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ORIGINAL ARTICLE

Random plasma glucose values measured in community dental practices: findings from The Dental Practice-Based Research Network

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Abstract
Objectives This study aimed to examine feasibility of testing and frequency of abnormal plasma glucose among dental patients in The Dental Practice-Based Research Network.
Methods Eligible dental patients were ≥19 years old and had at least one American Diabetes Association-defined risk factor for diabetes mellitus or an existing diagnosis of diabetes or pre-diabetes. Random (fasting not required) plasma glucose was measured in standardized fashion using a commercial glucometer. Readings <70 or >300 mg/dl triggered re-testing. Patients with glucose ≥126 mg/dl were referred for medical follow-up.
Results Of 498 subjects in 28 dental practices, 491 (98 %) consented and 418 (85.1 %) qualified for testing. Fifty-one patients (12.2 %) had diabetes; 24 (5.7 %) had pre-diabetes. Glucose ranged from 50 to 465 mg/dl. One hundred twenty-nine subjects (31 %) had readings outside the normal range; of these, 28 (6.7 %) had readings <80 mg/dl and 101 (24.2 %) had readings ≥126 mg/dl; in nine patients (seven with diabetes), glucose was >200 mg/dl.
Conclusions A significant proportion of patients tested had abnormal blood glucose. Routine glucose testing in dental practice of populations at risk or diagnosed with diabetes may be beneficial and community dental practices hold promise as settings for diabetes and pre-diabetes screening and monitoring.
Clinical relevance Results suggest that implementation of glucose measurement in dental practice may provide important clinical and health information for both patients and practitioners.

Keywords Diabetes · Screening · Dental practice

The DPBRN Collaborative Group includes practitioner–investigators, faculty investigators, and staff investigators who contributed to this DPBRN activity. A list is at www.dpbrn.org/users/publications/Default.aspx.

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Introduction

Diabetes mellitus is one of the most common and costly chronic diseases [1, 2]. It is the third leading cause of death in this country and the chief cause of blindness, end-stage renal disease, and non-traumatic limb amputation [3]. The prevalence of diagnosed diabetes in the USA is estimated at 7 % (more than 20 million people) [4], while pre-diabetes affects another 18 % (about 54 million) [5]. In addition to diagnosed diabetes and pre-diabetes, an estimated 4 % of the

American population may have the disease but have not been diagnosed [4]. Similarly, Scandinavian countries have been experiencing a significant increase in the number of type 2 diabetes cases, which affects approximately 6–8 % of the population. It has been estimated that 3–4 % of the Swedish population has undiagnosed disease (www.diabetes.dk; www.diabetes.no; www.diabetes.se), and diabetes control is less than ideal in Scandinavia [6]. Many of such at-risk individuals are unaware of their status [3, 7]. In this setting, additional opportunities for glucose monitoring are needed.

Community dental practices constitute an unexplored setting for glucose testing and screening for both diabetes and pre-diabetes. Plasma glucose values should be obtained at the point of care using widely available, easily applied methods. Glucose monitors (glucometers) are routinely used by both patients and health care professionals for screening and disease monitoring in home, office, and hospital-based settings, but are not currently a routine in dental offices. It is also worth noting that diabetes is a disease with strong connections to oral health, particularly periodontal disease. Hyperglycemia may also be related to increased risk for oral infections and delayed healing after dental surgery [2, 5]. Hence, information on plasma glucose levels may be of direct relevance to the dental practitioner. In order to determine its applicability, we studied the feasibility of glucose testing in community dental offices in the USA and Sweden. We report here the plasma glucose values obtained from the participants in this study.

Methods

The setting for this study was The Dental Practice-Based Research Network (DPBRN), which is a National Institutes of Health-funded, community practitioner-based research venture [8]. Details about DPBRN can be found at http://www.DentalPBRN.org. The study was open to all network members from Alabama, Mississippi, Florida, Georgia, Minnesota, Oregon, Washington State, and Sweden. Both general dentists and dental specialists were eligible to participate. The study was approved by the University of Alabama at Birmingham and all regional human research review boards. All dentists who participated in the study completed research training prior to study initiation at their office.

Dental practices from each DPBRN region were selected at random from among all interested members of the network. Practitioner–investigators participated in a training session that included familiarization with study documents and procedures. The study glucometer (FreeStyle Freedom Lite, Abbot Diabetes Care, Alameda, CA) was introduced and practitioners and their delegated staff were trained in its use. This instrument was selected after a thorough review of commercially available glucometers, their reliability, accuracy, and cost. We tested it on a convenience sample to insure consistency and accuracy prior to providing the glucometer to the practitioner–investigators. All practitioners and staff were trained to use the glucose meter and demonstrated its proper use as part of training for the protocol. In addition to the device, each participating practice was provided with lancets, strips, and meter calibration equipment.

The targeted study population was adults ≥19 years of age scheduled for routine dental examinations, regardless of their gender, race, or ethnicity. Consecutive eligible patients interested in the study completed a standardized form containing demographic information and questions regarding the American Diabetes Association (ADA)-determined risk factors for diabetes [7]. All patients with (1) a diagnosis of diabetes or pre-diabetes; (2) a self-reported history of hypertension or hypercholesterolemia; or (3) a body mass index (BMI) >25 kg/m^2 were eligible for glucose testing. BMI was calculated by office staff based on patient-reported height and weight, using a conversion chart on the form. All patient-provided information was checked against the patient's existing record and discrepancies were corrected. Patients who agreed to be tested did so after providing consent prior to glucose measurement.

Subjects had a drop of blood obtained from the tip of one of their fingers, which was analyzed by the glucometer per manufacturer's instructions. Readings of <70 or >300 mg/dl triggered re-testing. If the value of the second test differed by >20 % from the original reading, a third test was performed and the median value was chosen. Patients with repeated low blood glucose were given oral glucose; those with consistent readings >300 mg/dl were advised to seek urgent care from a physician. The remaining patients with glucose >126 mg/dl were given a card with their specific glucose reading and a standard letter of referral to their physician, providing details of the study and the subject's glucose test result. Additionally, all patients received ADA literature about diabetes and blood glucose values. The dental practitioner–investigators neither diagnosed disease nor suggested treatment to any hyperglycemic patient.

Power analyses for the feasibility aim of the study showed that 375 tested subjects would be sufficient to determine significance with a power of 0.8. We selected 126 mg/dl as a conservative threshold for referring patients to physicians as samples were not fasting, and the risk for both pre-diabetes and diabetes rise with higher non-fasting glucose values. Plasma glucose was examined both as a continuous and a dichotomized categorical variable (<126 vs. ≥126 mg/dl). Frequencies of demographic and medical characteristic were compared according to whether or not plasma glucose was elevated (≥126 mg/dl). Chi-square tests were used to assess statistical significance of differences observed. Logistic regression was used to identify independent associations of

these characteristics with elevated plasma glucose. Odds ratios (OR) and 95 % confidence intervals (CI) were calculated from the equations. Analysis of variance was used to assess statistical significances of mean plasma glucose levels (Kruskal–Wallis for non-parametric). We also examined a categorical variable that included glucose >200 mg/dl separately, but the small number of individuals in this category did not support a multivariable analysis. The value 200 mg/dl was selected since non-fasting readings above this level are highly associated with a diagnosis of diabetes [3, 8]. All analyses were performed with the SAS software package (SAS Institute, Cary, NC).

Results

Four hundred ninety-eight consecutive eligible patients were approached about the study in 28 participating practices (five or six practices from each DPBRN region). Of these, 491 (98.6 %) consented to be screened and 418 (85.1 %) had at least one ADA-defined risk factor qualifying them for the glucose test. Of the seven refusing patients, six did so because they had just been tested at home or in their physician's office. Characteristics of the screened patients are presented in Table 1.

There were 191 (45.7 %) females; the mean age of screened participants was 52.2 (SD 14.7), and 336 (80.4 %) were White, 41 (10.0 %) Black, 10 (2.4 %) Asian, 11 "other," and 20 unknown. For analysis, race was dichotomized into White and non-White (Table 2). Participants were roughly equally divided between the five DPBRN regions (Table 3). Fifty-one (12.2 %) patients had a diagnosis of diabetes, and 24 (5.7 %) had a diagnosis of prediabetes; 161 (38.5 %) reported hypertension, 140 (33.5 %) reported hypercholesterolemia, and 372 (89.0 %) had a BMI >25 kg/m^2. Overweight patients were distributed across all age groups (p=0.11) but there were more overweight men (93.2 %) than women (85.5 %, p=0.01). The prevalence of self-reported hypertension increased with age, from 15.3 % among those younger than 45 years to 71.9 % among those older than 65 (p<0.0001), but was equally divided between genders (p=0.9). Similarly, the prevalence of hypercholesterolemia also increased with age, from 16.8 % among the youngest age group to 56.1 % among the oldest (p<0.0001) and was roughly the same in men and women (p=0.21).

Glucose values ranged from 50 to 465 mg/dl. One hundred one (24.4 %) patients (27 with diabetes, 74 undiagnosed) who had glucose ≥126 mg/dl were advised to follow-up with their physician and were provided with pertinent literature from the ADA. Nine (2.2 %) hyperglycemic subjects (seven with diabetes) had glucose values >200 mg/dl; 28 (6.7 %) patients (two with diabetes) had glucose <70 mg/dl and were provided with glucose supplementation. Mean glucose values by practice location were not significantly different (p=0.17). In re-tested patients (n=35), the second reading was within 5 mg/dl from the original reading.

Table 4 presents the results of the analysis examining risk factors for glucose ≥126 mg/dl. In unadjusted analyses, the associations were in the expected directions. Older and non-

Table 1 Subject characteristics among 418 tested patients

Glucose	<126 mg/dl *N* (%)	≥126 mg/dl *N* (%)	*p*
Age (years)			
<45	103 (87.4)	16 (12.6)	0.014[a]
45–54	91 (75.2)	30 (24.8)	
55–64	65 (67.7)	31 (32.3)	
>65	56 (68.3)	26 (31.7)	
Gender			
Male	143 (74.4)	48 (25.7)	0.148
Female	174 (76.7)	53 (23.4)	
Race			
White	254 (75.3)	82 (24.7)	0.013[a]
Non-White	63 (76.8)	19 (23.2)	
Body mass index			
≤25 kg/m^2	34 (71.7)	12 (28.3)	0.005[a]
>25 kg/m^2	283 (76.1)	89 (23.9)	
Diagnosis of hypertension			
Yes	109 (67.7)	52 (32.3)	0.011[a]
No	207 (80.5)	50 (19.4)	
Diagnosis of high cholesterol			
Yes	98 (69.3)	42 (30.7)	0.069
No	219 (78.8)	59 (21.2)	

[a] Statistically significant

Table 2 Mean random plasma glucose values for 418 tested patients by demographics

Variable		Mean Glu	Standard error	*p*
Sex	Female	115.1	3.56	<0.0001
	Male	122.7	3.76	
Race	White	113.8	2.99	<0.0001
	Other	124.1	4.74	
Age (years)	<45	113.4	4.47	<0.0001
	45–54	120.1	4.25	
	55–64	122.5	4.69	
	>65	119.6	4.82	
Region	AL/MS	111.6	4.40	<0.0001
	FL/GA	121.6	4.46	
	MN	125.4	4.83	
	WA/OR	119.1	4.82	
	SK	116.9	5.55	

Glu glucose, *AL* Alabama, *MS* Mississippi, *FL* Florida, *GA* Georgia, *MN* Minnesota, *WA* Washington State, *OR* Oregon, *SK* Scandinavia

Table 3 Distribution of risk factors for diabetes among the five DPBRN regions

	AL/MS	FL/GA	MN	WA/OR	SK	*p*
Risk factor						
N (%)						
Overweight	79 (86.8)	77 (85.6)	62 (83.8)	82 (93.2)	72 (96.0)	0.061
Hypertension	41 (45.1)	43 (47.8)	28 (37.8)	24 (27.3)	25 (33.3)	0.033
Hypercholesterolemia	41 (45.1)	36 (40.0)	28 (37.8)	25 (28.4)	10 (13.3)	0.0002
(pre)DM	17 (17.6)	16 (15.2)	16 (19.1)	21 (21.2)	5 (4.5)	0.059
Total *N*	99	105	84	99	111	

AL Alabama, *MS* Mississippi, *FL* Florida, *GA* Georgia, *MN* Minnesota, *WA* Washington State, *OR* Oregon, *SK* Scandinavia

White patients were more likely to have high glucose, as were those with higher cholesterol and hypertension. Time since the last meal had no effect on glucose values. In adjusted analyses, only age was independently associated with glucose ≥126 mg/dl (adjusted OR 2.1 (95 % CI 1.05, 4.19) for 45–55 years old and adjusted OR 2.62 (95 % CI 1.34, 5.11) for >55, relative to those <45). Again, although not statistically significant, ORs for hypertension, BMI, and hypercholesterolemia were in the expected direction.

Discussion

Derangements in glucose metabolism are increasingly common in our times, both in the USA [9] and Europe [10]. The Centers for Disease Control and Prevention estimated that 94 % of the pre-diabetes patients have not been diagnosed. These disorders have been associated with various other morbid conditions including cardiovascular [11, 12], respiratory [13], and oral diseases [2, 5, 14]. Evidence suggests that early detection and treatment of hyperglycemia will lead to improved outcomes [10, 15, 16]. Additionally, a systematic review of the literature by a European group led to the conclusion that prevention or delay of frank diabetes in people at risk can be accomplished through changes in lifestyle, thus justifying efforts for detection of pre-diabetes in the community [17].

Very few studies have examined the possibility of testing glucose values in community dental practices, and results of the current study suggest that such an approach may have a great deal of merit. We reported that dental patients from a wide geographic area found glucose testing highly acceptable and the vast majority agreed to be screened in this setting [18]. A large proportion of these community dental patients had risk factors that the ADA recommends should prompt opportunistic screening. Further study that includes a diagnostic component and long-term follow-up may be warranted. Important questions left unanswered by this study include the link between the dental office and the health system and how to optimize communication as well as completion of diagnostic testing and treatment.

The proportion of qualifying patients with true disease may have been improved if we had added other inclusion criteria such as signs, symptoms, and a family history of diabetes. Our study had relatively broad inclusion criteria as its main aim was to examine the acceptance of testing. Nevertheless, the vast majority of patients we screened had at least one risk factor for diabetes and about one quarter were hyperglycemic. Severe hypo- or hyperglycemia was rare (35 patients) but the mere finding of glucose values as low as 50 mg/dl and as high as 465 mg/dl in ambulatory dental patients speaks for the utility of glucose monitoring in selected dental patients. We note that while the latter value is cause for concern and requires medical attention, the former (severe hypoglycemia) is a medical emergency, which has significant mortality if not addressed promptly [14].

The epidemiologic distribution of hyperglycemia in our study showed some expected as well as some surprising

Table 4 Risk factors associated with glucose ≥120 mg/dl

Risk factor	Unadjusted odds ratio	95 % confidence interval	Adjusted[a] odds ratio	95 % confidence interval
Age 45–54 vs. <45	2.29	1.15; 4.52	2.10	1.05; 4.19
Age ≥55 vs. <45	3.27	1.75; 6.11	2.62	1.34; 5.11
Men vs. women	1.13	0.72; 1.77	1.12	0.70; 1.78
Hypertension vs. none	1.98	1.26; 3.10	1.47	0.89; 2.41
High cholesterol vs. none	1.65	1.04; 2.61	1.19	0.72; 1.98
BMI >25 vs. ≤25 kg/m^2	0.80	0.40; 1.58	0.96	0.47; 2.07

[a]Adjusted for all other covariates in table and DPBRN region

findings. In the former category, age was the only adjusted significant predictor of hyperglycemia, whereas non-White race, male gender, and hypertension were significantly associated only in unadjusted analyses, possibly reflecting the relatively small sample. While hypercholesterolemia showed a trend toward significance, BMI was inversely associated with glucose readings, with greater BMI being less likely to be hyperglycemic. Time elapsed since the last meal was obtained for all patients; however, this variable was not included in the regression analysis as bivariate results showed no significant association with glycemia. Risk determination may have been improved by use of a validated tool developed by Tabaei et al. [19] but that task was beyond the objectives of the current study. We note that the power of this study to detect meaningful demographic differences is limited and such detection was not one of the aims of the project.

Several other limitations of our study are worth noting. First, although we were able to include 28 community dental practices in a wide regional distribution, these practices may not be representative of all dental practices. In this feasibility of glucose testing in dental practice study, we did not attempt to assess fasting glucose, which we felt would add considerable complexity. Fasting glucose would have likely provided more accurate results, although time since the last meal was not associated with glucose reading >126 mg/dl. The high acceptance of random glucose screening suggests that a more complex, possibly two-stage screening approach that includes fasting values may be worth testing. Similarly, obtaining the hemoglobin A1c may have provided a more reliable indicator of disease but the much higher cost of this test made it impractical and less likely to be adopted in clinical practice. However, others have demonstrated that elevated random glucose in individuals without a diagnosis of diabetes may have adequate sensitivity and specificity and thus be worth follow-up [20–22]. Another possible limitation is our reliance on the patients for their height and weight values. While measuring these at the time of the appointment would provide increased accuracy, dental offices are not typically equipped with the appropriate instruments and adding those to the study would have resulted in undue burden and limited the direct applicability of the study's results to routine clinical practice. We also did not assess whether participants had a regular source of medical care. It is possible that at least some dental patients may not have regular medical care, which would identify a compelling group for screening, and quantifying this proportion would be a good next step in future studies. Finally, our power to analyze differences among tested patients based on glucose values may have been inadequate. Hence, these results must be interpreted with caution.

Conclusions

Our study demonstrates that glucose testing in dental offices was highly acceptable to patients, with the great majority agreeing to be screened, and if risk factors were identified, they agreed to be tested. The testing resulted in abnormal values in at least one fourth of screened high risk individuals, most of whom did not carry a diagnosis of either diabetes or pre-diabetes from their physicians. Although the non-fasting nature of the glucose values in this study must be borne in mind, the results do suggest that dental offices could be an excellent venue both for screening for diabetes and pre-diabetes and identifying individuals with diabetes who may require closer monitoring by their physicians.

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