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RESEARCH ARTICLE

Medication Nonuse and Hospital Utilization: Medicaid Participants With Type 2 Diabetes in New York City

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Introduction: This study assesses the proportion of New York City Medicaid participants diagnosed with type 2 diabetes who did not have any claims for diabetes medication for an entire year and the association between nonuse of diabetes medication and subsequent hospitalizations.

Methods: The 2014–2016 New York State Medicaid claims data were used for this cohort study. Two types of hospitalizations were examined: all-cause hospitalizations and preventable diabetes hospitalizations. A potential association between medication nonuse and the number of hospitalizations in the following year was assessed using the negative binomial regression model, adjusting for individual- and neighborhood-level factors. The study was conducted in 2019–2020.

Results: Among the 117,183 individuals included in this study, 27.5% did not use any diabetes medication for an entire year. Compared with individuals using oral hypoglycemic medication only, the crude rate of all-cause hospitalizations among individuals who used no medication was approximately twice as high (37,111 vs 19,209 per 100,000 population), and the crude rate of preventable diabetes hospitalizations was almost 3 times as high (1,488 vs 537 per 100,000 population). Adjusting for individual- and neighborhood-level characteristics, medication nonuse was still associated with higher levels of all-cause hospitalizations (incidence rate ratio=1.26; 95% CI=1.21, 1.31) and preventable diabetes hospitalizations (incidence rate ratio=1.66; 95% CI=1.39, 1.99).

Conclusions: Medication use and adherence are important for managing diabetes. However, almost 30% of New York City Medicaid participants with type 2 diabetes had no claims for diabetes medication for an entire year. Significantly higher hospitalization rates among this group warrant attention from providers and policy makers.

INTRODUCTION

An estimated 13% of adults in the U.S. are living with diabetes, one of the leading causes of death and contributors to morbidities such as kidney failure, lower-limb amputations, and vision loss.[1] Management of diabetes is complex and requires a multilevel approach to ensure that individuals have meaningful healthcare encounters and necessary resources and services within their social and physical environments. Limited access to resources, including household income and neighborhood assets, can get in the way of people adopting and maintaining a healthy lifestyle and taking medications as prescribed for their diabetes and other comorbidities. Medication is key to effective management of diabetes, but research has found that nonadherence to medication is prevalent and is associated with acute health outcomes such as hospitalizations and higher healthcare expenditures.[2–9]

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Studies that assess diabetes medication adherence and associated health outcomes have generally focused on secondary nonadherence, which measures prescription refills among patients who have had at least 1 previous prescription fill for oral hypoglycemic (OH) therapy, insulin, or both. Therefore, individuals who did not have any records of prescription fills at a point in time—those who were never prescribed medication, who were prescribed medication but never filled the prescription (primary nonadherence), or previously filled a prescription but did not refill in the study period—have often been excluded from analysis.[10−14] However, according to the National Health Interview Survey, almost 20% of adults with diabetes reported currently taking no medication for their condition,[15] suggesting the need for a greater focus on medication nonuse as a detriment to diabetes management. Building on the evidence provided by cross-sectional surveys showing the potential extent of medication nonuse at a point in time,[16] it is important to further identify individuals who persistently do not use any medication over time and determine whether such persistent nonuse is associated with worse outcomes, such as excessive healthcare utilization. Administrative data sets that contain all healthcare claims for a given individual provide an opportunity to identify persistent nonusers of medication and assess the relationship between health outcomes and medication nonuse among individuals with diabetes.

This study assessed the proportion of adults in New York City (NYC) with type 2 diabetes and Medicaid coverage who did not have any claims for diabetes medication fills over the course of 1 year and whether these participants were more likely to experience subsequent hospitalizations than those who had claims for OH medication fills. Further comparisons were made with individuals who were adherent to OH medication and those who were on OH medication but nonadherent. Two types of hospitalizations were examined: all-cause hospitalizations and preventable diabetes hospitalizations. This analysis focused on all-cause hospitalizations because they have been the primary outcome of interest in most studies of diabetes medication use and associated health outcomes.[11−14] In addition, preventable diabetes hospitalizations were assessed as a narrower set of outcomes that are more directly attributable to medication nonuse and could be substantially reduced through medication use and adherence. As one of the few studies that focus on persistent nonuse of diabetes medication, this analysis contributes to the assessment of a potentially high-risk group that has not been closely examined and their health outcomes. Exploring these relationships within the population covered by Medicaid has added significance given the generally higher burden of diabetes prevalence than in other insured groups and examining differences within a similarly insured population accounts for variation introduced by varying benefit coverage across insurers.[17,18]

METHODS

Study Sample

Medicaid claims data for all New York State (NYS) participants in the program were obtained using Salient NYS Medicaid Enterprise System.[19] Inclusion criteria for the study sample consisted of the following: NYC residents aged 18–64 years in 2015, any diagnosis of type 2 diabetes based on International Classification of Diseases (ICD)-Ninth Revision and ICD-10 diagnostic codes in 2015 (Appendix Table 1, available online) and continuous enrollment in NYS Medicaid for 12 months in both 2015 and 2016. In addition, because there may be insufficient time to observe medication fills among individuals newly diagnosed in 2015, only those who had any enrollment and a type 2 diabetes diagnosis in 2014 were included. Less than 4% of individuals whose addresses could not be geocoded or who resided in nonresidential areas were excluded. The final study sample consisted of 117,183 individuals. The details of the sample selection are provided in Figure 1. The IRB at the NYC Department of Health and Mental Hygiene reviewed the study and determined the activity as exempt research.

Measures

Individuals diagnosed with type 2 diabetes were classified by medication status into 3 broad categories: no medication, OH medication without insulin, and insulin alone or in combination with OH medication. Less than 1% of individuals only had claims for noninsulin injectables and were not included in any of the 3 categories. The no-medication group included any individuals who did not have pharmacy claims for OH medication, insulin, or noninsulin injectables in 2015. The OH medication without insulin group included individuals with claims for therapeutic classes alpha-glucosidase inhibitors, biguanides (metformin), dipeptidyl peptidase-4 inhibitors, meglitinides, sodium-glucose transport protein 2 inhibitors, thiazolidinediones, sulfonylureas, or a combination of these classes but who did not have insulin claims in 2015. The insulin group was composed of individuals with any records for insulin in 2015.

The category of OH medication without insulin consisted of 2 subcategories: adherent to medication and nonadherent to medication. Proportion of days covered (PDC) was used to measure *adherence*, defined as a PDC of 80% or higher, a standard cut off for chronic disease medication.[20,21] PDC for each individual was calculated as a proportion of the number of nonoverlapping days of medication supply to the number of days in the *denominator period*, defined as the period between the date of the first medication fill in 2015 and the end of the year. If an individual had claims for >1 therapeutic class, a weighted average was calculated on the basis of the PDC and relative length of the denominator period for each therapeutic class. As recommended by the Pharmacy Quality Alliance, individuals with long hospital stays were not excluded from the analysis.[22] Finally, generic drug names instead of the commonly used national drug codes were used to identify medications of interest because national drug code lists may not be comprehensive or up to date (Appendix Table 2, available online).

Table 1. Continuously Enrolled Medicaid Participants Aged 18–64 Years Diagnosed With Type 2 Diabetes in New York City, by Medication Status in 2015

Individual characteristics	No medication[a]	Oral hypoglycemic[b]			Insulin	All
	n (%)	Any, *n* (%)	Adherent, *n* (%)	Nonadherent, *n* (%)	*n* (%)	*n* (%)
n (% of all individuals in study)	32,198 (27.5)	58,151 (49.6)	32,019 (59.0)[c]	22,284 (41.0)[c]	26,765 (22.8)	117,183 (100)
Demographics						
Female	18,250 (56.7)	31,171 (53.6)	17,082 (53.3)	11,921 (53.5)	14,606 (54.6)	64,080 (54.7)
Age, mean (SD)	51.5 (9.8)	53.1 (8.1)	54.1 (7.4)	52.2 (8.5)	51.7 (9.5)	52.3 (9)
Hispanic	10,293 (32)	19,481 (33.5)	10,456 (32.7)	7,678 (34.5)	11,085 (41.4)	40,886 (34.9)
NH Black	7,842 (24.4)	10,733 (18.5)	5,144 (16.1)	4,604 (20.7)	7,315 (27.3)	25,909 (22.1)
NH White	5,718 (17.8)	5,647 (9.7)	3,357 (10.5)	1,901 (8.5)	2,388 (8.9)	13,767 (11.7)
NH Asian/Pacific Islander	4,727 (14.7)	14,501 (24.9)	8,792 (27.5)	5,043 (22.6)	2,926 (10.9)	22,156 (18.9)
Other race/ethnicity	3,618 (11.2)	7,789 (13.4)	4,270 (13.3)	3,058 (13.7)	3,051 (11.4)	14,465 (12.3)
Primary and preventive care						
Primary care visit in 2015	22,517 (69.9)	51,628 (88.8)	28,592 (89.3)	19,835 (89)	22,387 (83.6)	96,593 (82.4)
Received an HbA1c test in 2015	20,347 (63.2)	53,312 (91.7)	29,918 (93.4)	20,223 (90.8)	24,093 (90)	97,801 (83.5)
Received an influenza vaccine in 2015	9,995 (31.0)	26,600 (45.7)	16,073 (50.2)	9,158 (41.1)	11,620 (43.4)	48,240 (41.2)
Comorbidities and social factors						
Housing instability	433 (1.3)	412 (0.7)	145 (0.5)	184 (0.8)	447 (1.7)	1,292 (1.1)
Mental-health diagnosis (any below)	10,823 (33.6)	13,461 (23.1)	7,436 (23.2)	4,945 (22.2)	9,903 (37)	34,214 (29.2)
Depression	6,598 (20.5)	8,861 (15.2)	4,918 (15.4)	3,272 (14.7)	6,729 (25.1)	22,207 (19)
Substance use disorder	3,595 (11.2)	4,441 (7.6)	2,081 (6.5)	1,850 (8.3)	4,134 (15.4)	12,182 (10.4)
Schizophrenia or bipolar disorder	4,899 (15.2)	4,918 (8.5)	2,839 (8.9)	1,685 (7.6)	3,404 (12.7)	13,230 (11.3)
Charleson Comorbidity Index, mean (SD)	2.8 (2)	2.6 (1.7)	2.7 (1.8)	2.6 (1.7)	3.8 (2.3)	3.0 (2.0)
Hospitalizations, 2015						
Any, N (CR per 100,000)	12,801 (39,757)	10,684 (18,373)	4,651 (14,526)	4,604 (20,661)	17,522 (65,466)	41,023 (35,008)
Any, *n* individuals (%)	6,182 (19.2)	5,974 (10.3)	2,876 (9.0)	2,486 (11.2)	7,256 (27.1)	19,427 (16.6)
Preventable diabetes, *n* (CR per 100,000)	458 (1422)	233 (401)	98 (306)	112 (502)	2,398 (8,960)	3,090 (2,637)
Preventable diabetes, *n* Individuals (%)	375 (1.2)	179 (0.3)	82 (0.3)	81 (0.4)	1,430 (5.3)	1,985 (1.7)
Hospitalizations, 2016 (subsequent)						
Any, *n* (CR per 100,000)	11,949 (37,111)	11,170 (19,209)	5,274 (16,471)	4,589 (20,593)	16,630 (62,133)	39,772 (33,940)
Any, *n* individuals (%)	5,872 (18.2)	6,135 (10.6)	3,096 (9.6)	2,475 (11.1)	6,606 (24.7)	18,629 (15.9)
Preventable diabetes, *n* (CR per 100,000)	479 (1488)	312 (537)	139 (434)	140 (628)	2,325 (8,688)	3,117 (2,660)
Preventable diabetes, *n* Individuals (%)	378 (1.2)	241 (0.4)	109 (0.3)	108 (0.5)	1,256 (4.7)	1,876 (1.6)

[a]Differences between no-medication group and each of the oral hypoglycemic use groups are statistically significant at $p<0.05$ or lower, with non-overlapping 95% CIs in all categories.
[b]Oral hypoglycemic group excluded individuals with insulin but included some individuals who also had noninsulin-injectable medications.
[c]Percentage of adherent and nonadherent individuals is among individuals with oral hypoglycemics for whom adherence was measured, n=54,303; 3,848 individuals were excluded owing to algorithm logic restrictions.
CR, crude rate; NH, Non-Hispanic.

The medication status categories are summarized below to enhance comprehension of the analysis:

- no medication (no OH/insulin/noninsulin injectables)
- OH medication
  - status: any OH
  - status: nonadherent (secondary adherence/nonadherence)
  - status: adherent (secondary adherence/nonadherence)
- insulin (insulin and any other medications)

Two types of hospitalizations in 2016 were examined: all-cause hospitalizations and preventable diabetes hospitalizations. All-cause hospitalizations included inpatient stays for any diagnosis. *Preventable diabetes hospitalizations* were defined using Prevention Quality Indicators (PQIs) 93, version 6 (ICD-10), September 2016, created by the Agency for Healthcare Research and Quality.[23] PQI 93 is a composite measure that includes PQI 1 (diabetes short-term complications), PQI 3 (diabetes long-term complications), PQI 14 (uncontrolled diabetes), and PQI 16 (lower extremity amputations).

Statistical Analysis

The potential association between medication nonuse in 2015 and the number of hospitalizations in 2016 was assessed using a hierarchical negative binomial regression model, adjusting for individual- and neighborhood-level covariates. Comparisons were first made with all individuals in the OH medication without insulin category and then with individuals in the subcategories of adherent and nonadherent to OH medication use. People with insulin claims were excluded from the regression analysis because of a greater likelihood of diabetes-related complications and a lack of validated measures of insulin adherence.[24] Individual-level covariates included sex, age, race/ethnicity (Hispanic, non-Hispanic [NH] Black, NH White, NH Asian, other or 2 or more races), any visit to a primary care provider in 2015, any hospitalization in 2015, mental health diagnosis (depression, substance use disorder, schizophrenia or bipolar disorders), and Charleson comorbidity index (exclusive of HIV owing to a lack of access to necessary data) in 2015 using ICD-Ninth Revision and ICD-10 codes.[25] A measure of housing instability, including homelessness,[26] based on ICD codes was also included as a control variable because housing instability is likely a confounding factor being that it has been found to be associated with increased hospital utilization and being that individuals experiencing housing instability may encounter greater difficulty in accessing medication.[27] A variable for receipt of an influenza

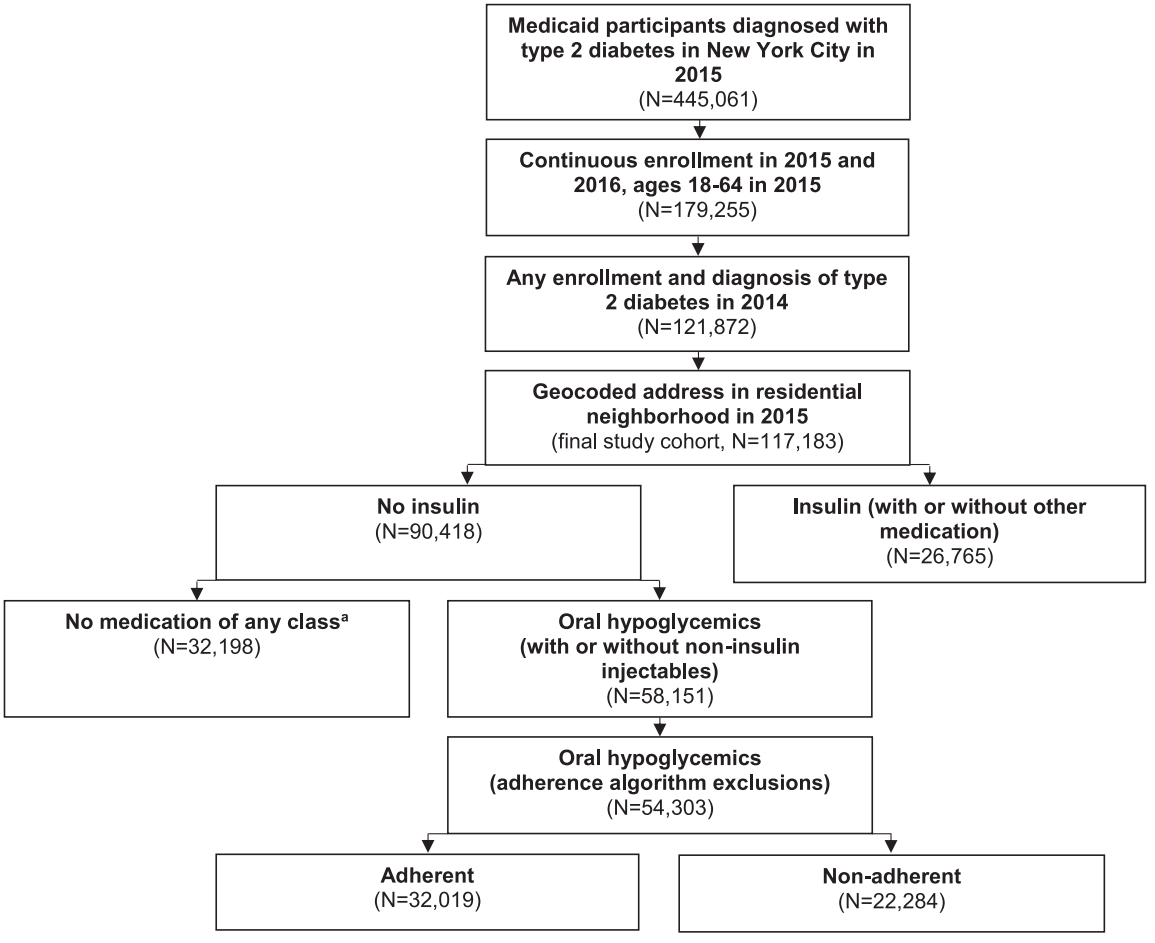

Figure 1. Study cohort selection and diabetes medication status classification in 2015.
[a]Individuals with claims for noninsulin injectables but without records for any other diabetes medication (*n*=69) were excluded from the analysis.

Table 2. Hierarchical Negative Binomial Model for Hospitalizations—Comparison of Medication Nonuse With Any Oral Hypoglycemic Use

Covariates	All-cause hospitalizations, Incidence rate ratio (95% CI)	Preventable diabetes hospitalizations, Incidence rate ratio (95% CI)
Any oral hypoglycemic medication[a]	1 (ref)	1 (ref)
No medication of any kind	**1.26** (1.21, 1.31)	**1.66** (1.39, 1.99)
Female	**0.95** (0.91, 0.98)	**0.62** (0.52, 0.72)
Age 18–29 years	1 (ref)	1 (ref)
Age 30–44 years	**0.76** (0.68, 0.85)	2.09 (0.92, 4.78)
Age 45–64 years	**0.73** (0.66, 0.81)	1.55 (0.69, 3.49)
Hispanic	1.05 (0.99, 1.11)	1.15 (0.87, 1.51)
NH Black	**1.21** (1.13, 1.28)	**1.64** (1.25, 2.15)
NH Asian/Pacific Islander	**0.65** (0.60, 0.70)	**0.38** (0.24, 0.60)
Other race/ethnicity	1.06 (0.98, 1.14)	**1.39** (1.01, 1.92)
NH White	1 (ref)	1 (ref)
Housing instability	**2.24** (2.07, 2.43)	**1.77** (1.17, 2.66)
Primary care visit in 2015	**0.76** (0.73, 0.79)	**0.51** (0.42, 0.60)
Influenza vaccine in 2015	**0.96** (0.92, 1.00)	0.86 (0.72, 1.02)
Charleson index: 1	1 (ref)	1 (ref)
Charleson index: 2	**1.37** (1.29, 1.45)	1.12 (0.78, 1.63)
Charleson index: 3	**1.45** (1.37, 1.54)	**2.28** (1.67, 3.12)
Charleson index: 4+	**2.13** (2.03, 2.24)	**5.09** (3.92, 6.60)
Mental-health diagnosis	**1.55** (1.49, 1.61)	1.09 (0.92, 1.28)
Neighborhood poverty: 25th percentile	1 (ref)	1 (ref)
Neighborhood poverty: 25th–75th percentile	0.97 (0.89, 1.04)	0.93 (0.71, 1.23)
Neighborhood poverty: 75th–99th percentile	0.93 (0.86, 1.01)	0.92 (0.69, 1.23)
Previous year hospitalization (all-cause/preventable diabetes)	**3.31** (3.19, 3.45)	**10.71** (8.58, 13.37)
N	90,349	90,349

Note: Boldface indicates statistical significance ($p<0.05$).
[a]Oral hypoglycemic group excludes individuals with insulin but may include some individuals who also have noninsulin-injectable medications.
NH, Non-Hispanic.

vaccine in 2015 was included to serve as an additional proxy for the healthy adherer effect or the idea that people who are more adherent may also be more likely to access necessary preventive interventions.[28] The percentage of residents in poverty was included as a neighborhood-level factor. *Neighborhoods* were defined as Neighborhood Tabulation Areas, which approximately correspond to historical NYC neighborhoods and represent an appropriate geography for examining neighborhood health.[29] Neighborhood-level random effects were included in all models, and statistical analyses were performed using Stata 12. A total of 90,349 individuals were included in the regression analysis comparing individuals in the no-medication group with those using OH medication only, and 86,501 individuals were included in a separate analysis comparing the no-medication group with OH adherent and nonadherent individuals (some exclusions were made owing to PDC algorithm logic).[20]

RESULTS

Among the 117,183 individuals included in the study, 32,198 or 27.5% had no diabetes medication claims for the entire year of 2015; 58,151 or 49.6% had claims for OH medication only; and 26,765 or 22.8% had claims for insulin alone or in combination with other medication (Table 1). Among those taking OH only, 59.0% had a PDC of 80% or higher and were considered adherent.

Because individuals on insulin tend to be in a more progressive stage of diabetes and have greater disease burdens—as shown by a higher Charleston Comorbidity Index score and higher rates of all-cause and preventable diabetes hospitalizations—the focus is on the comparisons between individuals not taking medication and those who used OH medication only. Although not specified in Table 1, all the differences presented below are statistically significant with nonoverlapping CIs. Individuals in the no-medication group were younger (mean age of 51.5 vs 53.1 years), more likely to be NH Black or White (24.4% and 17.8% vs 18.5% and 9.7%), were more likely to be housing unstable (1.3% vs 0.7%), more likely to be hospitalized in 2015 (19.2% vs 10.3%), more likely to have a mental health diagnosis (33.6% vs 23.1%), and less likely to visit a primary care provider (70.0% vs 88.8.%) or have an influenza vaccine (31.0%

vs 45.7%) than individuals who used OH medication only. The crude rate of all-cause hospitalizations in 2016 was approximately twice as high among individuals who did not use any medication (37,111 vs 19,209 per 100,000 population), and the crude rate of preventable diabetes hospitalizations was almost 3 times as high (1,488 vs 537 per 100,000 population). The significantly higher rates of hospitalizations among the no-medication group did not appear to be driven by a subgroup of people with a high frequency of utilization because the distribution of individuals by the number of hospitalizations was fairly similar to that of the group who used OH medication only (not shown).

Once accounting for differences in demographics, comorbidities, past hospitalizations, primary and preventive care use, social factors, and other attributes, medication nonuse was still associated with higher levels of all-cause hospitalizations (incidence rate ratio [IRR] =1.26; 95% CI=1.21, 1.31) and preventable diabetes hospitalizations (IRR=1.66; 95% CI=1.39, 1.99) in the subsequent year than among individuals using OH medication only (Table 2). Comparing those not taking medication with those who were adherent to OH medication, the differences in subsequent hospitalization rates were even larger (IRR=1.36; 95% CI=1.30, 1.42 for all-cause hospitalizations and IRR=1.97; 95% CI=1.57, 2.48 for preventable diabetes hospitalizations) (Table 3).

Subsequent hospitalization rates by adherence status were also assessed among the subset of individuals with medication data and for whom a PDC could be determined. Individuals who were nonadherent had higher crude rates of all-cause hospitalizations (20,593 vs 16,471 per 100,000 population) and preventable diabetes hospitalizations (628 vs 434 per 100,000 population) than those who were adherent to OH medication (Table 1). Adjusting for differences in observable characteristics in a regression model, the higher rates of all-cause hospitalizations (IRR=1.12; 95% CI=1.06, 1.18) and preventable diabetes hospitalizations (IRR=1.35; 95% CI=1.03, 1.76) among those who were nonadherent remained (Table 3).

DISCUSSION

Many studies have found adverse outcomes, including higher levels of hospital utilization, among individuals with type 2 diabetes who were nonadherent to diabetes medication.[11–14] However, these studies did not necessarily focus on individuals who do not use any medication. Among a large sample of adult Medicaid participants diagnosed with type 2 diabetes, this study found strikingly high rates of subsequent hospitalizations for those who did not use any medication. Compared with individuals who used OH medication only, the crude rate of all-cause hospitalizations was twice as high, and the crude rate of preventable diabetes hospitalizations was 3 times as high among individuals who did not use any medication. The disparities in hospitalization rates persist even after accounting for individual- and neighborhood-level differences. Because this study showed that almost 30% of NYC Medicaid participants who had been diagnosed with type 2 diabetes were not using diabetes medication of any kind for at least 1 year, the significantly higher rates of hospitalizations among them are particularly concerning and warrant additional attention.

This analysis uncovered several co-occurring behaviors and conditions of Medicaid participants who were not taking medication. First, individuals who did not use any medication received less general preventive services and diabetes-specific care (such as having a primary care visit or an HbA1c test), suggesting a potential link between access to preventive care and medication use. Second, the majority (69.9%) of individuals who did not use any medication had at least 1 touch point with primary care in 2015, and 63.2% had an HbA1c test done, indicating possible missed opportunities in the primary care encounter. In addition, individuals who did not use any medication were much more likely to have a mental health diagnosis than individuals who had used OH medication only, suggesting that having a co-occurring mental health diagnosis may pose additional challenges to accessing and using diabetes medication.[30,31] Other factors associated with medication nonuse, such as housing instability, suggest the need to focus on social risk factors to increase medication use and improve outcomes.[32,33]

In addition to showing a large proportion of Medicaid participants with diabetes not using any medication despite being diagnosed for at least 1 year, this analysis found an adherence rate <60% among those who had any OH medication fills. Together with patients who used no medication, this suggests that the rate of insufficient medication use is approximately 60% among diagnosed individuals who were not on insulin. This analysis also found higher rates of hospitalizations among those who were not adherent—the higher rate of all-cause hospitalizations is consistent with the findings of many other studies,[10–14] but a higher rate of preventable diabetes hospitalizations among individuals who are nonadherent to OH medication is not as well-documented. Previous research has shown that factors, including out-of-pocket costs, side effects of medication, comorbidities, limited health literacy, personal beliefs, access to care, and other challenges, contribute to medication nonadherence.[34–38] Although NYS Medicaid provides

Table 3. Hierarchical Negative Binomial Model for Hospitalizations—Comparison of Medication Nonuse With Adherence and Nonadherence With Oral Hypoglycemic Medication

Covariates	All-cause hospitalizations, incidence rate ratio (95% CI)	Preventable diabetes hospitalizations, incidence rate ratio (95% CI)
Adherent to oral hypoglycemic medication (PDC ≥80%)[a]	1 (ref)	1 (ref)
Nonadherent to oral hypoglycemic medication (PDC <80%)[a]	**1.12** (1.06, 1.18)	**1.35** (1.03, 1.76)
No medication of any kind	**1.36** (1.30, 1.42)	**1.97** (1.57, 2.48)
Female	**0.95** (0.91, 0.98)	**0.63** (0.54, 0.75)
Age 18–29 years	1 (ref)	1 (ref)
Age 30–44 years	**0.78** (0.69, 0.88)	2.39 (0.97, 5.89)
Age 45–64 years	**0.75** (0.67, 0.84)	1.78 (0.74, 4.31)
Hispanic	1.05 (0.99, 1.12)	1.16 (0.88, 1.55)
NH Black	**1.21** (1.13, 1.28)	**1.65** (1.25, 2.18)
NH Asian/Pacific Islander	**0.66** (0.61, 0.72)	**0.37** (0.23, 0.60)
Other race/ethnicity	1.06 (0.98, 1.14)	**1.40** (1.00, 1.94)
NH White	1 (ref)	1 (ref)
Housing instability	**2.16** (1.98, 2.35)	**1.81** (1.19, 2.75)
Primary care visit in 2015	**0.76** (0.73, 0.79)	**0.49** (0.41, 0.59)
Influenza vaccine in 2015	**0.96** (0.92, 1.00)	0.89 (0.74, 1.07)
Charleson index: 1	1 (ref)	1 (ref)
Charleson index: 2	**1.38** (1.30, 1.47)	1.19 (0.81, 1.74)
Charleson index: 3	**1.47** (1.38, 1.56)	**2.39** (1.73, 3.30)
Charleson index: 4+	**2.17** (2.06, 2.28)	**5.24** (3.99, 6.87)
Mental-health diagnosis	**1.55** (1.49, 1.61)	1.1 (0.93, 1.31)
Neighborhood poverty: 25th percentile	1 (ref)	1 (ref)
Neighborhood poverty: 25th–75th percentile	0.98 (0.90, 1.06)	0.93 (0.70, 1.24)
Neighborhood poverty: 75th–99th percentile	0.94 (0.86, 1.02)	0.9 (0.67, 1.21)
Previous year hospitalization (all-cause/preventable diabetes)	**3.29** (3.16, 3.42)	**10.52** (8.39, 13.18)
n	86,501	86,501

Note: Boldface indicates statistical significance ($p<0.05$).
[a]Oral hypoglycemic group excludes individuals with insulin but may include some individuals who also have noninsulin-injectable medications. The percentage of adherent and nonadherent individuals is among individuals with oral hypoglycemics for whom adherence was measured; 3,848 individuals were excluded owing to algorithm logic restrictions.
NH, Non-Hispanic; PDC, proportion of days covered.<

coverage for the cost of approved prescription drugs, copayments may still present a challenge for accessing required medications. Most interventions designed to improve medication adherence have been found to have modest effects, if any, and sustained medication adherence over time remains a challenge.[39] Some interventions that have shown to be effective include providing pharmacist consultations for management of comorbidities and prescribing combination pills where possible.[40] Although more research needs to be done to help patients improve and maintain management of diabetes, health systems can invest in proven interventions to increase medication adherence.[41] In addition, future work should focus on developing better surveillance for medication prescription and use the trajectory of individuals with chronic disease to understand the reasons for why some people may not have ever started taking medication, started but discontinued, or started but have trouble maintaining sustained adherence.

Limitations

This study has several limitations. First, there were only available data on medication fills but not on prescription for medication or actual use of medication. In addition, it is possible that some patients received medication from sources such as community health centers that were not accounted for in the analysis. Second, a majority of individuals who did not have medication claims in 2015 also did not have any medication claims in 2014 (data not shown), suggesting that the assessed impact of no medication use on hospitalizations may have resulted from multiple years of not using any medication. Third, although potentially confounding factors such as comorbidities were accounted for, there are others such as diet and exercise, which may be correlated with medication use as well as hospitalizations, which were not included in the regression model. Hence, the association between medication nonuse and subsequent hospitalizations may not represent a causal link. Fourth, because the focus is

on the Medicaid population who generally have lower income and higher disease burdens, the study findings may not be generalizable to the non-Medicaid population. Fifth, although only individuals who had a type 2 diabetes diagnosis in the previous year were included in the analysis, it is still possible that some of them were never prescribed any medication by their providers. Finally, some of the covariates included in the model may be imprecisely measured. For example, mental health conditions tend to be underdiagnosed, and *housing instability*, defined in this study solely by ICD codes, is likely underdiagnosed as well.

CONCLUSIONS

This study found that almost 30% of NYC Medicaid beneficiaries with type 2 diabetes had no claims for diabetes medication for an entire year and that these individuals had much higher all-cause and preventable diabetes hospitalization rates in the subsequent year. Nonuse of medication was associated with several factors, including reduced general preventive services and diabetes-specific care, a greater likelihood of mental health, and housing instability. Healthcare providers and policy makers may use the evidence uncovered in this study to provide assistance and support in diabetes medication management.

CRediT AUTHOR STATEMENT

Anna Zhilkova performed the analysis and drafted the manuscript. Shadi Chamany, Charlene Ngamwajasat, Samantha De Leon, and Winfred Wu contributed to the analysis and discussion and reviewed/edited the manuscript. Tsu-Yu Tsao conceptualized the analysis and drafted the manuscript.

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SUPPLEMENTAL MATERIAL

Supplemental materials associated with this article can be found in the online version at https://doi.org/10.1016/j.amepre.2022.04.005.

REFERENCES

1. Centers for Disease Control and Prevention. National diabetes statistics report 2020. Atlanta, GA: Centers for Disease Control and Prevention; 2022. Published 2020. Accessed April 25. https://www.cdc.gov/diabetes/pdfs/data/statistics/national-diabetes-statistics-report.pdf.
2. Bailey JE, Wan JY, Tang J, Ghani MA, Cushman WC. Antihypertensive medication adherence, ambulatory visits, and risk of stroke and death. *J Gen Intern Med.* 2010;25(6):495–503. https://doi.org/10.1007/s11606-009-1240-1.
3. Gaffney A, Bor DH, Himmelstein DU, Woolhandler S, McCormick D. The effect of Veterans Health Administration coverage on cost-related medication nonadherence. Health Aff (Millwood). 2020;39(1):33–40. https://doi.org/10.1377/hlthaff.2019.00481.
4. Jha AK, Aubert RE, Yao J, Teagarden JR, Epstein RS. Greater adherence to diabetes drugs is linked to less hospital use and could save nearly $5 billion annually. *Health Aff (Millwood).* 2012;31(8):1836–1846. https://doi.org/10.1377/hlthaff.2011.1198.
5. Reynolds K, An J, Wu J, et al. Treatment discontinuation of oral hypoglycemic agents and healthcare utilization among patients with diabetes. *J Diabetes Complications.* 2016;30(8):1443–1451. https://doi.org/10.1016/j.jdiacomp.2016.07.021.
6. Roebuck MC, Dougherty JS, Kaestner R, Miller LM. Increased use of prescription drugs reduces medical costs in Medicaid populations. *Health Aff (Millwood).* 2015;34(9):1586–1593. https://doi.org/10.1377/hlthaff.2015.0335.
7. Roebuck MC, Kaestner RJ, Dougherty JS. Impact of medication adherence on health services utilization in Medicaid. *Med Care.* 2018;56(3):266–273. https://doi.org/10.1097/MLR.0000000000000870.
8. Roebuck MC, Liberman JN, Gemmill-Toyama M, Brennan TA. Medication adherence leads to lower health care use and costs despite increased drug spending. *Health Aff (Millwood).* 2011;30(1):91–99. https://doi.org/10.1377/hlthaff.2009.1087.
9. Will JC, Zhang Z, Ritchey MD, Loustalot F. Medication adherence and incident preventable hospitalizations for hypertension. *Am J Prev Med.* 2016;;50(4):489–499. https://doi.org/10.1016/j.amepre.2015.08.021.
10. Curtis SE, Boye KS, Lage MJ, Garcia-Perez LE. Medication adherence and improved outcomes among patients with type 2 diabetes. *Am J Manag Care.* 2017;23(7):e208–e214.
11. Ho PM, Rumsfeld JS, Masoudi FA, et al. Effect of medication nonadherence on hospitalization and mortality among patients with diabetes mellitus. *Arch Intern Med.* 2006;166(17):1836–1841. https://doi.org/10.1001/archinte.166.17.1836.
12. Lau DT, Nau DP. Oral antihyperglycemic medication nonadherence and subsequent hospitalization among individuals with type 2 diabetes. *Diabetes Care.* 2004;27(9):2149–2153. https://doi.org/10.2337/diacare.27.9.2149.
13. Lo-Ciganic WH, Donohue JM, Jones BL, et al. Trajectories of diabetes medication adherence and hospitalization risk: a retrospective cohort study in a large state Medicaid program. *J Gen Intern Med.* 2016;31(9):1052–1060. https://doi.org/10.1007/s11606-016-3747-6.
14. Shenolikar RA, Balkrishnan R. Oral antidiabetes medication adherence and health care utilization among Medicaid-enrolled type 2 diabetic patients beginning monotherapy. *Diabetes Care..* 2008;31(2):e5. https://doi.org/10.2337/dc07-1442.
15. Blewett LARDJ, Griffin R, King ML, Williams KCW. *IPUMS Health Surveys: National Health Interview Survey, version 6.3.* Minneapolis, MN: IPUMS; 2019. Published 2018. Accessed October 14. https://nhis.ipums.org/nhis/.
16. Kyanko KA, Franklin RH, Angell SY. Adherence to chronic disease medications among New York City Medicaid participants. *J Urban Health.* 2013;90(2):323–328. https://doi.org/10.1007/s11524-012-9724-4.
17. Epiquery: NYC interactive health data system. Community health survey. New York City Department of Health and Mental Hygiene; 2022. Accessed April 19. http://nyc.gov/health/epiquery.
18. Tan E, Yang W, Pang B, Dai M, Loh FE, Hogan P. Geographic variation in antidiabetic agent adherence and glycemic control among patients with type 2 diabetes. *J Manag Care Spec Pharm.* 2015;21(12):1195–1202. https://doi.org/10.18553/jmcp.2015.21.12.1195.
19. *Salient NYS Medicaid Enterprise System: Includes Payment Cycles Through 2219.* Accessed March 10, 2020.

20. Calculating proportion of days covered (PDC) for antihypertensive and antidiabetic medications: an evaluation guide for grantees. National Center for Chronic Disease Prevention and Health Promotion. *Centers for Disease Control and Disease.* 2022 Updated April 10, 2020. Accessed April 25. https://hdsbpc.cdc.gov/s/article/Calculating-Medication-Adherence-for-Antihypertensive-and-Antidiabetic-Medications-A-Guide-for-state-Evaluators.
21. Choudhry NK, Shrank WH, Levin RL, et al. Measuring concurrent adherence to multiple related medications. *Am J Manag Care.* 2009;15(7):457–464.
22. Nau DP. *Proportion of days covered (PDC) as a preferred method of measuring medication adherence.* Alexandria, VA: Pharmacy Quality Alliance; 2022. Published 2012. Accessed April 19. https://sep.yimg.com/ty/cdn/epill/pdcmpr.pdf.
23. Prevention quality indicators overview. Agency for Healthcare Research and Quality. https://www.qualityindicators.ahrq.gov/modules/pqi_resources.aspx. Updated July, 2021. Accessed April 19, 2022.
24. Stolpe S, Kroes MA, Webb N, Wisniewski T. A systematic review of insulin adherence measures in patients with diabetes. *J Manag Care Spec Pharm.* 2016;22(11):1224–1246. https://doi.org/10.18553/jmcp.2016.22.11.1224.
25. Quan H, Sundararajan V, Halfon P, et al. Coding algorithms for defining comorbidities in ICD-9-CM and ICD-10 administrative data. *Med Care.* 2005;43(11):1130–1139. https://doi.org/10.1097/01.mlr.0000182534.19832.83.
26. Peterson R, Gundlapalli AV, Metraux S, et al. Identifying homelessness among veterans using VA administrative data: opportunities to expand detection criteria. *PLOS ONE.* 2015;10(7):e0132664. https://doi.org/10.1371/journal.pone.0132664.
27. Treglia D, Johns EL, Schretzman M, et al. When crises converge: hospital visits before and after shelter use among homeless New Yorkers. *Health Aff (Millwood).* 2019;38(9):1458–1467. https://doi.org/10.1377/hlthaff.2018.05308.
28. Brookhart MA, Patrick AR, Dormuth C, et al. Adherence to lipid-lowering therapy and the use of preventive health services: an investigation of the healthy user effect. *Am J Epidemiol.* 2007;166(3):348–354. https://doi.org/10.1093/aje/kwm070.
29. New York City neighborhood health atlas. New York City Department of Health and Mental Hygiene. https://www1.nyc.gov/site/doh/health/neighborhood-health/nyc-neighborhood-health-atlas.page. Updated January 19, 2018. Accessed August 2, 2019.
30. Aikens JE. Prospective associations between emotional distress and poor outcomes in type 2 diabetes. *Diabetes Care.* 2012;35(12):2472–2478. https://doi.org/10.2337/dc12-0181.
31. Lin EH, Katon W, Von Korff M, et al. Relationship of depression and diabetes self-care, medication adherence, and preventive care. *Diabetes Care.* 2004;27(9):2154–2160. https://doi.org/10.2337/diacare.27.9.2154.
32. Berkowitz SA, Meigs JB, DeWalt D, et al. Material need insecurities, control of diabetes mellitus, and use of health care resources: results of the Measuring Economic Insecurity in Diabetes study. *JAMA Intern Med.* 2015;175(2):257–265. https://doi.org/10.1001/jamainternmed.2014.6888.
33. Berkowitz SA, Kalkhoran S, Edwards ST, Essien UR, Baggett TP. Unstable housing and diabetes-related emergency department visits and hospitalization: a nationally representative study of safety-net clinic patients. *Diabetes Care.* 2018;41(5):933–939. https://doi.org/10.2337/dc17-1812.
34. Gagnon MD, Waltermaurer E, Martin A, Friedenson C, Gayle E, Hauser DL. Patient beliefs have a greater impact than barriers on medication adherence in a community health center. *J Am Board Fam Med.* 2017;30(3):331–336. https://doi.org/10.3122/jabfm.2017.03.160129.
35. Fernández A, Quan J, Moffet H, Parker MM, Schillinger D, Karter AJ. Adherence to newly prescribed diabetes medications among insured Latino and White patients with diabetes. *JAMA Intern Med.* 2017;177(3):371–379. https://doi.org/10.1001/jamainternmed.2016.8653.
36. Osborn CY, Cavanaugh K, Wallston KA, et al. Health literacy explains racial disparities in diabetes medication adherence. *J Health Commun.* 2011;16(3):268–278. suppl. https://doi.org/10.1080/10810730.2011.604388.
37. Eaddy MT, Cook CL, O'Day K, Burch SP, Cantrell CR. How patient cost-sharing trends affect adherence and outcomes: a literature review. *P T.* 2012;37(1):45–55.
38. Nam S, Chesla C, Stotts NA, Kroon L, Janson SL. Barriers to diabetes management: patient and provider factors. *Diabetes Res Clin Pract.* 2011;93(1):1–9. https://doi.org/10.1016/j.diabres.2011.02.002.
39. Volpp KG, Troxel AB, Mehta SJ, et al. Effect of electronic reminders, financial Incentives, and social support on outcomes after myocardial infarction: the HeartStrong randomized clinical trial. *JAMA Intern Med.* 2017;177(8):1093–1101. https://doi.org/10.1001/jamainternmed.2017.2449.
40. Kini V, Ho PM. Interventions to improve medication adherence: a review. *JAMA.* 2018;320(23):2461–2473. https://doi.org/10.1001/jama.2018.19271.
41. Williams JL, Walker RJ, Smalls BL, Campbell JA, Egede LE. Effective interventions to improve medication adherence in type 2 diabetes: a systematic review. *Diabetes Manag (Lond).* 2014;4(1):29–48. https://doi.org/10.2217/dmt.13.62.