Adherence to the American Diabetes Association's Glycemic Goals in the Treatment of Diabetes Among Older Americans, 2001–2018

Phuc Le,[1] Gina Ayers,[2] Anita D. Misra-Hebert,[1,3] Shoshana J. Herzig,[4] William H. Herman,[5,6] Victoria A. Shaker,[1] and Michael B. Rothberg[1]

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OBJECTIVE

To assess trends in HbA_{1c} and appropriateness of diabetes medication use by patient health status.

RESEARCH DESIGN AND METHODS

We conducted cross-sectional analysis of 2001–2018 National Health and Nutrition Examination Survey (NHANES). We included older adults age ≥65 years who had ever been told they had diabetes, had HbA_{1c} >6.4%, or had fasting plasma glucose >125 mg/dL. Health status was categorized as good, intermediate, or poor. Being below goal was defined as taking medication despite having HbA_{1c} ≥1% below the glycemic goals of the American Diabetes Association (ADA), which varied by patient health status and time period. Drugs associated with hypoglycemia included sulfonylureas, insulin, and meglitinides.

RESULTS

We included 3,539 patients. Mean HbA_{1c} increased over time and did not differ by health status. Medication use increased from 59% to 74% with metformin being the most common drug in patients with good or intermediate health and sulfonylureas and insulin most often prescribed to patients with poor health. Among patients taking medications, prevalence of patients below goal increased while prevalence of those above goal decreased from 2001 to 2018. One-half of patients with poor health and taking medications had below-goal HbA_{1c}; two-thirds received drugs associated with hypoglycemia. Patients with poor health who were below goal had 4.9 (95% CI 2.3–10.4) times the adjusted odds of receiving drugs associated with hypoglycemia than healthy patients.

CONCLUSIONS

In accordance with ADA's newer *Standards of Medical Care in Diabetes*, HbA_{1c} goals were relaxed but did not differ by health status. Below-goal HbA_{1c} was common among patients with poor health; many were prescribed medications associated with a higher risk of hypoglycemia.

Diabetes affects more than one in four Americans aged ≥65 years (1). The management of diabetes is complex in older adults because they have a higher

[1]*Center for Value-Based Care Research, Cleveland Clinic, Cleveland, OH*
[2]*Department of Pharmacy and Center for Geriatric Medicine, Cleveland Clinic, Cleveland, OH*
[3]*Healthcare Delivery and Implementation Science Center, Cleveland Clinic, Cleveland, OH*
[4]*Division of General Medicine, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, MA*
[5]*University of Michigan School of Public Health, Ann Arbor, MI*
[6]*University of Michigan Medical School, Ann Arbor, MI*

Corresponding author: Phuc Le, lep@ccf.org

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prevalence of chronic comorbidities and functional limitations (2). They have shorter life expectancies and less time to experience the benefits of intensive glycemic control, which usually take years to accrue. Older patients may also suffer from geriatric conditions (e.g., dementia, depression, vision impairment, and arthritis) that make it difficult to manage diabetes medications and increase the risk for adverse drug effects (3), especially hypoglycemia (4,5). Consequently, various organizations, including the American Geriatric Society and the American College of Physicians, have recommended more lenient glycemic targets for older patients (6,7).

The American Diabetes Association (ADA)'s *Standards of Medical Care in Diabetes* have evolved to reflect this complexity. Until 2003, the guideline referred to a hemoglobin A_{1c} (HbA_{1c}) of $<$7% as the target for active older adults who could be expected to live 10–20 more years (8). Higher targets for those with advanced diabetes complications, life-limiting conditions, and cognitive or functional impairment were considered reasonable, but no specific glycemic target was given. In 2004, the ADA followed the American Geriatrics Society in recommending a target of $<$8% for frail older adults with life expectancies of $<$5 years and $<$7% for others (9,10). In 2013, the ADA offered a framework for determining health status and corresponding glycemic targets, acknowledging patient heterogeneity as an important determinant of treatment goals (3,11). Targets were $<$7.5% for healthy patients with good functional status; $<$8% for patients with advanced complications, life-limiting conditions, or cognitive impairment; and $<$8.5% for those with poor health and at the end of life. In 2021, the ADA removed HbA_{1c} targets for patients in poor health and instead recommended avoiding symptomatic hyperglycemia (12).

Little is known about response to these changes in clinical practice. During 2007–2010, more than one-half of patients with diabetes aged $\geq$65 years had HbA_{1c} levels $<$7% (13). Notably, the rate of tight glycemic control did not differ by health status during 2001–2010, and one-half of older patients were taking insulin or sulfonylureas—medications associated with a higher risk of hypoglycemia (14). Because these studies predate the newer recommendations, it is unclear whether patient health status is now accounted for in prescribing medications or determining HbA_{1c} goals. In this study, we assessed how well treatment of diabetes adhered to changes in ADA's glycemic goals among older adults. Specifically, we estimated HbA_{1c} levels from 2001 to 2018 and assessed whether treatment goals differed by health status. For patients in poor health, we also examined the use of medications associated with a higher risk of hypoglycemia. Understanding current practice can help to focus future efforts to personalize care to reduce harms from hypoglycemia.

RESEARCH DESIGN AND METHODS

Data Source and Study Population

We performed a retrospective analysis of 2001–2018 data from National Health and Nutrition Examination Survey (NHANES), which is a repeated cross-sectional survey with information about the health and nutritional status of community-dwelling U.S. population. NHANES is conducted by the National Center for Health Statistics (NCHS), which are released in 2-year cycles and representative of the noninstitutionalized civilian U.S. population living within the 50 states and the District of Columbia. Sample designs have changed over time with oversampling of certain subgroups being done in recent survey cycles to increase precision (15). As our study used data without personal identifiers, it was exempted by the Cleveland Clinic Internal Review Board. We included people aged $\geq$65 years who had ever been told they had diabetes, had HbA_{1c} $>$6.4%, or had fasting plasma glucose $>$125 mg/dL. Participants with missing data for both HbA_{1c} and fasting plasma glucose were excluded. To adjust for the change in diagnostic methods and equipment over the years, we calibrated fasting plasma glucose as recommended by NHANES (16–18). There were a change in laboratory instruments and locations for measuring HbA_{1c} during 2001–2010, but no adjustment for HbA_{1c} across survey cycles was recommended (19).

Ascertainment of Health Status

We characterized the health of the study population as good, intermediate, or poor based on the ADA's recommendation for identifying treatment goals in older adults (11,12) (Supplementary Table 1). Patients in poor health had chronic kidney disease requiring dialysis, stage 3–4 congestive heart failure (CHF), oxygen-dependent lung disease, impairments in two or more activities of daily living (ADL), or limited life expectancy based on the Schonberg Index (20). Because NHANES did not report the severity of CHF or chronic lung disease directly, we considered the patient's ability to walk between rooms, with "much difficulty" or "unable to do" as proxies for advanced disease in patients with those diagnoses. ADL impairment was defined as reporting "much difficulty" or "unable to do" regarding dressing; using fork, knife, cup; walking between rooms; and getting in and out of bed. Patients with $\geq$18 points on the Schonberg Index—equivalent to 69% 5-year mortality—were considered to have limited life expectancy. NHANES does not contain data on metastatic cancer.

Patients in intermediate health had three or more coexisting chronic illnesses, two or more instrumental ADL (iADL) impairments, or mild-to-moderate cognitive impairment. Chronic conditions included arthritis, cancer, CHF, lung disease (emphysema, chronic bronchitis, and chronic obstructive pulmonary disease), myocardial infarction, and stroke and were based on self-report. Incontinence was defined as answering yes to "at least a few times a week" for questions on "urinated before reaching the toilet" or "leak urine during nonphysical activities." Hypertension was defined as systolic blood pressure $\geq$140 mmHg, diastolic blood pressure $\geq$90 mmHg, or use of antihypertensive drugs. We calculated estimated glomerular filtration rate (eGFR) using the Chronic Kidney Disease Epidemiology Collaboration equation and defined chronic kidney disease as eGFR $<$60 mL/min/1.73 m^2 (21). We defined depression as Patient Health Questionnaire-9 (PHQ-9) score $\geq$10 but could not assess it prior to 2005–2006, when the PHQ-9 was first administered (22). We identified iADL impairments as patients report that they had "much difficulty" or were "unable to do" regarding managing money, doing house chores, preparing meals, and going out to movies/events. No information about falls or other iADLs was available. Mild-to-

moderate cognitive impairment was defined as answering yes to the question, "Are you limited in any way because of difficulty remembering or because you experience periods of confusion?" Because we had no information about severity of memory problems, we categorized cognitive impairment alone as intermediate health. Excessive alcohol use was defined as consuming more than one drink per day for women or more than two drinks per day for men. Participants not meeting criteria for poor or intermediate health were considered to have good health.

Outcome Measures

During the NHANES interview, participants were asked to show containers of prescription medications they had used within the past 30 days. For antihyperglycemic medications, we assessed the use of all available diabetes medications and reported in more detail the use of seven drug classes preferred by the ADA: metformin, sulfonylureas, thiazolidinediones, dipeptidyl peptidase 4 inhibitors, glucagon-like peptide 1 receptor agonists, sodium–glucose cotransporter 2 inhibitors, and insulin. Medications associated with a higher risk of hypoglycemia included sulfonylureas, meglitinides, and insulin.

We defined treatment as at goal if HbA_{1c} was between 0 and 1% below the ADA's specified treatment goals, below goal if HbA_{1c} was lower than the treatment goals by 1% or more, and above goal if HbA_{1c} was higher than the goal. We chose the 1% cutoff to define treatment being below goal because most noninsulin diabetes medications decrease HbA_{1c} by between 0.5% and 1.25%, so a patient with an HbA_{1c} of $>$1% below the target could presumably reach the target with at least one fewer medication (23). In addition, because the ADA's glycemic targets have changed over time, our definition was specific to each time period: for 2001–2004, an HbA_{1c} goal of $<$7% for all patients; for 2005–2012, $<$7% for patients with good or intermediate health and $<$8% for patients with poor health; and 2013–2018, $<$7.5% for good, $<$8% for intermediate, and $<$8.5% for poor health. In sensitivity analysis, we used two more stringent definitions of HbA_{1c} being below goal: *1*) being lower than ADA's treatment goals by $\geq$1% or more (as in main analysis) plus use of any medications associated with a higher risk of hypoglycemia and *2*) being $<$7% (regardless of time period) plus use of any medications associated with a higher risk of hypoglycemia.

Statistical Analysis

Descriptive statistics (survey-weighted ANOVA for continuous variables or Pearson χ^2 test for categorical variables) were used to compare the demographic and socioeconomic factors by health status (good, intermediate, and poor). Outcomes were examined for the whole study population, by health status, and by time period (2001–2004, 2005–2012, 2013–2018) corresponding to changes in the ADA's glycemic targets. We estimated the weighted proportion of patients who were at, below, and above goal by health status and study period. This analysis was limited to patients with available HbA_{1c} values who were taking diabetes medications or who reported a diagnosis of diabetes. In addition, we calculated the weighted proportion of patients using medication by drug class, health status, and time period and weighted proportion of patients who were below goal and taking medications associated with a higher risk of hypoglycemia. We also assessed the association between health status and receipt of medications associated with a higher risk of hypoglycemia among patients who were below goal, using multivariable logistic regression. We determined potential confounding factors based on clinical importance and review of the univariate analysis. Specifically, we retained factors with a *P* value $<$0.2 in univariate analysis for the final multivariable model. Potential risk factors examined included patient demographic and socioeconomic characteristics (age, sex, race/ethnicity, education, insurance status, and income) and other important clinical and behavioral risk factors (BMI, tobacco and alcohol use). Family income was divided by the poverty guidelines, specific to the survey year, family size, and geographic location, to obtain the ratio of family income to poverty. Because we included patients on monotherapy and combination therapy together, the prevalence by diabetes drug class could sum to $>$100%. Trends in HbA_{1c} and medication use were assessed using logistic or linear regression with the midpoint of each study period as a continuous independent variable. We used Stata 14.2 (College Station, TX) and accounted for the complex survey design of NHANES in all analyses including descriptive statistics. A two-sided *P* value of $<$0.05 was considered statistically significant and was not adjusted for multiple comparisons (24–27). We followed the NCHS's rules to determine the reliability of estimated means and proportions and suppressed estimates that did not meet the standards (15,28,29).

RESULTS

Patient Characteristics and Comorbidities

The final sample included 3,539 patients, 1,699 of whom participated in 2011–2018 NHANES. The weighted prevalence of diagnosed diabetes was 79% (95% CI 77–80). Among excluded patients, 1,133 were due to missing both HbA_{1c} and glucose values. Mean age was 73.2 years, 49% were male, and 71% were non-Hispanic White (Table 1). Most were either never or former smokers, and 10% drank alcohol excessively. On average, patients had three comorbidities; the most common were hypertension, arthritis, and kidney disease. Approximately 10% had one or more ADL impairments and 19% had one or more iADL impairments. Overall, 39%, 55%, and 6% of patients had good, intermediate, and poor health, respectively. People with poor health were older and more likely to be female and have higher BMI, lower education, and lower income (*P* value $<$0.001).

Trends in HbA_{1c} and Adherence to Treatment Goals

Among participants who had HbA_{1c} measured (97% of patients), weighted mean HbA_{1c} increased from 2001 to 2018 (Table 2). The increase was statistically significant among patients taking one or more antihyperglycemic drugs but not those receiving no medication. Weighted mean HbA_{1c} increased over time for each health status group, and by 2013–2018 it was not significantly different among the groups (*P* value $>$0.05). In patients with an HbA_{1c} below goal who received a medication associated with hypoglycemia, weighted mean HbA_{1c} also increased significantly over time.

Table 1—Patient characteristics and comorbidities by health status among U.S. older adults (age ≥65 years) with diabetes

Characteristic	Overall (N = 3,539)	Health status			P
		Healthy (n = 1,433)	Intermediate (n = 1,842)	Poor (n = 264)	
Age, mean	73.2 (73–73.5)	71.8 (71.5–72.1)	73.9 (73.5–74.3)	76.0 (75.2–76.9)	<0.001
Male, %	49 (47–51)	58 (54–62)	44 (41–47)	43 (36–51)	<0.001
BMI, mean	30.9 (30.7–31.2)	29.9 (29.5–30.3)	31.5 (31.1–31.9)	33.2 (31.5–34.9)	<0.001
Non-White, %	29 (27–32)	29.9 (29.5–30.3)	31.5 (31.1–31.9)	39 (31–47)	<0.001
High school or higher, %	67 (64–69)	33 (29–37)	26 (23–28)	51 (43–59)	0.001
Uninsured, %	2 (1–2)	2 (1–3)	2 (1–2)	NR	0.396
Income-to-poverty ratio, %					
<1	13 (12–15)	11 (10–13)	13 (11–15)	25 (19–33)	<0.001
1 to <2	32 (30–35)	28 (25–31)	35 (31–39)	33 (26–40)	
2 to <4	32 (30–34)	33 (30–37)	31 (28–35)	29 (23–37)	
≥4	23 (20–26)	28 (24–32)	21 (17–25)	13 (7–22)	
Smoking, %					
Never smokers	47 (45–49)	51 (47–54)	45 (41–48)	46 (38–55)	0.016
Former smokers	46 (43–48)	44 (41–47)	47 (43–50)	48 (40–57)	
Current smokers	7 (6–9)	6 (4–7)	9 (7–11)	NR	
Alcohol drinking, %					
Never users	67 (64–70)	60 (54–64)	72 (69–75)	76 (64–85)	<0.001
Some users	29 (27–32)	35 (31–40)	25 (22–29)	23 (14–36)	
Excessive users	3 (2–5)	5 (3–8)	2 (1–4)	1 (0–3)	
Comorbidity					
No. of comorbidities, mean	2.9 (2.8–3)	1.5 (1.5–1.6)	3.7 (3.6–3.7)	4.2 (3.8–4.6)	<0.001
Arthritis, %	57 (54–59)	31 (28–35)	73 (70–75)	72 (63–79)	<0.001
Cancer, %	20 (18–21)	8 (7–10)	27 (24–29)	27 (20–35)	<0.001
Heart failure, %	15 (13–16)	1 (1–2)	22 (19–24)	37 (30–45)	<0.001
Depression, %	9 (8–11)	1 (1–2)	14 (11–16)	26 (17–37)	<0.001
COPD, %	17 (15–19)	4 (3–5)	24 (21–28)	28 (20–37)	<0.001
Hypertension, %	91 (90–92)	85 (82–87)	95 (93–97)	95 (91–97)	<0.001
Incontinence, %	27 (25–30)	7 (5–9)	39 (35–42)	55 (45–64)	<0.001
Kidney, %*	37 (35–39)	15 (12–18)	50 (46–53)	59 (51–67)	<0.001
Heart attack, %	16 (14–17)	3 (2–4)	24 (21–26)	24 (17–33)	<0.001
Stroke, %	14 (12–15)	3 (2–4)	19 (17–22)	34 (27–41)	<0.001
Memory problem, %	17 (15–19)	NA	26 (29–26)	39 (31–46)	<0.001
Functional status, %					
One or more ADL impairments	9 (8–11)	1 (1–2)	7 (5–8)	88 (83–91)	<0.001
ADL impairments, mean	0.16 (0.14–0.19)	0.01 (0.01–0.02)	0.07 (0.06–0.08)	1.94 (1.75–2.12)	<0.001
One or more iADL impairments	19 (17–20)	4 (3–5)	23 (20–25)	75 (67–82)	<0.001
iADL impairments, mean	0.31 (0.28–0.35)	0.04 (0.03–0.05)	0.35 (0.31–0.39)	1.75 (1.5–2)	<0.001
Use of any diabetes medications, %	68 (66–70)	66 (63–70)	69 (65–72)	72 (64–78)	0.407

Data are mean or percentage (95% CI) as indicated. All patients with diagnosed and undiagnosed diabetes were included in this analysis. All estimates were calculated with the complex survey design accounted for. COPD, chronic obstructive pulmonary disease; NA, not applicable because patients with memory problem were categorized in either intermediate or poor health group; NR, not reported based on the National Center for Health Statistics Data Presentation Standards for Proportions (28). *Kidney disease was defined as having eGFR <60 mL/min/1.73 m^2.

Among participants with available HbA_{1c} values who received one or more medications, the weighted proportion of patients whose HbA_{1c} was at goal (between 0 and 1% below ADA's glycemic goals) decreased from 44% to 33% (P value <0.001). Weighted prevalence of patients with an HbA_{1c} above goal also decreased over time, but patients in good health were more likely to have an HbA_{1c} above goal than those in poor health (35% vs. 15%, respectively; P value = 0.004). During the same time, weighted prevalence of patients with an HbA_{1c} below goal increased from 16% to 43% (P value <0.001). Overall, patients with poor health were more likely to have an HbA_{1c} below goal than patients with good health (57% vs. 21%, respectively; P < 0.001). In sensitivity analysis, with a definition of an HbA_{1c} lower than ADA's treatment goals by ≥1% plus use of any medications associated with hypoglycemia, prevalence of patients whose HbA_{1c} was below goal increased from 12% to 18% (P = 0.031) (Supplementary Table 2). With a definition of an HbA_{1c} <7% plus use of medications associated with hypoglycemia, proportion

Table 2—HbA_{1c} levels and percentage of patients with HbA_{1c} above and below goal by era among U.S. older adults (age ≥65 years) with diabetes

	All survey cycles (2001–2018)	2001–2004	2005–2012	2013–2018	P_{trend}
HbA_{1c}, mean					
All patients (100%, *n* = 3,393)	6.9 (6.9–7.0)	6.8 (6.7–6.9)	6.9 (6.8–6.9)	7.0 (6.9–7.1)	0.004
Patients not on diabetes medications (32%, *n* = 1,108)	6.6 (6.5–6.6)	6.6 (6.4–6.8)	6.6 (6.5–6.7)	6.5 (6.3–6.6)	0.211
Patients on diabetes medications (68%, *n* = 2,285)					
All (100%, *n* = 2,285)	7.1 (7–7.1)	6.9 (6.8–7.1)	7.0 (6.9–7.1)	7.2 (7.1–7.3)	0.001
By health status					
Good health (38%, *n* = 878)	7.1 (7–7.2)	6.9 (6.7–7.1)	7.0 (6.9–7.2)	7.3 (7.1–7.5)	0.016
Intermediate health (56%, *n* = 1,236)	7.1 (7–7.1)	7.0 (6.8–7.2)	7.0 (6.8–7.1)	7.1 (7–7.3)	0.153
Poor health (6%, *n* = 171)	7.1 (6.9–7.3)	6.2 (5.7–6.8)	7.0 (6.7–7.3)	7.3 (7–7.6)	0.002
Patients who reported a diagnosis of diabetes (78%, *n* = 2,611)					
All (100%, *n* = 2,611)	7 (6.9–7.1)	6.8 (6.7–7)	6.9 (6.9–7)	7.1 (7–7.2)	<0.001
Patients on diabetes medication (83%, *n* = 2,174)	7.1 (7–7.2)	6.9 (6.8–7)	7 (6.9–7.1)	7.2 (7.1–7.3)	<0.001
Patients not on diabetes medication (17%, *n* = 437)	6.5 (6.4–6.7)	6.7 (6.3–7)	6.6 (6.4–6.9)	6.4 (6.2–6.6)	0.133
By health status					
Good health (36%, *n* = 974)	7 (6.9–7.2)	6.7 (6.5–6.9)	7 (6.8–7.1)	7.2 (7–7.4)	0.001
Intermediate health (57%, *n* = 1,430)	7 (6.9–7.1)	6.9 (6.7–7.1)	6.9 (6.8–7)	7 (6.9–7.2)	0.469
Poor health (7%, *n* = 207)	7 (6.8–7.2)	6.6 (6–7.3)	7 (6.6–7.4)	7.1 (6.8–7.4)	0.159
Patients who had HbA_{1c} below goal yet received a medication associated with hypoglycemia (10%, *n* = 324)§	6.1 (6–6.2)	5.6 (5.4–5.7)	5.8 (5.7–5.9)	6.4 (6.3–6.4)	<0.001
Treatment status among patients taking medications, %					
At goal*					
All (100%, *n* = 843)	38 (35–42)	44 (37–51)	42 (38–47)	33 (28–38)	<0.001
By health status					
Good health (43%, *n* = 358)	44 (39–49)	41 (30–54)	46 (39–53)	43 (35–51)	0.947
Intermediate health (53%, *n* = 441)	36 (32–40)	46 (37–56)	42 (36–48)	26 (20–34)	0.001
Poor health (4%, *n* = 44)	28 (20–39)	NR	27 (15–42)	NR	NA
Below goal†					
All (100%, *n* = 609)	29 (26–32)	16 (12–22)	18 (15–21)	43 (39–48)	<0.001
By health status					
Good health (27%, *n* = 167)	21 (17–25)	NR	14 (10–19)	27 (22–34)	0.024
Intermediate health (61%, *n* = 345)	32 (27–36)	14 (9–20)	16 (12–21)	53 (45–61)	<0.001
Poor health (12%, *n* = 97)	57 (46–67)	NR	NR	NR	NA
Above goal‡					
All (100%, *n* = 833)	32 (30–35)	40 (34–46)	40 (36–45)	24 (20–28)	<0.001
By health status					
Good health (41%, *n* = 353)	35 (30–41)	43 (33–53)	40 (33–48)	30 (22–39)	0.044
Intermediate health (56%, *n* = 450)	32 (29–36)	40 (32–49)	42 (36–49)	21 (16–26)	<0.001
Poor health (3%, *n* = 30)	15 (10–22)	NR	19 (11–32)	NR	NA
Treatment status among patients who reported a diagnosis of diabetes, %					
At goal*					
All (100%, *n* = 926)	37 (34–40)	41 (36–47)	42 (38–46)	30 (26–35)	0.001
By health status					
Good health (43%, *n* = 388)	43 (39–48)	43 (33–54)	45 (38–52)	42 (35–50)	0.801
Intermediate health (53%, *n* = 491)	34 (30–38)	41 (33–48)	43 (37–49)	23 (18–30)	<0.001
Poor health (4%, *n* = 47)	24 (17–34)	NR	22 (13–34)	NR	NA
Below goal†					
All (100%, *n* = 801)	33 (30–36)	22 (17–28)	20 (17–24)	48 (44–52)	<0.001
By health status					
Good health (25%, *n* = 219)	23 (20–27)	22 (14–35)	16 (11–22)	29 (24–35)	0.132
Intermediate health (63%, *n* = 458)	36 (32–40)	21 (15–28)	18 (14–22)	58 (52–65)	<0.001
Poor health (12%, *n* = 124)	59 (49–68)	NR	59 (45–72)	NR	NA
Above goal‡					
All (100%, *n* = 884)	30 (28–33)	36 (32–41)	38 (33–43)	22 (18–26)	<0.001
By health status					
Good health (40%, *n* = 367)	34 (29–39)	34 (26–44)	39 (32–47)	29 (21–37)	0.231
Intermediate health (57%, *n* = 481)	30 (27–33)	39 (32–45)	39 (33–45)	19 (15–23)	<0.001
Poor health (3%, *n* = 36)	17 (11–25)	NR	NR	NR	NA

Data are mean or percentage (95% CI) as indicated. Analyses were limited to patients with available HbA_{1c} values. All estimates were calculated with the complex survey design accounted for. NA, not applicable; NR, not reported based on the National Center for Health Statistics Data Presentation Standards for Proportions (28). §HbA_{1c} ≥1% below target and use of either sulfonylurea, insulin, or meglitinides; *HbA_{1c} between 0 and 1% below target; †HbA_{1c} ≥1% below target; ‡HbA_{1c} higher than target. The ADA's glycemic targets were specific for patient health status and time period (3,8–11).

of patients who were below goal decreased from 47% to 20% ($P < 0.001$). Regardless of the definition used, patients in poor health were more likely than those in good health to be below goal. Results were the same for patients who reported a diagnosis of diabetes (Table 2 and Supplementary Table 3).

Use of Antihyperglycemic Medications

Overall, pharmacological treatment for diabetes increased significantly from 2001 to 2018 (Supplementary Fig. 1). More patients initiated medications and more patients received three or more drugs over time. The weighted prevalence of patients using diabetes medication did not differ by health status (Supplementary Table 4).

Among patients taking medication, the weighted proportion of those using metformin increased from 44% to 70% and that of insulin increased from 20% to 30% (Fig. 1). Proportion of patients using dipeptidyl peptidase 4 inhibitors also increased, while use of sulfonylureas and thiazolidinediones decreased substantially. During 2001–2018, three-fourths of patients in good health received metformin, and one in five was prescribed insulin. In contrast, insulin and sulfonylureas were the two most common drugs among patients with poor health; 43% of patients received either of them (Supplementary Table 5). When we limited the analysis to patients with poor health and eGFR >45 mL/min/1.73 m^2, 52%, 44%, and 43% of them received metformin, insulin, and sulfonylurea, respectively.

Among patients taking medications whose HbA_{1c} was below goal, 50% (95% CI 45–56) received a medication associated with a higher risk of hypoglycemia. The weighted prevalence of patients using these drugs (sulfonylureas in particular) decreased significantly, from 74% to 41%. Across health status, the weighted prevalence among patients with poor health whose HbA_{1c} was below goal was double that among those with good health, 70% vs. 32%, respectively (P value <0.05) (Fig. 2). In multivariable analysis, patients with poor health and taking medications whose HbA_{1c} was below goal had 4.9 times the adjusted odds (95% CI 2.3–10.4) of receiving a drug associated with a higher risk of hypoglycemia compared with patients with good health (Supplementary Table 6). Our findings were similar among patients who reported a diagnosis of diabetes (Supplementary Figs. 2 and 3 and Supplementary Tables 5 and 7).

CONCLUSIONS

Using a representative sample of the noninstitutionalized U.S. population, we assessed changes in diabetes treatment among older U.S. adults from 2001 to 2018, during which time the ADA's recommendations for glycemic control in older patients evolved. We found that weighted mean HbA_{1c} increased slightly, from 6.8% to 7.0%, and that the increase was limited to patients who received pharmacologic treatment and was independent of health status. Proportion of patients with an HbA_{1c} at goal (between 0 and 1% below ADA's glycemic goals) or above goal decreased over time and was highest among patients in good health. Meanwhile, the prevalence of patients having an HbA_{1c} below goal increased from 2001–2004 to 2013–2018. In addition, patients with poor health were the most likely to have an HbA_{1c} below goal; overall, more than one-half of those who took any medications had an HbA_{1c} >1% below goal. Taken together, these findings suggest that in accordance with the ADA's recommendation, glycemic targets for older patients have been relaxed. In addition, the increase in HbA_{1c} did not differ between patients in good health, who may benefit from tighter control, and those with limited life expectancy who may experience net harm from such an approach. We found that patients with poor and intermediate health frequently had an HbA_{1c} below goal, while ~35% of patients in good health were above their glycemic goal.

Another concerning finding involves the choice of diabetes medications. In our study, U.S. older adults with diabetes had a significant burden of comorbidities—three additional chronic conditions on average—and 6% were in poor health with limited life expectancy. Although the number of diabetes medications prescribed did not differ by health status, the specific classes of drugs did. During 2001–2018, healthy patients were more than twice as likely to receive metformin as patients in poor health, even after we accounted for chronic renal disease. Conversely, patients in poor health were most likely to receive sulfonylureas and insulin, putting them at risk for hypoglycemia. This stands in direct contradiction to the ADA's Standards of Care (12). There are several possible explanations for our findings. On one hand, physicians may not be aware of the recommendation to de-escalate care for patients in poor health or they may be unable to convince such patients that a higher HbA_{1c} is actually in their best interest. In a vignette

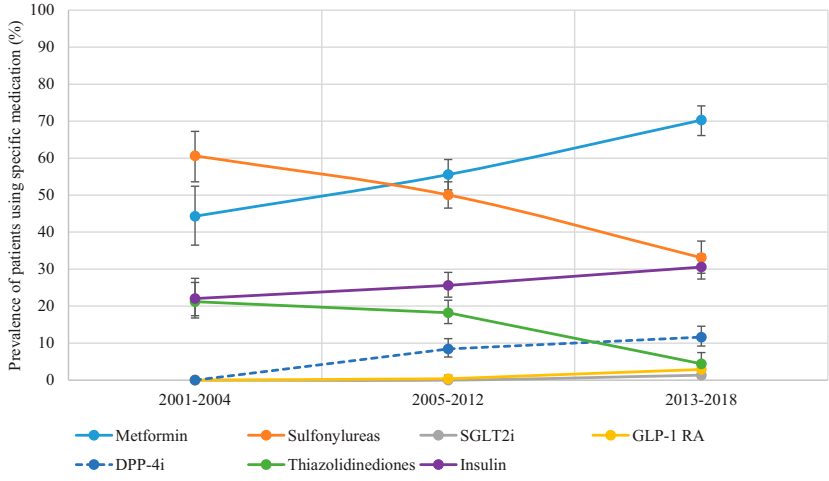

Figure 1—Prevalence (%) of patients using diabetes medications by drug class among U.S. older adults (age ≥65 years) with diabetes, 2001–2018. The analysis was limited to patients who received at least one diabetes medication. All estimates were calculated with the complex survey design accounted for. The vertical bars represent 95% CIs. DPP-4i, dipeptidyl peptidase 4 inhibitors; GLP-1 RA, glucagon-like peptide 1 receptor agonists; SGLT2i, sodium–glucose cotransporter 2 inhibitors.

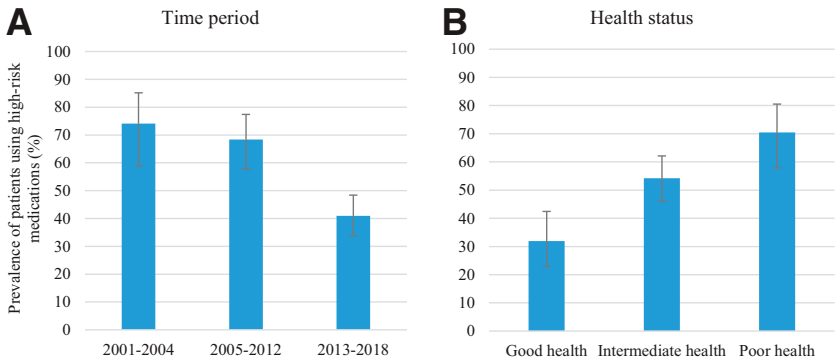

Figure 2—Prevalence (%) of patients using any diabetes medication associated with a higher risk of hypoglycemia among those who were pharmacologically treated to an HbA_{1c} below goal by time period (*A*) and health status (*B*) in U.S. older adults (age ≥65 years) with diabetes. Being below goal was defined as having an HbA_{1c} lower than the ADA's glycemic targets by ≥1%. The American Diabetes Association's glycemic targets were specific for patient health status and time period (3,8–11). Medications associated with a higher risk of hypoglycemia included sulfonylureas, meglitinides, and insulin. The analysis was limited to patients who had available HbA_{1c} values, received at least one diabetes medication, and had an HbA_{1c} below goal. All estimates were calculated with the complex survey design accounted for. The vertical bars represent 95% CIs. Both the *P* value for trends over time and *P* value for comparison across health status were <0.05.

study of primary care physicians in 2017 investigators found that 75% would intensify therapy for an 80-year-old woman with long-standing heart disease, cognitive impairment, impaired iADLs, and HbA_{1c} of 8.5%, while 35% would intensify therapy for the same patient at HbA_{1c} 7.5% (30). On the other hand, patients may have contraindications to other medication classes or not be able to afford them. In our study, patients in poor health had lower income than healthier counterparts. This complex problem is beyond the scope of the current study and requires further investigation, but our findings are concerning given the high rate of use for medications that can cause hypoglycemia.

In previous studies of diabetes in older patients, investigators found that potential overtreatment was common, occurring in 50–62% of patients age >65 years, and that one-half of patients received drugs associated with a higher risk of hypoglycemia (14,31,32). They also found that rates of overtreatment did not change over a 10-year period. Most of these studies were conducted with data prior to 2011 and included a definition of HbA_{1c} <7% for identification of tight glycemic control (14,32). As a measure of potential overtreatment, this definition is problematic because this cutoff assumes that tight control is inappropriate for all patients, even those who are otherwise in good health and treated with medications like metformin, which are unlikely to cause hypoglycemia. In addition, in these studies investigators did not stratify glycemic goals by health status and, hence, could not assess the impact of changes in newer ADA guidelines. Our study builds on these previous findings by including a period during which the ADA clearly recommended more lenient targets for older patients. In addition, we avoid using the term "overtreatment" to refer to HbA_{1c} measures below goal, using instead a more objective and nonjudgmental definition of treatment goal that incorporates health status. By comparing current treatment with guideline recommendations, our study highlights contemporary issues of treatment goals and use of drugs associated with a higher risk of hypoglycemia, especially among patients with poor health. Of note, with a constant HbA_{1c} goal of <7% and medications associated with hypoglycemia, prevalence of patients with HbA_{1c} below goal decreased from 47% to 20%. This finding is consistent with the observed increase in mean HbA_{1c} but contrasts with the findings of our main analysis with use of time-variant goals. It suggests that clinical practice was largely consistent over time and unresponsive to changes in the ADA's guidelines. However, regardless of definition used, patient health status was not accounted for in clinical practice, demonstrating that there is still much work to be done.

The ADA guidelines do not differentiate goals based on medication class. However, for medications that do not cause hypoglycemia, benefits and harms of tight control are less clear. While in the Action to Control Cardiovascular Risk in Diabetes (ACCORD) study (33) patients randomized to a glycemic goal of <6.0% had higher overall mortality, neither the Action in Diabetes and Vascular Disease: Preterax and Diamicron MR Controlled Evaluation (ADVANCE) study (34) (glycemic target <6.5%) nor the Veterans Affairs Diabetes Trial (35) (absolute reduction of 1.5%) found harm. It is unclear to what extent the specific medications used in ACCORD may have contributed to the excess mortality. On the other hand, benefits of tight control in reducing diabetes complications may take years to accrue (33,36,37). Therefore, decisions regarding glycemic goals in older patients must balance these uncertain benefits against medication side effects, inconvenience, and cost.

It is also important to clarify that the ADA glycemic goals are meant to guide clinical decision-making more broadly, and the categorization should not be applied blindly. Specific individuals with well-controlled conditions (e.g., hypertension) or non–life-threatening conditions (e.g., incontinence a few times a week) may certainly benefit from lower HbA_{1c} values, especially if not exposed to medications that can cause hypoglycemia. Our health status definition operationalized from the ADA's guideline was intended to describe population-based trends—not specific decisions. Although some patients might have been misclassified in either direction, NHANES data did not allow further discrimination among these patients. In clinical care, physicians should use clinical judgment to assess patients' health status before determining treatment goals. Lastly, some of the newer diabetes medications, such as sodium–glucose cotransporter 2 inhibitors and glucagon-like peptide 1 agonists, have benefits beyond lowering HbA_{1c} and may be appropriate regardless of patients' current glycemic control (38–40).

Our study has several additional limitations. First, although NHANES is a population-based survey and representative of noninstitutionalized U.S. adults, residents of nursing homes or other long-term care facilities are not included. Patients with

dementia were also less likely to be able to attend the intensive interview and exam process of NHANES. Therefore, our findings cannot be generalizable to this sickest population, who might have a different rate of being treated below goal or patterns of diabetes drug use. Second, we categorized patients' health status based on the ADA and the American Geriatric Society's framework, but the data were incomplete. NHANES does not include all questions for ADLs, iADLs, the severity of cognitive impairment, and some end-stage chronic diseases, leading to potential misclassification of some patients. For example, we used "difficulty walking between rooms" to identify late-stage CHF or oxygen-dependent lung disease but did not know for sure whether the difficulty arose from the condition or other causes. We also conservatively used the response of "much difficulty" to identify limited ADLs. Third, we applied only one HbA_{1c} target to identify patients who were below goal regardless of health status in the period of 2001–2004 because earlier ADA guidelines did not specify a value. Fourth, because NHANES is cross-sectional, we could not capture whether physicians had recently changed medication to prevent hypoglycemia for patients with low HbA_{1c}. Fifth, because of lack of data in NHANES we could not exclude all patients with type 1 diabetes who have absolute insulin requirement and different treatment targets. Sixth, patients with missing HbA_{1c} (3% of the sample) were excluded, and they may have different treatment patterns. Finally, because our data analysis ended with the 2017–2018 survey cycle, we could not assess the implication of the removal of HbA_{1c} target for patients with the poorest health status or current use of newer medications recommended in the ADA's 2021 guideline.

In conclusion, we found that in a nationally representative sample of U.S. older adults with diabetes, mean HbA_{1c} increased from 2001 to 2018 in all health status groups. Although patients aged ≥65 years are most vulnerable to adverse health outcomes, treatment to an HbA_{1c} to ≥1% below goal was common, particularly among patients in poor health. At the same time, having an HbA_{1c} above goal was most prevalent in patients with good health. Following publication of more lenient ADA recommendations, HbA_{1c} targets appear to have been relaxed but we found no evidence of differentiation by patient health status. Of particular concern, more than two-thirds of patients with poor health who had an HbA_{1c} below goal used a medication associated with a higher risk of hypoglycemia. Future efforts to improve quality of care for diabetes among older patients should focus on identifying patients' health status and tailoring therapeutic goals to match expected benefit of treatment.

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