treat and prevent chronic illnesses and the growing consensus that adherence is an important part of disease management. Study results routinely show that proper adherence can lead to lower net healthcare costs, particularly for patients with cardiovascular disease.[2-7] Recent work also demonstrates that some health plans are systematically associated with higher medication adherence and better patient outcomes.[8] This evidence coincides with the growing use of adherence measures in pay-for-performance systems such as the Medicare Advantage Star Rating System.

There is also a growing effort to increase quality monitoring for individual physicians. As part of the 2010 Affordable Care Act (ACA), CMS reports information on individual physician quality through the Physician Compare Initiative.[9] More recently, the Medicare Access and CHIP Reauthorization Act of 2015 created the Quality Payment Program, through which some participating physicians receive reimbursement modifications based on reported quality metrics, including some based on adherence. However, despite the use of these metrics, it is not well established whether adherence varies systematically across physicians or correlates with the quality of medical care provided. Although the association between adherence and outcomes has been established generally, it is possible that at the individual physician level the signal to noise ratio is too

weak to make it a useful reimbursement tool. More work is needed to understand if some physicians are better than others in terms of promoting medication adherence and, if so, what this means for patient outcomes.

This study compares average patient medication adherence with select outcomes-based quality measures at the physician level using Medicare claims data. We do this for all patients in a nationally representative sample of Medicare data who have diabetes or congestive heart failure (CHF), 2 expensive chronic conditions that require extensive medication management to treat. We examine whether there are systematic differences in patient adherence across physicians and how those differences are associated with improved patient outcomes. Although this analysis cannot indicate a causal relationship between physician behavior and medication adherence and patient outcomes, it can evaluate whether any association exists between systematic physician-level differences in medication adherence and patient outcomes. Establishing that such a relationship exists is a necessary first step toward validating the use of physician-level measures of medication adherence in incentive-based reimbursement schemes.

TAKEAWAY POINTS

- In both the diabetes and congestive heart failure disease spaces, average levels of patient medication adherence (calculated at the physician level) are significant predictors of patient health.
- Average rates of hospitalization, emergency care, and comorbidities are lower among patients treated by physicians with high average adherence rates; this correlation persists after controlling for individual patient characteristics.
- The utility of average medication adherence as a potential measure of physician quality should be examined.

TABLE 1. Summary of Quality Outcome Measures

Measure	Description
Diabetes	
Uncontrolled diabetes admission rate	The number of unique inpatient hospitalizations for uncontrolled diabetes per 1000 patients with diabetes for a physician in a year.
Emergency care for hypoglycemia/ hyperglycemia	The annual number of ED visits involving hypoglycemia or hyperglycemia per 1000 patients with diabetes for a physician in a year.
Diabetes, short-term complications	The annual number of hospitalizations for short-term diabetes complications per 1000 patients with diabetes for a physician in a year.
Diabetes, long-term complications	The annual number of hospitalizations for long-term diabetes complications per 1000 patients with diabetes for a physician in a year.
CHF	
Hospitalization rate for primary or comorbid conditions	The percent of a physician's patients with CHF with an inpatient hospitalization that has a primary or secondary diagnosis of CHF, diabetes, CAD, or hypertension.
ED visit rate for primary or comorbid conditions	The percent of a physician's patients with CHF with an ED visit that has a primary or secondary diagnosis of CHF, diabetes, CAD, or hypertension.

CAD indicates coronary artery disease; CHF, congestive heart failure; ED, emergency department.

DATA AND METHODS

This study uses linked Medicare parts A (inpatient), B (outpatient), and D (pharmacy) claims data from a nationally representative, randomly selected 20% sample of Medicare beneficiaries 65 years and older with fee-for-service coverage of Medicare parts A, B, and D. Additionally, beneficiary enrollment, demographic information, and vital status come from the Medicare Denominator File. The inpatient data provide information on all hospital stays, including length of stay, the diagnosis-related group associated with the stay, and up to 10 individual procedure codes and diagnostic codes. The outpatient data include information on outpatient hospital visits, home hospice care, and the use of durable medical equipment. It also includes all claims submitted by physicians and other health providers, including physician office visits. The Part D prescription drug information provides information on prescription drug events, including the National Drug Code, number of days supplied, and date of service. These Part D data are linked with individual beneficiaries' vital status from the Denominator File, which contains geographic identifiers, date of birth, date of death, gender, race, and age. Because Part D did not begin until 2006, we restrict our analysis to patients from 2007 through 2009. Although these data are older, they provide a useful perspective because they are based on a period prior to the passage of the ACA, when physician prescribing patterns were likely unaffected by the recent drive toward improved quality metrics.[10-12]

We provide a brief summary of our analytical methods in this paragraph. Complete details are provided in the technical **eAppendix** (available at **ajmc.com**). We assess the relationship between adherence and several measures of patient health (including rates of hospitalization, emergency department [ED] care, and comorbidities), all calculated at the physician level. The full set of outcomes considered is listed in **Table 1**. To accomplish this, we first used claims data to generate a measure of patient-level adherence, the proportion of days covered (PDC). We next executed a series of patient-level regressions, in which 2 classes of outcomes (medication adherence and quality measures based on patient health) were modeled as a function of patient characteristics (including age, gender, and comorbid conditions) and physician fixed effects. We then predicted physician-level adherence and quality values from these regressions, calculated at the population mean of those patients. This produced measures of physician-level adherence and quality that controlled for observable differences

TABLE 2. Variation in Patient Characteristics Across Physicians

	Mean	IQR		90th Percentile
		25th Percentile	75th Percentile	
Patients with diabetes				
Number of physician-years	947,271			
Patients with PDC of 80% or better	40.2%	30.8%	50.0%	58.3%
Rate per 1000 patients				
Uncontrolled diabetes	36.2	0.0	54.1	90.9
Emergency care for hypoglycemia/hyperglycemia	7.7	0.0	10.5	25.6
Short-term diabetes complications	7.0	0.0	8.2	23.8
Long-term diabetes complications	97.3	40.0	137.9	200.0
Number of patients per physician-year	52	15	51	103
Total per-patient medical expenditures, $	39,954	18,104	52,511	77,396
Patients with CHF				
Number of physician-years	625,023			
Patients with PDC of 80% or better	36.2%	27.3%	44.7%	53.8%
Hospitalization rates				
CHF	49.5%	38.9%	60.3%	69.2%
Diabetes	29.8%	21.2%	37.5%	46.2%
CAD	29.4%	20.0%	37.6%	46.6%
Hypertension	59.3%	48.2%	71.0%	80.0%
Number of patients per physician-year	34	13	35	65
Total per-patient medical expenditures, $	54,723	34,125	67,781	92,080

CAD indicates coronary artery disease; CHF, congestive heart failure; IQR, interquartile range; PDC, proportion of days covered.

TABLE 3. Association Between Physician-Level Measures of Adherence and Health Outcomes for Patients With Diabetes[a]

Average Adherence	Rate per 1000 Patients			
	Uncontrolled Diabetes	Emergency Care for Hypoglycemia/ Hyperglycemia	Short-Term Diabetes Complications	Long-Term Diabetes Complications
Unadjusted				
Low	49.6	9.9	10.2	128.1
Moderate	35.2	7.5	6.6	95.3
High	22.1	5.3	3.9	64.3
Adjusted				
Low	45.9	8.8	5.9	113.0
Moderate	35.9	7.1	4.4	92.6
High	26.3	5.9	3.1	71.4

[a]Table reports unadjusted and adjusted rates of adverse events for patients with diabetes at the physician level. Adjusted rates are the predicted values from multivariate regressions holding the patient characteristics at their mean values across physicians. Adherence is measured as the weighted average of adherence across physicians to β-blockers, angiotensin-converting enzyme inhibitors, angiotensin receptor blockers, calcium channel blockers, oral antidiabetes medications, and statins, with the weights defined as the number of patients using the drug in the year. Adherence is defined as a proportion of days covered for each medication of 80% or better.

in physician patient populations. Next, we regressed the generated physician-level quality measures on the generated physician-level measures of medication adherence. Because we employed a 2-stage model, we used bootstrap methods to estimate standard errors. Finally, we examined the relative extent to which physician fixed effects and individual patient comorbidity profiles predict patient health outcomes, using analysis of variance.

RESULTS

In Table 2, we report differences in patient characteristics, aggregated to the physician-year level. The table shows average medication adherence for patients with diabetes and patients with CHF, patient outcomes, number of patients per physician-year, and mean total annual medical expenditures. Our measure of medication adherence is higher in the diabetes sample than the CHF sample, with a mean of 40.2% PDC (interquartile range [IQR], 30.8%-50.0%) for patients with diabetes compared with 36.2% for patients with CHF (IQR, 27.3%-44.7%). The private-sector patients considered by Seabury et al[8] showed similar results in that adherence was higher for patients with diabetes than those with CHF, but the average adherence levels were much higher in the private-sector data, perhaps reflecting the sicker nature of patients in Medicare. The average medical expenditures per patient-year are high: $39,954 for patients with diabetes and $54,723 for patients with CHF. Complication rates and spending levels in this analysis are higher than those seen in many other studies because this sample is composed of patients who saw a physician at least once in the year, restricted to physicians who see a relatively large number of patients with diabetes or CHF.

The average physician-year in the data covered 52 patients in the diabetes sample and 34 patients in the CHF sample. These figures are skewed by a subset of physicians who see a large number of patients; the physician in the 90th percentile saw 103 patients with diabetes and 65 with CHF in a year.

Table 3 compares the differences in health outcomes with average adherence across physician-years in the diabetes sample. The top panel reports the unadjusted association between outcomes and adherence, whereas the bottom panel reports the association between outcomes and adherence adjusted for patient characteristics, including age, sex, and comorbidities. For each outcome, the complication rate is averaged across physicians with low, moderate, or high average medication adherence among their patients. The

results show a clear relationship between the average adherence and outcomes of a physician's patients with diabetes. In the top "unadjusted" panel, physicians whose patients have low adherence have 49.6 patients per 1000 with uncontrolled diabetes compared with 22.1 per 1000 among physicians with high medication adherence. A similar relationship, in terms of both direction and magnitude, holds for ED visits and short-term and long-term complications. The magnitude of the effect diminishes following adjustment for patient characteristics: 45.9 per 1000 patients of physicians with low average adherence have uncontrolled diabetes compared with 26.3 per 1000 patients of physicians with high average adherence. In all cases, the bootstrap tests found that groupwise differences were statistically significant (P <.01 in all cases).

Table 4 reports analogous results for the CHF sample. As with the diabetes sample, patients of physicians with better average adherence also experienced better average outcomes. The unadjusted CHF hospitalization rate of patients of the low-adherence physicians was 51.8% compared with 45.7% for patients of physicians with high average adherence, a difference of 6.1 percentage points or 11.8%. In terms of CHF-related ED visits, the rate was 16.4% for patients of physicians with low adherence compared with 13.5% for physicians with high average adherence, a 17.8% difference. These results are consistent in terms of direction and magnitude for hospitalizations and ED visits for the other conditions. Comparing the top and bottom panels indicates that the regression adjustment for age, gender, and comorbidities has very little effect on the magnitude of the difference across physicians with low-adherence or high-adherence patients. As in the diabetes sample, in all cases the differences are statistically significant at the 1% level (P <.01).

Table 5 compares the proportion of the variance in the regression models of each medication adherence measure and outcome that is explained by physician fixed effects or patients' own comorbidity profiles. Physician fixed effects consistently account for a much larger portion of the explained variation than do individual comorbidities. In the diabetes sample, physician fixed effects account for about 15% to 20% of the explained variation in medication adherence and 3% to 5% in outcomes. This is considerably more than patient comorbidities, which generally account for less than 1% of the explained variation in outcomes. For the CHF sample, physician fixed effects account for somewhat less of the explained variation in adherence (about 15%-18%) but more of the explained variation in outcomes (about 8%-11%). However, patient comorbidities still account for very little of the explained variation, typically 2% or less. One possible explanation is that the patient comorbidity profile is a relatively weak predictor of patient health, although some comorbidities (eg, depression) are strongly indicative of worse outcomes. In any case, the analyses from Tables 3 through 5 suggest that there are unobserved characteristics of physicians that systematically predict medication adherence and, further, that unobserved characteristics are predictive of patient outcomes. Of course, which unobserved characteristics led to better patient adherence and which led to better patient outcomes remains unknown.

TABLE 4. Association Between Physician-Level Measures of Adherence and Health Outcomes for Patients With CHF[a]

Average Adherence	Percent of Patients at Physician Level With Hospitalization or Emergency Care for			
	CHF	Diabetes	CAD	Hypertension
Unadjusted				
Hospitalizations				
Low	51.8	32.7	31.3	63.3
Moderate	50.2	30.0	29.9	59.9
High	45.7	26.3	26.5	53.9
ED visits				
Low	16.4	4.3	1.2	7.6
Moderate	15.5	3.7	1.1	6.6
High	13.5	3.1	1.0	5.3
Adjusted				
Hospitalizations				
Low	51.4	31.9	31.1	62.4
Moderate	50.0	29.9	29.9	59.7
High	46.1	27.0	26.9	54.6
ED visits				
Low	16.3	4.3	1.2	7.4
Moderate	15.4	3.8	1.2	6.6
High	13.7	3.3	1.1	5.7

CAD indicates coronary artery disease; CHF, congestive heart failure; ED, emergency department.

[a]Table reports unadjusted and adjusted rates of adverse events for patients with CHF at the physician level. Adjusted rates are the predicted values from multivariate regressions holding the patient characteristics at their mean values across physicians. Adherence is measured as the weighted average of adherence across physicians to β-blockers, angiotensin-converting enzyme inhibitors, angiotensin receptor blockers, and diuretics, with the weights defined as the number of patients using the drug in the year. Adherence is defined as a proportion of days covered for each medication of 80% or better.

DISCUSSION

Our analysis finds a strong correlation between medication adherence and patient outcomes at the physician level. This suggests that measuring the medication adherence of a physician's patients can provide a signal of provider performance as measured by patient outcomes. More effort should be given to developing physician-level and/or disease-specific quality indications based on adherence and to evaluating whether the use of these measures could improve care and outcomes for patients with chronic diseases.

Although the relationship between improved adherence and better outcomes is well established at the patient level, it has not been established that the same relationship holds for individual physicians.[4] Recent work shows that adherence can be a similarly useful measure of health plan performance.[8] Prior work also shows that physicians with different measured quality also vary systematically in their prescribing patterns. For example, patients with type 2 diabetes of physicians who routinely prescribe metformin as frontline therapy have better outcomes than those of physicians who prescribe sulfonylureas.[13] However, in this study we explicitly documented a correlation between improved patient

TABLE 5. Percent of Variation in Medication Adherence and Outcomes Explained by Physician Fixed Effects and Comorbid Conditions[a]

	Variation Explained by Physician Fixed Effects	Variation Explained by Comorbidities
Patients with diabetes		
Adherence measures		
ACE inhibitors/ARBs	19.2%	0.4%
β-Blockers	19.8%	0.3%
Oral antidiabetes medications	17.3%	0.9%
Statins	16.1%	0.5%
Calcium channel blockers	46.3%	0.4%
Outcome measures		
Uncontrolled diabetes	4.9%	0.5%
Emergency care for hypoglycemia/hyperglycemia	3.6%	0.1%
Short-term diabetes complications	3.4%	0.0%
Long-term diabetes complications	5.5%	1.8%
Patients with CHF		
Adherence measures		
ACE inhibitors/ARBs	15.0%	1.1%
β-Blockers	16.2%	0.8%
Diuretics	17.9%	0.3%
Outcome measures		
CHF hospitalizations	10.4%	1.7%
Diabetes hospitalizations	8.0%	1.1%
CAD hospitalizations	9.0%	0.9%
Hypertension hospitalizations	11.2%	2.3%

ACE indicates angiotensin-converting enzyme; ARB, angiotensin receptor blocker; CAD, coronary artery disease; CHF, congestive heart failure.

[a]Table reports the percent of variation in adherence and outcomes that can be explained by physician characteristics and comorbid conditions. Estimates are equal to the partial sum of squares for physician fixed effects and for comorbid conditions over the total sum of squares. Comorbid conditions are modeled as indicator variables for any of the following conditions in the year: ulcer, depression, allergic rhinitis, migraine, osteoarthritis, chronic sinusitis, anxiety or tension disorder, epilepsy, gastric acid disorder, glaucoma, irritable bowel syndrome, malignancies, psychotic illness, thyroid disorder, rheumatoid arthritis, tuberculosis, HIV, anemia, or chronic obstructive pulmonary disease.

outcomes and improved adherence to medication in the case of both diabetes and CHF.

Unfortunately, our data do not cast light on *why* some physicians have patients with better medication adherence. Evidence suggests that many physicians feel untrained or ill equipped to promote medication adherence.[14] If that is true, it is possible that the systematic differences in medication adherence across physicians could reflect something intrinsic about the physician–patient relationship. Past work has found that good physician–patient relationships were important for promoting medication adherence.[15-17] Other work has found that physician characteristics, such as job satisfaction and propensity to schedule follow-up visits, were associated with improved adherence.[18] At the very least, the existing evidence is clear that there is an association between a physician's engagement with patients and better medication adherence by patients. Future work should better establish the activities or qualities of physicians that promote medication adherence and use these to develop physician guidelines to help promote these more broadly. Additionally, there is likely correlation between average adherence at the physician level and average adherence at the pharmacy level; future work should investigate which of these levels is better able to influence adherence.

Our findings suggest that medication adherence measures have the potential to be a useful quality measurement tool, at least for chronic conditions for which prescription medications are an important component of treatment. There are many potential advantages to using medication adherence as a quality metric. For one, although medication use is imperfect, there are commonly accepted and objective metrics that can be constructed using pharmacy claims data. Also, medication use is much more common than many types of complications, so it can be more accurately measured and is potentially more informative than a performance metric based on outcomes.

Although more needs to be done to establish a causal result, the cost implications could be large. Seabury et al[8] demonstrated that in addition to predicting outcomes, plan-level medication adherence is a strong signal of costs. In other words, plans whose patients had better adherence also had lower total average expenditures among their patients with diabetes and CHF. Although it is unclear how much of the difference between high- and low-adherence physicians is actually due to factors within a physician's control, our findings suggest the potential for large savings if we can sufficiently train and incentivize physicians to help their patients better adhere to their medication regimens. In the United States in 2014, there were more than 330,000 ED admissions for hyperglycemia or hypoglycemia and about 1 million for CHF.[19] Prior studies have estimated the cost of these admissions at around $2000 each.[20,21] If improved adherence reduced the incidence of these events by even a small amount, the cost savings would be large. For example, a 5% reduction in each type of admission would yield an estimated cost savings of almost $130 million. This suggests a need for careful, rigorous evaluation of new initiatives such as the Quality Payment Program to better understand what impact, if any, incentivizing physicians to improve quality has on patient outcomes.

Limitations

This study has several important limitations. First, our sample was large, but it was limited to Medicare patients. Although we expect the relationship between adherence and outcomes to generalize to commercial patients, this should be demonstrated in future work. Also, the quality measures were limited by the fact that our data are claims based and lack information about disease severity. Some outcomes that we considered are relatively rare, and many physicians had no patients with these complications. Thus, although the relationship between adherence and outcomes is informative in the aggregate, patient outcomes may provide limited information about the performance of any single provider. Further studies might consider how closely average medication adherence predicts more

clinically relevant measures of provider performance (eg, average glycated hemoglobin levels). Also, although we defined good adherence as having a PDC above 80%, the level chosen by CMS, it would be useful to evaluate the predictive ability of different threshold values.

Another limitation is that we only measured an association between average adherence and patient outcomes, and this relationship may not be causal. If healthier patients systematically select to certain physicians, it could overstate the correlation between adherence and outcomes due to what is known as the "healthy adherer" effect. For example, Dormuth et al[22] found that patients with better adherence also display many other positive health habits, such as safer driving. Although it is not clear that patients systematically select to physicians according to unobserved health factors, if they do, it would significantly impact the interpretation of our findings. If the association that we estimated represents a true causal relationship, then we would expect that tying reimbursement to adherence could improve outcomes for patients by providing physicians with enhanced incentives for better performance. If, on the other hand, high-adherence patients self-select toward some physicians more than others, reimbursing physicians based on adherence would simply reward physicians for something they have limited impact on. This could even generate adverse incentives, if it promoted "cream skimming" and gave physicians incentives to avoid sick patients. We find some evidence to suggest that the selection across providers is relatively minor, at least according to noncardiovascular comorbid conditions. Nevertheless, this accentuates the importance of understanding the mechanisms through which physicians influence adherence, as this will help policy makers devise quality metrics and reimbursement schemes to promote the right incentives to providers and unlock value for patients.

An additional limitation is that it is difficult to precisely measure adherence to injectable medications in claims data, due to the lack of information on titration instructions. This adds some uncertainty to our findings for the diabetes population, but that uncertainty is partially offset by the parallel conclusions in the CHF population. Also, some patients are seen by more than 1 physician in a given year and thus may contribute to the adherence and outcome fixed effects for multiple physicians. We assume that no single patient could create significant correlation across physicians, based on the fact that we required a minimum of 10 patients per physician.

Lastly, we were unable to adjust for the effect of social determinants of health (SDH). Several studies have demonstrated that SDH and patient outcomes are closely related. However, the observational claim-based Medicare database provides very limited information on SDH, which may result in unmeasured confounding.[23,24]

CONCLUSIONS

We sought to assess the potential for utilization of physician-level measures of medication adherence as quality indicators. For both CHF and diabetes and controlling for other factors, we found that the patients of physicians with higher average rates of adherence have better health outcomes than do patients of physicians with low average rates of adherence. This suggests that medication adherence may be a useful indicator of quality of care at the physician level. ■

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eAppendix

Study Sample

The goal of this analysis is to compare the medication adherence of individual patients to the performance metrics of their physicians. To do this requires the creation of a patient-level file that aggregates to the level of the physician. In the first, step, creating the patient-level file, we use the diagnoses in the medical claims to identify patients with 1 of 2 chronic conditions in a year: diabetes or CHF. Diabetes and CHF are identified based on the presence of the relevant ICD-9-CM codes listed as the primary or secondary diagnosis in 1 inpatient claim or at least 2 outpatient claims within a 30-day window over 1 calendar year. We require at least 2 separate outpatient codes to help eliminate cases where the ICD-9-CM is listed on a claim as a possible diagnosis for testing and examination, but the patient is later determined not to have the disease (eg, a rule-out diagnosis). Diabetes patients are flagged based on an ICD-9-CM diagnosis code(s) of 250.xx, while CHF patients are flagged based on an ICD-9-CM diagnosis code of 428.xx (where a .xx indicates all possible sub-code). Each individual is included in the sample in each year that they meet these inclusion criteria and are continuously enrolled for the entire calendar year. This excludes anyone who turned 65 and becomes Medicare eligible during the calendar year, but does not exclude someone whose first claim for the disease occurs in the middle of a calendar year. To create the physician-level file, we use the provider identifiers on the medical claims to identify physicians who treat patients with diabetes or CHF during a calendar year. We then aggregate all diabetes or CHF patients into physician-patient-year files, creating separate files for diabetes and CHF patients. This means that the same physician or patient could be in either file. Moreover, because patients often see more than 1 physician in a year, the same patient could be matched to different physicians in the same file(s). We consider all physicians the patients see in a year, including primary care providers and specialists. To minimize outliers on the physician level, we also only include physicians in a year in the diabetes or CHF samples if they saw at least 10 diabetes or CHF patients, respectively, during the calendar year.

Performance Measures

As interest in measuring and tracking the quality of healthcare has risen, so too has the number of different quality metrics available. There is an enormous number of quality measures that are available and used to try and quantify the quality of care provided to different patients in different settings. These measures are often very disease-specific, and many include process or patient satisfaction measures that cannot be captured with medical claims data. We focus on

patient outcome-related measures specific to diabetes and CHF that can be readily collected from medical claims data. Specifically, we follow Seabury, Lakdawalla et al. (2015)[8] and use 2 sets measures, 1 each for medication adherence and outcomes, based on measures endorsed by the National Quality Forum (NQF). The NQF is a non-profit organization that provides detail and documentation on quality measures, and attempts to promote scientific and policy consensus by specifically endorsing measures that meet there criteria.[10] CMS uses these quality measures in the many different quality reporting programs that cover physicians, plans, and hospitals.[8]

Our measures that are based on medication adherence focus on the percentage of days covered (PDC) over a 1-year period for classes of drugs treating CHF and diabetes. PDC is a commonly used measure of medication adherence that is similar to the historically better-known medication possession ratio (MPR). The MPR measures the number of days over a fixed time period in which the patient has medication based on the length of their prescription fills. So, suppose a patient in the sample filled their first 30-day prescription on January 1st, 2008 and was observed filling five 30-day refills, this would translate into an MPR of approximately 50% (6 months out of 12) in 2008. The PDC is similar except that it adjusts the days supplied to not double-count overlapping prescriptions within the same drug class (so it represents more of a class-specific as opposed to molecule-specific measure of adherence).[11]

Because we are not concerned with any particular drug molecule, and patients with diabetes and CHF often use multiple types of medication to manage their disease, we follow Seabury et al. (2015)[8] and create an index of adherence that combines the information on PDC across multiple drug classes. The drug classes that we use are based on treatment guidelines for diabetes and CHF. For diabetes patients these include beta-blockers, angiotensin-converting enzyme (ACE) inhibitors, angiotensin receptor blockers (ARBs), calcium-channel blockers, oral diabetes medications, and statins. For CHF, these include beta-blockers, ACE inhibitors, ARBs, and diuretics. For each disease, we identify all patients prescribed any of these types of medications at least once and compute the PDC for the remainder of the calendar year after the fill date of the first prescription. That is, if a patient filled their first prescription on the 200th day of the year, their PDC would be computed over 165 days (166 for patients in 2008). Based on the NQF measures, we identify patients with a PDC of 80% or more during the calendar year as being adherent to their medication. While the 80% threshold does not necessarily have a strong clinical justification, it is a commonly used benchmark in quality measures (including by CMS in some provider incentive plans).

We measure patient outcomes using the specification of quality measures endorsed by NQF that measure disease complications generally considered preventable for the 2 diseases, as described in Table 1 and based on the analysis in Seabury et al. (2015)[8]. The diabetes outcomes measures are based on the rates of acute events including four different conditions: inpatient admissions for uncontrolled diabetes, emergency care for hypoglycemia or hyperglycemia, short-term diabetes complications, and long-term diabetes complications. Given that some outcomes are relatively uncommon, we reported them in terms of rates per 1,000 patients. The CHF outcome measures are less specific, involving inpatient events or emergency room visits for CHF or for other co-morbid conditions that could be worsened by poor disease control: diabetes, coronary artery disease, or hypertension. The CHF sample is considerably sicker on average than the diabetes population, and these outcomes are much more common on average than the diabetes complications, so we measure these in terms of percent of patients per year.

Statistical Analysis

A. Measuring physician differences in outcomes and adherence

In our analysis, we propose to describe how variation in medication adherence across physicians correlates with variation in physician-level patient outcomes. While the empirical implantation of this is relatively straightforward, this approach is limited by the fact that correlation could be confounded by systematic differences in the underlying health of patients. Conceptually, our ideal experiment would be to randomly assign patients to individual physicians, and observe patient adherence and outcomes and whether they improve. In this case, we could simply compare physician-level mean unadjusted outcomes and the adherence of their patients, denoted as $\bar{y}_i^q$ and $\bar{y}_i^a$, respectively (where i denotes an individual provider), and compare them (in levels and in gains). However, variation in adherence and patient health across physicians is likely not random. We attempt to mitigate selection bias by adjusting measures of adherence and outcomes using the following 2-step process proposed by Seabury et al. (2015), though as we discuss below, this approach has limitations.

In the first step, we estimate the regression model:

$$y_{ij} = \theta_i + \beta X_j + \epsilon_{ij} \quad (1)$$

The variable y_{ij} represents some outcome measure for patient j who visits provider i. We run separate models for each different outcome in each sample. This includes separate regressions for each complication as well as for the adherence to each of the medications that comprise the index of medication adherence that we describe below. In this specification, the parameter θ_i

represents individual physician fixed effects while the vector X_i contained individual-level covariates including age, gender and health status as measured by co-morbid conditions. Specifically, these include ulcer, depression, allergic rhinitis, migraine, osteoarthritis, chronic sinusitis, anxiety or tension disorder, epilepsy, gastric acid disorder, glaucoma, irritable bowel syndrome (IBS), malignancies, psychotic illness, thyroid disorder, rheumatoid arthritis, tuberculosis, HIV, anemia or COPD. Other common conditions that were related to cardiovascular health (eg, acute myocardial infarction or hypertension) were excluded because the onset of claims could be endogenously related to individuals' medication use or other healthcare related to their diabetes or CHF.

The estimated fixed effects $\hat{\theta}_i$ are the key parameters of interest from the first stage regression. With these we capture the systematic variation in observed quality outcomes and adherence across individual physicians that cannot otherwise explained by observable patient characteristics. Let y_{ij}^a denote medication adherence and y_{ij}^q denote performance as measured by patient outcomes. We estimated the adjusted physician-level measures of adherence and performance using the following prediction values from the regression models:

$$\hat{y}_i^a = \hat{\theta}_i^a + \hat{\beta}^a \bar{X} \tag{2}$$

$$\hat{y}_i^q = \hat{\theta}_i^q + \hat{\beta}^q \bar{X} \tag{3}$$

where $\bar{X}$ is equal to the mean of all other characteristics in the full patient samples. In this formulation, the effect of the individual patient heterogeneity is captured by $\hat{\beta}^a \bar{X}$ and $\hat{\beta}^q \bar{X}$, which is fixed across physicians. Thus, the only variation in predicted adherence or predicted performance across physicians came from the fixed effects $\hat{\theta}_i^a$ and $\hat{\theta}_i^q$. Thus, our empirical test of the relationship between medication adherence and quality at the physician level essentially boil down to a test of $cov(\hat{\theta}_i^a, \hat{\theta}_i^q) < 0$. Note that the hypothesized covariance is negative because we expect adherence to have positive effects on patients while the performance measures we use are essentially bad outcomes (complications) for patients.

This regression adjustment eliminates observed heterogeneity in the patient population across providers but does not necessarily address unobserved heterogeneity across providers that could be correlated with both medication adherence and health outcomes. Thus, the association between physician-level adherence and outcomes are not necessarily causal, and the findings should be interpreted accordingly.

B. An Index of Medication Adherence

As noted above, we compute the average level of medication adherence across the patients of individual physicians separately. In the diabetes sample, we compute adherence for beta-blockers, ACE inhibitors, ARBs, calcium-channel blockers, oral diabetes medications, and statins, and in the CHF sample we compute average adherence to beta-blockers, ACE inhibitors, ARBs, and diuretics. We then combine the PDC measures into a single index of medication adherence of both unadjusted ($\bar{y}_i^a$) and adjusted ($\hat{y}_i^a$) adherence for each physician according to the relative frequency with their patients took each medication. Specifically, we combined the individual class-level measures of adherence into a single weighted average according to the following steps:

1. We first compute the average unadjusted ($\bar{y}_{di}^a$) and adjusted ($\hat{y}_{di}^a$) adherence separately for each drug d at the physician level.

2. Compute weights $w_{di} = \frac{N_{di}}{\sum_d N_{di}}$, where N_{di} is the number of patients taking the drug who sees physician i. Note that because some patient take more than 1 drug, N_{di} will be greater than the total number of people in the seen by the physician (necessary for the weights to sum to 1).

3. Construct the weighted average of medication adherence across drugs at the physician level: $\bar{y}_i^a = \sum_d w_{di}\bar{y}_{di}^a$ and $\hat{y}_i^a = \sum_d w_{di}\hat{y}_{di}^a$.

To simplify interpretation of the results, we compare physicians across broad categories of high, moderate and low adherence according to the value of the index. Specifically, we stratify individual physicians into categories of high, moderate and low adherence according to whether their weighted average is above the 75th percentile, between the 75th and 25th percentile, or below the 25th percentile across all physicians, respectively. Again, note that physicians are stratified differently according to the distribution of unadjusted or adjusted adherence (though, in practice, the stratification is similar).

Note that because the Part D File data we use do not link individual physicians to specific prescriptions, we do not assess adherence to specific prescriptions of individual providers. That

is, we assess whether physicians' patients are more or less likely to adhere to their diabetes or CHF medications compared to other physicians' patients, regardless of who prescribed the medication. Thus, we are not directly measuring the adherence to medications a physician prescribes, we only measure the adherence of patients with whom a physician has an office visit. To the extent that patients see multiple physicians but only 1 physician prescribes a given medication, this would introduce measurement error that we would expect to attenuate the relationship between physician and adherence towards zero.

C. Comparing Physician Differences

After stratifying physicians into these groups, we compare the values of $\bar{y}_i^q$ and $\hat{y}_i^q$ across groups to see if the observed quality outcomes differ systematically according to their medication adherence. To do this we regress the adjusted health outcomes against the medication adherence variables as the independent variables using ordinary least squares (OLS) regression. Because we control for other covariates in the first stage, we compute these differences in the second stage without further adjustment. Because we use a 2-step estimation procedure, where we use regression to adjust for physician characteristics in the first step and regress adjusted outcomes against adjusted adherence in the second step, we use a bootstrap procedure to estimate the variances and conduct inference of the differences across the low, moderate and high adherence physicians. Specifically, we resample individual patients with replacement and computed *p*-values for differences across low, moderate and high adherence physicians using bootstrap variance estimates based on 200 draws.

D. Analysis of Variance

The primary goal of this analysis is to determine whether or not physician-specific differences in average medication adherence matter in terms of their ability to predict outcomes, and if so how much. Ideally we would have perfect information about an individual's overall health status as well as detail about the activities that physicians undertake, and we could drill down more precisely on which activities have a bigger impact on adherence. Unfortunately, our information on patient health is limited to claims-based co-morbidity profiles while we have little information about physicians and none about what kind of steps they do or don't take to manage a patient's medication adherence. Nevertheless, we can compare the predictive power of physician heterogeneity generally to that of a patient's observable health status. If physicians were doing nothing on their own to influence medication adherence or outcomes and were

simply selecting more or less health patients, we might expect that physician heterogeneity to be relatively less predictive than a patient's own health status.

To test for this, in addition to looking at mean differences across physicians we also compare how much of the variation in adherence and outcomes were explained by fixed physician comparisons. We utilize a simple analysis of variance (ANOVA) technique that estimates the percent of the variation explained by the model that is attributed to physician fixed effects. Formally, we divide the partial sum of squares for physician fixed effects by the total explained sum of squares. Then, for the sake of comparison, we conduct a similar analysis with the other patient co-morbidities. Note that this analysis is not focused on whether physician heterogeneity or patient co-morbidities are strong predictors of adherence or outcomes overall, rather it tests the relative predictive power of the 2 within the context of the same regression model.