Changes in Screening Practices for Prediabetes and Diabetes Since the Recommendation for Hemoglobin A_{1c} Testing

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OBJECTIVE

Screening involves the presumptive identification of asymptomatic individuals at increased risk for unrecognized disease. We examined changes in screening practices for prediabetes and diabetes since January 2010, when HbA_{1c} was first recommended as an option for screening and diagnosis.

RESEARCH DESIGN AND METHODS

We studied members without diabetes of an HMO ≥45 years of age continuously enrolled for ≥3 years and assigned to primary care clinicians affiliated with a large academic health system. We defined screening as the first oral glucose tolerance test, HbA_{1c}, or glucose test performed between 2010 and 2014.

RESULTS

Of 12,772 eligible patients, 9,941 (78%) were screened at least once over 3 years. HbA_{1c} was the initial screening test 14% of the time and glucose 86% of the time. Of those screened with HbA_{1c}, 63% had abnormal results defined as HbA_{1c} ≥5.7% (≥39 mmol/mol). Of those tested with glucose, 30% had abnormal results defined as glucose ≥100 mg/dL, and 5% had abnormal results defined as glucose ≥126 mg/dL. Patients with abnormal HbA_{1c} levels and those with glucose levels ≥126 mg/dL were equally likely to be scheduled for follow-up appointments (41% vs. 39%), but those with abnormal HbA_{1c} levels were more likely to be diagnosed with prediabetes or diabetes (36% vs. 26%).

CONCLUSIONS

As we observed in 2004, rates of screening are high. HbA_{1c} is still used less frequently than glucose for screening but is more likely to result in a clinical diagnosis. Evidence to support guidelines to define the role of random glucose screening, including definition of appropriate cut points and follow-up, is needed.

Diabetes is estimated to affect 30.3 million people in the U.S. (1). Of those, ~7.2 million (23.8%) remain undiagnosed (1). In addition, 84.1 million Americans are estimated to have prediabetes, and only 11.6% of them report being diagnosed (1). Starting in January 2010, following a report from an International Expert Committee in 2009 (2), the American Diabetes Association (ADA) recommended that all individuals without diabetes ≥45 years of age be screened for diabetes at 3-year intervals using HbA_{1c}, fasting glucose, or 2-h oral glucose tolerance tests (OGTTs) (3). In addition, the ADA recommended the use of these tests to identify a subgroup of people at increased

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risk for type 2 diabetes (3). In 2000, we studied screening practices for type 2 diabetes through the University of Michigan Health System (UMHS) and found that random glucose tests were frequently performed, but fasting glucose tests were infrequently performed and that follow-up of abnormal random glucose test results and the overall yield of screening were very low (4). Little is known about changes in diabetes screening practices since the ADA recommended HbA_{1c} as an option for screening and screening recommendations were expanded to include screening for prediabetes. We therefore performed a follow-up study of screening practices within the UMHS over a 3-year interval following the updated 2010 recommendations.

RESEARCH DESIGN AND METHODS

We performed analyses for people enrolled in Blue Care Network of Michigan (BCN) who were assigned to UMHS clinicians for primary care. BCN is an HMO with ~830,000 members. Members eligible for the study were ≥45 years of age, did not have a diagnosis of diabetes or take antidiabetic medications, were continuously enrolled in BCN for at least 3 years any time in the 4-year period between 1 January 2010 and 31 December 2013, and had valid UMHS medical record numbers (N = 12,772). Prior diagnoses of diabetes were determined by inclusion in the BCN diabetes registry that uses diagnosis codes and pharmacy data to determine diabetes status as recommended by the Centers for Medicare and Medicaid Services (5).

BCN laboratory claims data were searched for the first outpatient or inpatient diabetes screening test performed in the 3-year study period. A diabetes screening test was defined as a claim for an OGTT, a laboratory or point-of-care (POC) HbA_{1c}, a laboratory glucose test performed either as an individual test or as part of a panel, or a POC glucose test. BCN laboratory claims and the UMHS Clinical Laboratory do not systematically distinguish between fasting and random glucose levels so we were unable to always differentiate between those tests. In order to better describe the types of glucose tests performed, we randomly sampled 100 tests and performed medical record reviews to determine whether they were obtained as panels or individual tests, when they were drawn, and whether free text comments indicated that they were fasting samples.

The date of the first screening test was defined as the index date. If a patient had claims for more than one test on the index date, we used a hierarchical classification system to define the first diabetes screening test. The order was: OGTT, HbA_{1c}, laboratory glucose, and POC glucose. An abnormal result was defined as a 2-h OGTT glucose ≥140 mg/dL, HbA_{1c} ≥5.7% (≥39 mmol/mol), or a glucose ≥100 mg/dL or alternatively ≥126 mg/dL. Screened subjects were stratified into groups based on age and whether the screening result was normal or abnormal. For subjects who were not screened, the index date was selected as the date of the office visit within the 3-year screening period that was closest to the midpoint. Subjects were stratified into groups based on age (Fig. 1).

BCN claims data were used to calculate the prevalence of screening and the screening methods used for the total population and by age and sex group (Fig. 1, nonshaded boxes). Basic demographic and clinical characteristics for the total population were described using number and percent, and differences between those screened and not screened and those screened with an HbA_{1c} test versus another test were assessed using χ^2 tests. To assess factors independently associated with screening and screening with HbA_{1c}, we constructed multivariate logistic regression models with the outcome defined as any screening test versus no screening test and an HbA_{1c} screening test versus any other screening test. The predictors were defined as age, sex, race, one or more claims for overweight/obesity, hypertension, or dyslipidemia, and at least one primary care physician (PCP) visit in the 3-year time interval.

For samples of patients, we also reviewed the electronic medical records for the 6-month period after the index date to determine if the notes or problem summary list included a comment from the clinician interpreting the screening test result as abnormal, if a follow-up appointment was scheduled and/or attended, what diagnosis (if any) was made, and what treatment (if any) was prescribed (Fig. 1, shaded boxes). Nutrition and physical activity counseling were defined as recommendations documented as free text in the electronic medical record that the patient reduce calories, avoid snacks, increase physical activity, or begin walking. Nutrition and physical activity referrals were defined as documentation of recommendations to enroll in a formal nutrition or physical activity program (e.g., Weight Watchers or the YMCA) or referrals to a dietitian or diabetes educator.

To sample patients for medical record reviews, we stratified them according to the type of screening test performed: OGTT with or without HbA_{1c} test, HbA_{1c} test only, HbA_{1c} and laboratory glucose test, laboratory glucose test only, and POC glucose test only. We then stratified those groups into subgroups with progressively higher levels of screening hyperglycemia (glucose <100 mg/dL or HbA_{1c} <5.7% [<39 mmol/mol], glucose 100–125 mg/dL or HbA_{1c} 5.7–6.4% [39–46 mmol/mol], and glucose ≥126 mg/dL or ≥HbA_{1c} 6.5% [≥47 mmol/mol]). We randomly sampled 100 people from each subgroup for chart review. If there were <100 people in a group, we performed chart reviews for all of them. We then combined the laboratory and POC glucose testing groups as well as the HbA_{1c} only and HbA_{1c} plus laboratory glucose testing groups for analysis. The results were weighted to the total population using sampling weights based upon the inverse probability of selection. Results are presented as the weighted number and percent.

Data from chart reviews were used for descriptive analyses to determine the percentage of screened subjects who had abnormal results possibly indicative of prediabetes or diabetes, the percentage of people who, within 6 months of the abnormal screening test, had a note from a clinician interpreting the test results as abnormal, had a follow-up appointment scheduled, attended a follow-up appointment, and were subsequently diagnosed with diabetes or prediabetes. We also conducted sensitivity analyses stratified according to the initial screening test (HbA_{1c} or other) and according to the initial glucose level (≥100 mg/dL or ≥126 mg/dL) to assess follow-up. Finally, we assessed the frequency of treatment for clinician-diagnosed prediabetes and diabetes within 6 months of screening and

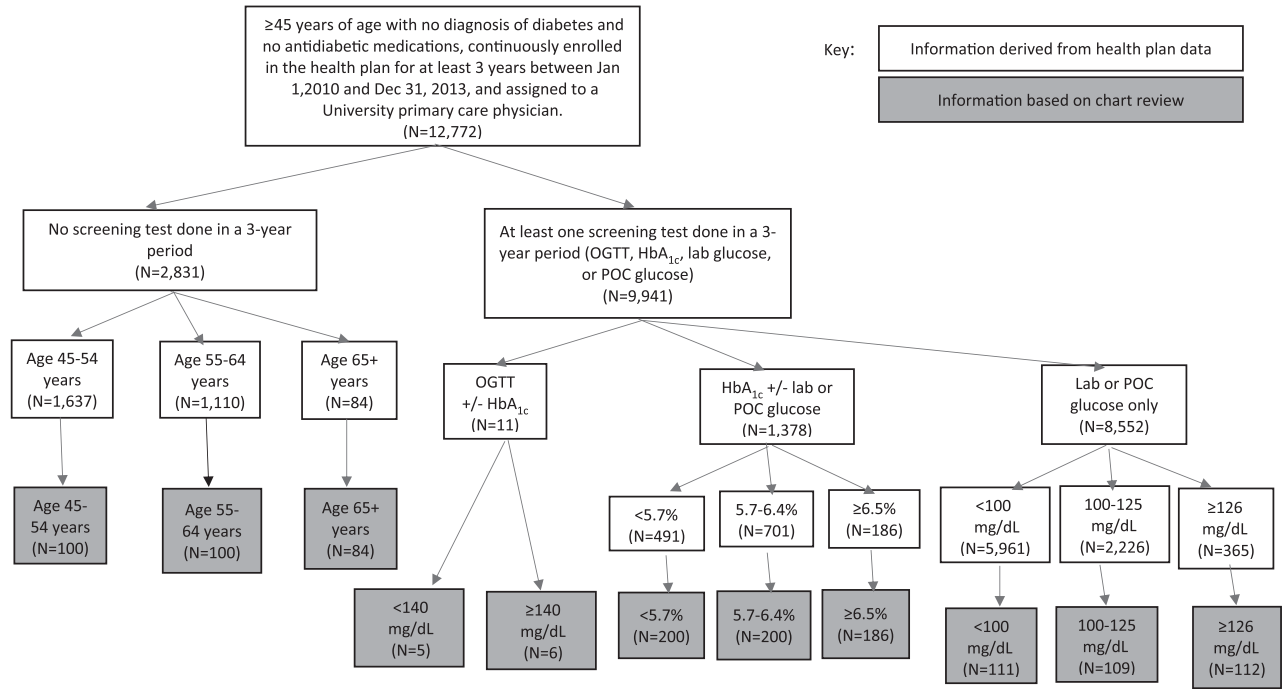

Figure 1—Study population.

again conducted sensitivity analyses to assess rates of diagnosis according to the initial glucose level.

The study was reviewed and approved by the University of Michigan Institutional Review Board. All analyses were performed using SAS 9.3 (SAS Institute, Cary, NC).

RESULTS

Using health plan claims data, we identified 12,772 patients without diabetes ≥45 years of age who met eligibility criteria. The mean age was 55 ± 6 years, and 56% were women. The majority of patients were white (83%). Five percent were Asian, 3% African American, and 8% of unknown race. Within a 3-year time frame, 9,941 (78%) of patients were screened at least once for prediabetes or diabetes with a glucose test (*N* = 8,552, 86%) or HbA_{1c} (*N* = 1,378, 14%) or OGTT (*N* = 11, 0%) as the initial screening test (Table 1). Within a 3-year time frame, 2,322 patients (18%) had at least one HbA_{1c} test performed.

Reviews of electronic medical records were performed for samples of 284 subjects who were not screened and 929 subjects who were screened (Fig. 1). The results from the sampled patients were then weighted to the total population. Based upon the random sample of medical record reviews performed for patients with laboratory glucose testing, we determined that 82% of glucose tests were performed as parts of panels: 55% as comprehensive metabolic panels, 41% as basic metabolic panels, and 4% as renal panels. Eighteen percent of glucose tests were performed as individual tests. Only one-third of glucose tests obtained as a part of panels were drawn before 9 A.M., whereas 50% of glucose tests ordered as individual tests were drawn before 9 A.M. Only 8% of glucose tests ordered as panels were noted to be fasting as opposed to 44% of glucose tests ordered as individual tests. Fasting glucose tests were drawn at 8:38 A.M. (7:41–9:14 A.M.), and glucose tests not specified as fasting were drawn at 10:00 A.M. (8:34 A.M.–12:35 P.M.) [median (interquartile range)].

Of the 8,552 patients initially screened with glucose tests, 924 (11%) had follow-up HbA_{1c} tests performed. Patients with higher glucose levels were more likely to have follow-up HbA_{1c} tests performed (43% if glucose ≥126 mg/dL, 16% if glucose 100–125 mg/dL, and 7% if glucose <100 mg/dL). The time interval between the initial glucose test and the follow-up HbA_{1c} test was shorter for patients with higher glucose levels (53% within 6 months if glucose ≥126 mg/dL, 27% within 6 months if glucose 100–125 mg/dL, and 19% within 6 months if glucose <100 mg/dL).

Although initial screening rates were not different for men and women, the percentage of patients screened increased significantly with age (75% for those 45–54 years of age, 80% for those 55–64 years of age, and 86% for those ≥65 years of age) (Table 2). Nonwhite patients, people who had claims diagnoses of overweight or obesity, hypertension, or dyslipidemia, and those who made at least one PCP visit were more likely to be screened and more likely to be initially screened with HbA_{1c} than with other tests (Table 2). When we included the risk factors for screening that were statistically significant in univariate analyses in Table 2 into a multivariate model, age was no longer a significant predictor (Supplementary Table 1). The significant independent predictors of screening versus no screening included female sex (odds ratio [OR] 1.3 [95% CI 1.2–1.4]), nonwhite race (OR 1.3 [95% CI 1.1–1.6]), overweight or obesity (OR 1.9 [95% CI 1.5–2.5]), hypertension (OR 2.3 [95% CI 2.0–2.8]), dyslipidemia (OR 1.8 [95% CI 1.5–2.1]), and at least one PCP visit (OR 2.4 [95% CI 2.0–2.9]) (Supplementary Table 1). The significant independent predictors of screening with HbA_{1c} versus with another test included nonwhite race (OR

Table 1—Prevalence of screening and screening methods by age and sex

	Members without diabetes	Screened	Screening method [*n* (% of screened)]			
			OGTT	HbA_{1c} (± laboratory or POC glucose)	Laboratory glucose	POC glucose
Women and men						
Age 45–54 years	6,564	4,927 (75)	8 (0)	675 (14)	4,225 (86)	19 (0)
Age 55–64 years	5,605	4,495 (80)	3 (0)	629 (14)	3,850 (86)	13 (0)
Age ≥65 years	603	519 (86)	0 (0)	74 (14)	445 (86)	0 (0)
Total	12,772	9,941 (78)	11 (0)	1,378 (14)	8,520 (86)	32 (0)
Women						
Age 45–54 years	3,776	2,877 (76)	6 (0)	402 (14)	2,453 (85)	16 (1)
Age 55–64 years	3,151	2,525 (80)	1 (0)	330 (13)	2,188 (87)	6 (0)
Age ≥65 years	266	224 (84)	0 (0)	34 (15)	190 (85)	0 (0)
Total	7,193	5,626 (78)	7 (0)	766 (14)	4,831 (86)	22 (0)
Men						
Age 45–54 years	2,788	2,050 (74)	2 (0)	273 (13)	1,772 (86)	3 (0)
Age 55–64 years	2,454	1,970 (80)	2 (0)	299 (15)	1,662 (84)	7 (0)
Age ≥65 years	337	295 (88)	0 (0)	40 (14)	255 (86)	0 (0)
Total	5,579	4,315 (77)	4 (0)	612 (14)	3,689 (85)	10 (0)

Data are *n* (%) unless otherwise indicated. The date of the first screening test was defined as the index date. If a patient had claims for more than one test on the index date, we used a hierarchical classification system to define the first diabetes screening test. The order was: OGTT, HbA_{1c}, laboratory glucose, and POC glucose.

1.4, 95% CI 1.1–1.6), overweight or obesity (OR 2.0 [95% CI 1.8–2.4]), hypertension (OR 1.3 [95% CI 1.2–1.5]), dyslipidemia (OR 1.3 [95% CI 1.1–1.5]), and at least one PCP visit (OR 1.5 [95% CI 1.2–1.8]) (Supplementary Table 1).

Based upon weighted estimates informed by medical record reviews, we found that 30% of patients having a glucose test had abnormal results defined as ≥100 mg/dL, and 5% had abnormal results defined as ≥126 mg/dL (Table 3). Sixty-three percent of those initially screened with HbA_{1c} had abnormal results defined as ≥5.7% (≥39 mmol/mol). Because 37% of clinicians interpreted glucose ≥126 mg/dL as abnormal, and 33% interpreted HbA_{1c} ≥5.7% (≥39 mmol/mol) as abnormal, we combined those two groups and found that 12% of screened subjects had abnormal results as defined by these tests and cut points (Table 3).

Within 6 months of having an abnormal result defined as glucose ≥100 mg/dL, only 15% had a note from a clinician interpreting the test result as abnormal. Twenty-six percent of those with abnormal results had a follow-up appointment scheduled, and 11% of those with abnormal results were subsequently diagnosed with dysglycemia defined as impaired fasting glucose, impaired glucose tolerance, prediabetes, or diabetes (Table 3). Patients who had initial glucose test results ≥126 mg/dL were more likely to have the results documented as being abnormal (37%), to have follow-up visits scheduled (39%), and to be diagnosed with dysglycemia (26%) (Table 3). Patients who had abnormal initial HbA_{1c} test results (HbA_{1c} ≥5.7% or ≥39 mmol/mol) were as likely as patients who had initial glucose test results ≥126 mg/dL to have the results documented as being abnormal (33%), to have a follow-up visit scheduled (41%), and more likely to be diagnosed with dysglycemia (36%) (Table 3). When the groups with glucose ≥126 mg/dL and HbA_{1c} ≥5.7% (≥39 mmol/mol) were combined, 35% had notes from clinicians interpreting the test result as abnormal, 41% had follow-up appointments scheduled, and 32% were diagnosed with dysglycemia.

Based upon weighted estimates informed by medical record reviews, we found that of those diagnosed by clinicians as having prediabetes or diabetes within 6 months of their initial screening test, 74% were diagnosed with prediabetes (impaired fasting glucose, impaired glucose tolerance, or prediabetes), and 26% were diagnosed with diabetes. For patients diagnosed with prediabetes, mean screening HbA_{1c} was 6.2 ± 0.3%, and mean glucose was 116 ± 10 mg/dL. For patients diagnosed with diabetes, mean screening HbA_{1c} was 8.2 ± 2.3%, and mean glucose was 247 ± 137 mg/dL. Of all screening tests performed, only 4% led to a diagnosis of prediabetes, and only 1.5% led to a diagnosis of diabetes within 6 months.

Although not the primary focus of this report, we also assessed the frequency of treatment for clinician-diagnosed prediabetes and diabetes within 6 months of screening (Table 4). Of those diagnosed with prediabetes, 71% were counseled by the clinician on nutrition during a follow-up visit, and 12% were referred to a dietitian or diabetes educator. Sixty-one percent of those diagnosed with prediabetes were counseled on the benefits of physical activity by the clinician, and 2% were referred to physical activity programs. Seven percent of patients diagnosed with prediabetes received metformin pharmacotherapy within 6 months of the diagnosis. For those diagnosed with prediabetes, we also assessed follow-up according to whether the patient was screened with a glucose test or an HbA_{1c} test. Regardless of which test was performed, over half the patients received nutrition counseling and/or physical activity counseling after being diagnosed with prediabetes. However, greater percentages of patients who were screened with HbA_{1c} tests received referrals to nutrition and/or physical activity programs or received prescriptions for metformin.

Of those diagnosed with diabetes, 83% were counseled by the clinician on nutrition during a follow-up visit, and 39% were referred to a dietitian (Table 4). Sixty percent of those diagnosed with diabetes were counseled on the benefits of physical activity, and 4% were referred

Table 2—Characteristics of the total population, stratified by screening status and screening test

Characteristic	Total population	*N* (%) screened	*N* (%) not screened	*P* value*	*N* (%) screened with HbA_{1c}	*N* (%) screened with another test	*P* value†
N	12,772	9,941 (78)	2,831 (22)		1,378 (14)	8,563 (86)	
Age				<0.0001			0.8863
45–54 years	6,564	4,927 (75)	1,637 (25)		675 (14)	4,252 (86)	
55–64 years	5,605	4,495 (80)	110 (20)		629 (14)	3,866 (86)	
≥65 years	603	519 (86)	84 (14)		74 (14)	445 (86)	
Sex				0.2397			0.4168
Women	7,193	5,626 (78)	1,567 (22)		766 (14)	4,860 (86)	
Men	5,579	4,315 (77)	1,264 (23)		612 (14)	3,703 (86)	
Race				0.0007			0.0057
White	10,544	8,176 (78)	2,368 (22)		1,083 (13)	7,093 (87)	
Nonwhite	1,213	992 (82)	221 (18)		163 (16)	829 (84)	
PCP visits				<0.0001			<0.0001
None in past 3 years	5,076	3,017 (60)	2,059 (41)		231 (8)	2,786 (92)	
At least one in past 3 years	7,696	6,924 (90)	772 (10)		1,147 (17)	5,777 (83)	
Weight‡				<0.0001			<0.0001
Normal weight	11,441	8,684 (76)	2,757 (24)		1,055 (12)	7,629 (88)	
Overweight/obese	1,331	1,257 (94)	74 (6)		323 (26)	934 (74)	
Blood pressure§				<0.0001			<0.0001
Normotensive	8,524	5,986 (70)	2,538 (30)		659 (11)	5,327 (89)	
Hypertension	4,248	3,955 (93)	293 (7)		719 (18)	3,236 (82)	
Cholesterol‖				<0.0001			<0.0001
No dyslipidemia	7,446	5,375 (69)	2,371 (31)		581 (11)	4,794 (89)	
Dyslipidemia	5,026	4,566 (91)	460 (9)		797 (17)	3,769 (83)	

**P* value refers to statistical tests comparing those who were screened vs. those who were not screened. †*P* value refers to statistical tests comparing those who were screened with HbA_{1c} vs. those who were screened with another test. ‡Weight is defined as the presence or absence of a claims diagnosis for overweight or obesity in the time period (ICD-9 codes: 278.0, 278.00, and 278.01). §Blood pressure is defined as the presence or absence of a claim for hypertension in the time period (ICD-9 codes: 401.x–405.x). ‖Cholesterol is defined as the presence or absence of a claim for dyslipidemia in the time period (ICD-9 codes: 272.0, 272.2, and 272.4).

to physical activity programs. About half of patients diagnosed with diabetes received diabetes education from the clinician (49%), and more than half were referred to diabetes education programs (55%). Fifty-eight percent of patients with newly diagnosed diabetes received pharmacotherapy for their diabetes within 6 months of their diagnosis. The vast majority of the prescriptions were for metformin (81%). The remainder were for a sulfonylurea and/or insulin either alone or in combination.

CONCLUSIONS

In January 2010, the ADA first recommended that HbA_{1c} be an option for screening and diagnosis of prediabetes and diabetes (2). The impact of this recommendation on screening practices is not well described. This study examined screening practices in a single, large, academic health system over a 4-year period following the publication of this recommendation. We found that over the recommended 3-year screening interval, the rate of screening was 78% using an OGTT, a laboratory or POC HbA_{1c} test, a laboratory glucose test performed as a part of a panel or as an individual test, or a POC glucose test. In 1998–2000, the rates of screening in the same health system had been 69% (4). If we defined screening as testing with an OGTT, HbA_{1c}, or a glucose test specifically marked as fasting, the rate of screening in 2010–2013 was 20%. If we defined screening as testing with an OGTT, HbA_{1c}, or glucose level drawn before 9 A.M., the rate of screening was 35%. Screening appropriately targeted those with diabetes risk factors, including older age, nonwhite race, and diagnoses of overweight or obesity, hypertension, and dyslipidemia. Older age was not an independent predictor of screening, possibly because of its association with obesity, hypertension, and dyslipidemia. The increased frequency of screening among people with hypertension and dyslipidemia may also indicate that people with these conditions are more likely to have chemistry panels performed to monitor electrolytes, renal function, and hepatic function. Those with at least one primary care visit were also significantly more likely to be screened than those who saw only nonprimary care clinicians, suggesting that PCPs may order more laboratory panels.

When compared with the results of our previous study, we found that glucose testing, although less frequently performed than previously, remained the most common test (86% in 2010–2013 vs. 98% in 1998–2000). The majority (82%) of glucose testing was still done as part of chemistry panels. Only 18% of glucose testing was performed using individual glucose tests. The frequency of initial HbA_{1c} testing increased from 2 to 14% after the new ADA recommendations were published, and 18% of patients had at least one HbA_{1c} test performed during the 3-year screening interval. Eleven percent of patients who had glucose tests performed as their initial screening test had HbA_{1c} tests performed as follow-up tests during the study period, and the probability and promptness of follow-up HbA_{1c} testing were directly related to the degree of hyperglycemia. Nevertheless, the overall rate of HbA_{1c} screening remains lower

Table 3—Frequency of follow-up of abnormal screening results within 6 months by age and type of screening test

			6-month follow-up period [*n* (% of abnormal*)]					
	Screened	Abnormal screening result [*n* (%)]	Clinician interpretation of results being abnormal	Follow-up appointment scheduled	Follow-up appointment attended	Clinician diagnosis of dysglycemia*	Clinician diagnosis of prediabetes†	Clinician diagnosis of diabetes
Screened with laboratory glucose: abnormal result defined as laboratory glucose ≥100 mg/dL								
Age 45–54 years	4,173	1,198 (29)	119 (10)	227 (19)	223 (19)	95 (8)	74 (6)	21 (2)
Age 55–64 years	3,614	1,115 (31)	248 (22)	347 (31)	299 (27)	186 (17)	151 (14)	35 (3)
Age ≥65 years	477	180 (38)	7 (4)	74 (41)	48 (27)	4 (2)	4 (2)	0
Total	8,264	2,493 (30)	174 (15)	648 (26)	570 (23)	284 (11)	228 (9)	56 (2)
Screened with laboratory glucose: abnormal result defined as laboratory glucose ≥126 mg/dL								
Age 45–54 years	4,173	178 (4)	53 (30)	49 (28)	46 (26)	28 (16)	7 (4)	21 (12)
Age 55–64 years	3,614	206 (6)	93 (45)	103 (50)	100 (49)	75 (37)	40 (19)	35 (17)
Age ≥65 years	477	25 (5)	7 (29)	7 (29)	4 (14)	4 (14)	4 (14)	0
Total	8,264	408 (5)	153 (37)	160 (39)	149 (37)	107 (26)	50 (12)	56 (14)
Screened with HbA_{1c}: abnormal result defined as HbA_{1c} ≥5.7% (≥39 mmol/mol)								
Age 45–54 years	561	323 (58)	105 (33)	139 (43)	133 (41)	107 (33)	67 (21)	39 (12)
Age 55–64 years	564	380 (67)	134 (35)	150 (40)	135 (36)	153 (40)	109 (29)	44 (12)
Age ≥65 years	71	48 (69)	8 (16)	18 (37)	17 (35)	10 (20)	6 (12)	4 (8)
Total	1,196	752 (63)	247 (33)	307 (41)	285 (38)	269 (36)	182 (24)	87 (12)
Screened with laboratory glucose or HbA_{1c}: abnormal result defined as laboratory glucose ≥126 mg/dL or HbA_{1c} ≥5.7% (≥39 mmol/mol)								
Age 45–54 years	4,734	458 (10)	158 (35)	188 (41)	179 (39)	135 (30)	75 (16)	60 (13)
Age 55–64 years	4,178	563 (13)	205 (36)	232 (41)	213 (38)	206 (37)	127 (23)	79 (14)
Age ≥65 years	548	73 (13)	15 (20)	25 (34)	21 (28)	13 (18)	9 (13)	4 (5)
Total	9,460	1,094 (12)	378 (35)	445 (41)	413 (38)	354 (32)	211 (19)	143 (13)

Results in this table are based on weighted numbers and percentages and may not add up to 100%. *Dysglycemia is defined here as a cumulative measure of impaired fasting glucose, impaired glucose tolerance, prediabetes, or diabetes. †Prediabetes is defined as impaired fasting glucose, impaired glucose tolerance, or prediabetes.

Table 4—Frequency of treatment for clinician-diagnosed prediabetes and diabetes within 6 months of screening by age and sex

		Treatment for prediabetes [*n* (% of clinician-diagnosed prediabetes)]				
	Clinician diagnosis of prediabetes	Nutrition counseling	Nutrition referral	Physical activity counseling	Physical activity referral	Pharmacotherapy
Women and men						
Age 45–54 years	144	97 (67)	12 (9)	91 (63)	2 (1)	12 (8)
Age 55–64 years	262	192 (73)	33 (13)	158 (60)	7 (3)	19 (7)
Age ≥65 years	9	5 (49)	4 (38)	5 (49)	0	0
Total	415	293 (71)	49 (12)	254 (61)	9 (2)	31 (7)
Women						
Age 45–54 years	59	16 (26)	7 (11)	20 (34)	2 (3)	12 (21)
Age 55–64 years	105	82 (78)	21 (20)	84 (80)	7 (7)	12 (11)
Age ≥65 years	0	0	0	0	0	0
Total	163	97 (60)	27 (17)	103 (63)	9 (6)	24 (15)
Men						
Age 45–54 years	85	82 (96)	6 (7)	72 (84)	0	0
Age 55–64 years	157	110 (70)	13 (8)	74 (47)	0	7 (4)
Age ≥65 years	9	5 (49)	4 (38)	5 (49)	0	0
Total	252	196 (78)	22 (9)	150 (60)	0	7 (3)

		Treatment for diabetes [*n* (% of clinician-diagnosed diabetes)]						
	Clinician diagnosis of diabetes	Nutrition counseling	Nutrition referral	Physical activity counseling	Physical activity referral	Pharmacotherapy	Diabetes education counseling	Diabetes education referral
Women and men								
Age 45–54 years	61	47 (76)	27 (43)	25 (41)	1 (2)	40 (64)	37 (60)	42 (68)
Age 55–64 years	81	72 (89)	26 (32)	59 (73)	6 (7)	43 (53)	32 (40)	38 (46)
Age ≥65 years	4	3 (75)	4 (100)	3 (75)	0 (0)	3 (75)	3 (75)	1 (25)
Total	146	121 (83)	57 (39)	88 (60)	7 (4)	85 (58)	72 (49)	81 (55)
Women								
Age 45–54 years	25	17 (70)	12 (48)	11 (44)	1 (4)	15 (59)	19 (76)	18 (74)
Age 55–64 years	29	26 (90)	11 (36)	21 (71)	2 (7)	11 (36)	11 (36)	12 (39)
Age ≥65 years	1	1 (100)	1 (100)	1 (100)	0 (0)	1 (100)	1 (100)	1 (100)
Total	55	45 (81)	24 (43)	33 (60)	3 (5)	26 (47)	30 (55)	31 (56)
Men								
Age 45–54 years	37	30 (81)	15 (40)	14 (38)	0 (0)	25 (68)	18 (49)	24 (64)
Age 55–64 years	52	46 (88)	16 (30)	39 (75)	4 (7)	32 (62)	22 (42)	26 (51)
Age ≥65 years	3	2 (67)	3 (100)	2 (67)	0 (0)	2 (67)	2 (67)	0 (0)
Total	91	77 (85)	33 (36)	55 (60)	4 (4)	59 (65)	42 (46)	50 (54)

Results in this table are based on weighted numbers and percentages and may not add up to 100%.

than the rate of glucose testing. This may represent a delay in translating new guidelines into clinical practice or the persistence of "routine" testing with chemistry panels for patients at lower risk. Our results also show that as recommended by the ADA, POC glucose tests are not being used as a diabetes screening test by most clinicians. OGTTs were almost never performed as a screening test for nonpregnant adults (only 11 times in the 3-year period) despite being recommended for screening by the ADA.

Although HbA_{1c} screening was performed less frequently than glucose testing, the results of HbA_{1c} screening were more likely to be abnormal than the results of glucose testing, suggesting that providers were more likely to order HbA_{1c} tests for higher risk patients. Patients screened with HbA_{1c} were slightly more likely to be nonwhite and to be overweight or obese than patients screened with glucose levels. An HbA_{1c} test result ≥5.7% (≥39 mmol/mol) was more likely than a glucose test result ≥100 mg/dL but no more likely than a glucose test result ≥126 mg/dL to lead to a follow-up visit within 6 months. An HbA_{1c} test result ≥5.7% was more likely than a glucose test result ≥126 mg/dL to lead to a diagnosis of either prediabetes or diabetes within 6 months of the testing date. Our results differ from those of a previous study that used data from the 2012 National Ambulatory Medical Care Survey and found that <1% of screened patients with HbA_{1c} levels between 5.7 and 6.4% (39 mmol/mol and 46 mmol/mol) received a diagnosis of prediabetes (6).

When we looked at counseling and treatment for prediabetes for those tested with glucose versus those screened with HbA_{1c}, we found that regardless of which test was performed, over half of patients received nutrition and/or physical activity counseling. However, a greater percentage of patients who were screened with HbA_{1c} tests received referrals for nutrition and/or physical activity programs or prescriptions for metformin. For those with newly diagnosed prediabetes, only 7% received metformin pharmacotherapy within 6 months, consistent with the

findings of Moin et al. (7), who found that <4% of patients with prediabetes were prescribed metformin in a 3-year period.

Most patients newly diagnosed with diabetes received nutrition counseling (83%), but only 58% were prescribed pharmacologic therapy within 6 months despite the ADA's recommendation that metformin therapy be initiated at diagnosis (8). Because the ADA's recommendation was initially published in 2009, this may reflect a delay in uptake.

In summary, we found that glucose or HbA_{1c} testing is frequent in adults ≥45 years of age (78%) and that testing appropriately targets higher risk individuals. If one considers an appropriate screening test to be only an OGTT, HbA_{1c}, or glucose test marked as fasting or performed before 9 A.M., rates of screening are lower (20–35%). Unfortunately, the yield of screening remains low. In total, 4% of tests led to a diagnosis of prediabetes, and only 1.5% led to a diagnosis of diabetes within 6 months. This could reflect a failure to perform definitive diagnostic tests in those with abnormal screening tests or a low prevalence of these disorders in the population. Between 1998 and 2000, only 0.4% of tests led to a diagnosis of diabetes within 6 months.

There may be several reasons for this. First, we found low rates of follow-up of potentially abnormal screening tests, especially glucose levels only slightly >100 mg/dL. This may be due to the fact that as many as 86% of glucose tests were not fasting, and there is no universally agreed upon cut point to define an abnormal random glucose test. Various authors have recommended cut point values ranging between 100 and 140 mg/dL (6,9–12). A recent study by Bowen et al. (10) concluded that a single random glucose ≥100 mg/dL is more strongly associated with undiagnosed diabetes than traditional risk factors including age ≥45 years, BMI ≥25 kg/m^2, nonwhite race, family history of diabetes, hypertension, hyperlipidemia, and cardiovascular disease and that the odds of having undiagnosed prediabetes or diabetes are threefold higher for those with random glucose ≥100 mg/dL (vs. <100 mg/dL) after adjustment for traditional risk factors. Several studies have shown random glucose to be an effective screening test, with abnormal results requiring follow-up with a definitive diagnostic test (9–12). Unfortunately, the ADA's recommendation that a random glucose level ≥200 mg/dL, when accompanied by symptoms or signs of frank diabetes, be used to diagnose diabetes may lull practitioners into believing that random glucose levels <200 mg/dL are normal. Even when performed as a part of chemistry panels, random glucose levels ≥126 mg/dL, and possibly ≥100 mg/dL, deserve follow-up with a definitive diagnostic test, either an HbA_{1c} or fasting glucose tests (10). Perhaps reassuringly, when we examined the follow-up for patients with laboratory glucose tests stratified by glucose levels, we found that scheduling follow-up appointments was substantially better (39%) for patients with glucose levels ≥126 mg/dL. Although abnormal glucose levels, even when obtained as part of a panel, appear to prompt a response from the clinician, the frequency of follow-up of random glucose levels could still be improved.

Second, there may have been a lack of awareness among practitioners that HbA_{1c} values between 5.7 and 6.4% (39 mmol/mol and 46 mmol/mol) are abnormal given that the ADA recommendation that HbA_{1c} be used for screening and diagnosis was not published until January 2010 (3). Third, the U.S. Preventive Services Task Force guidelines published in 2008 recommended screening for type 2 diabetes only in patients with hypertension (13). As such, clinicians may not have felt that screening was indicated for patients ≥45 years of age without hypertension. A previous study found that guideline-directed screening might miss a large percentage of adults with dysglycemia (14). The more recent 2015 U.S. Preventive Services Task Force guidelines are now in line with those of the ADA and recommend screening for those 40–70 years of age who are overweight or obese.

There are a number of limitations to our study. First, we have considered all glucose tests to be screening tests. We acknowledge that diabetes screening may not be the primary purpose when glucose tests are ordered as a part of chemistry panels. Considering those tests to be screening tests may result in an overestimate of the frequency of screening in routine clinical practice. Indeed, if we consider only glucose levels explicitly noted to be fasting or glucose levels drawn before 9 A.M. to be screening tests, total rates of screening are between 20 and 35% as opposed to 78%. Second, because we defined the screening test as the first test in an arbitrarily defined 3-year time interval, we may have misclassified follow-up tests as primary screening tests and vice versa. Because chemistry panels are ordered more frequently than HbA_{1c} tests, this may have lowered the apparent frequency of HbA_{1c} screening. A total of 18% of patients had at least one HbA_{1c} test performed during the 3-year screening interval. Third, our study population was drawn from a single health care delivery system in a single state and was quite homogeneous with respect to race. Limited geographic distribution may affect the generalizability of our results, and the lack of diversity may have made it difficult for us to detect differences in screening practices by race. Fourth, ascertainment of follow-up was based on review of random samples of electronic medical records. To the extent these random samples may not have been representative of the general population, we may have under- or overestimated rates of follow-up. Finally, although our results show an increase in rates of HbA_{1c} screening between 1998 and 2000 and 2010 and 2013, screening practices have likely continued to change since 2014.

The results of our study suggest that perhaps contrary to popular belief, rates of screening for prediabetes and diabetes are high. Nearly 80% of patients eligible for screening had at least one biochemical measure of glycemia over a 3-year period. The initial test was much more likely to be a glucose level (usually as a part of a panel) than a measurement of HbA_{1c}. In our study, providers behaved as if having a random glucose level ≥126 mg/dL was comparable to having an HbA_{1c} level ≥5.7% and merited follow-up. Because measurement of glucose remains much more frequent than measurement of HbA_{1c}, evidence to support guidelines to define the role of random glucose screening including the definition of appropriate cut points and follow-up is needed. Although still used less frequently than glucose testing, HbA_{1c} testing is now being performed more frequently for screening, is more likely to be performed for high-risk

patients, and is associated with higher rates of diagnosis, referral, and treatment. This is an important finding, as timely intervention can prevent or delay progression of prediabetes to type 2 diabetes (15).

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References

1. Centers for Disease Control and Prevention. *National Diabetes Statistics Report, 2017: Estimates of diabetes and its burden in the United States*. Atlanta, GA, Centers for Disease Control and Prevention, United States Department of Health and Human Services, 2017

2. Nathan DM, Balkau B, Bonora E, et al.; International Expert Committee. International Expert Committee report on the role of the A1C assay in the diagnosis of diabetes. Diabetes Care 2009;32:1327–1334

3. American Diabetes Association. Diagnosis and classification of diabetes mellitus [published correction appears in Diabetes Care 2010;33:e57]. Diabetes Care 2010;33(Suppl. 1):S62–S69

4. Ealovega MW, Tabaei BP, Brandle M, Burke R, Herman WH. Opportunistic screening for diabetes in routine clinical practice. Diabetes Care 2004;27:9–12

5. Health Insurance Marketplace. Quality rating system measure technical specifications [Internet]. Available from https://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/QualityInitiativesGenInfo/Downloads/2016-QRS-Measure-Technical-Specifications.pdf. Accessed 11 January 2017

6. Mainous AG III, Tanner RJ, Baker R. Prediabetes diagnosis and treatment in primary care. J Am Board Fam Med 2016;29:283–285

7. Moin T, Li J, Duru OK, et al. Metformin prescription for insured adults with prediabetes from 2010 to 2012: a retrospective cohort study. Ann Intern Med 2015;162:542–548

8. Nathan DM, Buse JB, Davidson MB, et al.; American Diabetes Association; European Association for the Study of Diabetes. Medical management of hyperglycemia in type 2 diabetes: a consensus algorithm for the initiation and adjustment of therapy: a consensus statement of the American Diabetes Association and the European Association for the Study of Diabetes. Diabetes Care 2009;32:193–203

9. Johnson SL, Tabaei BP, Herman WH. The efficacy and cost of alternative strategies for systematic screening for type 2 diabetes in the U.S. population 45–74 years of age. Diabetes Care 2005;28:307–311

10. Bowen ME, Xuan L, Lingvay I, Halm EA. Random blood glucose: a robust risk factor for type 2 diabetes. J Clin Endocrinol Metab 2015; 100:1503–1510

11. Somannavar S, Ganesan A, Deepa M, Datta M, Mohan V. Random capillary blood glucose cut points for diabetes and pre-diabetes derived from community-based opportunistic screening in India. Diabetes Care 2009;32:641–643

12. Rolka DB, Narayan KM, Thompson TJ, et al. Performance of recommended screening tests for undiagnosed diabetes and dysglycemia. Diabetes Care 2001;24:1899–1903

13. Norris SL, Kansagara D, Bougatsos C, Fu R; U.S. Preventive Services Task Force. Screening adults for type 2 diabetes: a review of the evidence for the U.S. Preventive Services Task Force. Ann Intern Med 2008;148:855–868

14. O'Brien MJ, Lee JY, Carnethon MR, et al. Detecting dysglycemia using the 2015 United States Preventive Services Task Force screening criteria: a cohort analysis of community health center patients. PLoS Med 2016;13:e1002074

15. Knowler WC, Barrett-Connor E, Fowler SE, et al.; Diabetes Prevention Program Research Group. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. N Engl J Med 2002;346:393–403