Development of a clinical guideline to predict undiagnosed diabetes in dental patients

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Abstract

A clinical guideline can predict undiagnosed diabetes in dental patients

Background – In 2007, 17.9 million people in the United States had diagnosed diabetes, and 5.7 million had undiagnosed diabetes. The authors developed a clinical guideline to help dentists identify patients with undiagnosed diabetes.
Methods – The authors used classification and regression tree (CART) methods to generate different prediction models using data from the Third National Health and Nutrition Examination Survey (NHANES III) (1988-1994) and data from NHANES 2003-2004 for external validation. They classified participants who answered »No« to the question »Have you ever been told by a physician that you have diabetes?« and who had a fasting plasma glucose level greater than or equal to 126 mg per dl as having undiagnosed diabetes. The authors used oral examination data regarding the presence or absence of marginal periodontitis and waist circumference, as well as data on participants' self-reported oral health status, weight, age, family history and race or ethnicity. The authors chose the best prediction model by means of 10-fold cross-validation, as well as internal and external validation methods, which evaluated each prediction model by comparing sensitivity, specificity, area under the receiver operating characteristic curve and ease of use criteria (N = 7,545).
Results – The authors' final clinical guideline for predicting undiagnosed diabetes in dental patients had a sensitivity of 82.4 percent, a specificity of 52.8 percent and a receiver operating characteristic area under the curve of 0.72. They found that waist circumference, age, self-reported oral health status, self-reported race or ethnicity and self-reported weight information could be used to predict the risk of having undiagnosed diabetes (range, 0.1 to 9.1 percent).
Conclusion – Dental care providers should consider using a clinical guideline that includes the following predictors: waist circumference, age, self-reported oral health, self-reported weight and self-reported race or ethnicity, as well as any additional information on periodontal status and family history of diabetes.

This article was originally published in: Journal of American Dental Association 2011;142:28-37.

Key Words: Undiagnosed diabetes; dental office; clinical guideline

Diabetes is the seventh leading cause of death in the United States (1). In 2007, 17.9 million people in the United States had diagnosed diabetes, and 5.7 million people had undiagnosed diabetes (1). Investigators have proposed programs to screen for undiagnosed diabetes, which could be cost-effective if implemented (2-7). Most of these studies, however, were conducted in general medical settings (5-7). Investigators have proposed programs to screen for undiagnosed diabetes in the dental office, but few have proposed and tested specific clinical algorithms (8-14). In April 2007, the investigators associated with The Scottsdale Project, a consensus group that brought together a wide range of medical and dental experts, discussed the quality of existing evidence related to associations between diabetes and periodontal disease (11). They concluded that »there is sufficient evidence of a bidirectional relationship between diabetes and periodontal disease to formulate guidelines for screening for undiagnosed diabetes and the comanagement of patients with diabetes in the clinical practice of dentistry and dental hygiene.« However, a specific clinical guideline was not formulated for use with dental patients.

The oral manifestations of diabetes, which might give a dentist the first indication that a patient has the disease, include dry mucous membranes (xerostomia or dry mouth), periodontal diseases, oral candidiasis, burning mouth sensation (glossopyrosis), impaired wound healing, recurrent oral infections and acetone breath (15-17). Providing dental treatment to a patient who has uncontrolled diabetes could be life-threatening to the patient in the event of a hypoglycemic reaction (15). Given the increase in the prevalence of diabetes, it stands to reason that the number of dental patients who have undiagnosed diabetes will increase (1,8). Sixty percent of Americans see a dentist at least once per year for routine, nonemergency dental care (12,18). The total estimated annual cost of diabetes in 2007 was $174 billion: $116 billion in excess medical expenditures and $58 billion in reduced national productivity (2). Hence, the use of a validated clinical guideline to screen for undiagnosed diabetes could result in patients' having fewer severe cases of diabetes, fewer medical problems and lower medical expenses (11,19,20).

Borrell and colleagues (14,21) developed the first prediction model specifically for use in the dental office to identify a population at high risk of developing diabetes. Using a logistic regression model, they found evidence that the probability of a patient's having undiagnosed diabetes in conjunction with a self-reported family history of diabetes, hypertension, high cholesterol and periodontal disease was between 27 and 53 percent. Strauss and colleagues (8,9) further explored the opportunity to identify patients at risk of having undiagnosed diabetes at the time of the dental visit and concluded that 93 percent of patients with periodontitis met the American Diabetes Association guidelines for diabetes screening compared with 63 percent of patients without periodontitis. Heikes and colleagues (5) developed a simple noninvasive screening tool to calculate the probability that a person in the United States has either undiagnosed diabetes or prediabetes by using classification and regression tree (CART) methods. Their diabetes risk calculator, however, was not designed specifically for the dental setting. In addition, Borrell and colleagues (14,21) selected predictors on the basis of prior clinical knowledge, but they may have omitted factors that could have improved predicting patients with undiagnosed diabetes in the dental office.

To expand on previous research in this area, we considered a wider range of risk factors using a systematic approach to generate a clinically useful and objectively validated guideline to predict undiagnosed diabetes in dental patients.

Participants and Methods

Our study population consisted of participants from the Third National Health and Nutrition Examination Survey (NHANES III) (1988-1994) (22). NHANES III was designed to study the health and nutritional status of a nationally representative sample of adults and children in the United States. NHANES III investigators obtained demographic, socioeconomic, dietary and health-related characteristics from the participants through the use of interview questionnaires. These investigators also obtained direct health measurements from medical, dental and physiological examinations, as well as laboratory tests. We excluded participants if they had no fasting glucose measurement or dental information, were younger than 20 years or were pregnant at the time of examination. We split the NHANES III data into two data sets of equal size. We used the first data set (called »the training data set«) for model development and the 10-fold cross-validation method and the second data set (called »the testing data set«) for internal validation. We performed external validation by using the NHANES 2003-2004 data set.

We classified a participant as having undiagnosed diabetes if he or she answered »No« to the question »Have you ever been told by a physician that you have diabetes?« and had a fasting plasma glucose level greater than or equal to 126 mg per dl. To identify predictors for undiagnosed diabetes, we examined studies that focused on prediction rules, questionnaires or risk scores for diabetes, as well as the literature related to either prediabetes or undiagnosed diabetes. We searched MEDLINE (to May 2010), EMBASE (to May 2010) and reference lists of relevant articles up to May 2010 to identify risk factors reported by the authors of prior studies. We excluded predictors that were not measured or were otherwise unavailable for more than one-half of the participants from our analysis. From NHANES III (22), we extracted biomarker information on blood testing and dental disease from the questionnaire and oral examinations for which periodontal disease was recorded.

We used the clinical definitions proposed by the Centers for Disease Control and Prevention working group for use in population-based surveillance of periodontitis for our study. The definition of moderate periodontitis was having at least two or more interproximal sites with a clinical attachment level of 4 mm or greater (not on the same tooth) or at least two or more interproximal sites with a pocket depth of greater than or equal to 5 mm (not on the same tooth) (23). NHANES III investigators measured patients' self-reported oral health status by means of the question »How would you describe the condition of your natural teeth: excellent, very good, good, fair or poor?« They also obtained patients' self-reported weight by means of the question "How much do you weigh without clothes or shoes (in pounds)?" We chose to use self-reported weight instead of measured weight, because 1,888 participants' measured weight had not been recorded. Most participants' records had self-reported weight information, and the Pearson correlation between measured and self-reported weight was 0.9. NHANES III investigators obtained body-composition information, including waist circumference and waist-to-hip ratio, by means of physical examination. We preferred to use waist circumference for our analysis because it has a stronger association with central adiposity and a lower measurement error than does waist-to-hip ratio (24).

CART is a nonparametric statistical analysis method that uses recursive partitioning of the data and calculates the probability of the outcome of interest (in our study, of having undiagnosed diabetes) on the basis of several of the most important risk factors (25-28). It is a useful method for developing clinical decision trees that are simple to interpret. CART works well with data sets that have large numbers of predictors (26,29). Variables are selected in sequence on the basis of their contributions and importance to the prediction (26). For a prediction model to be useful and generalizable to other settings, validation is important (30,31). A good prediction model should predict accurately not only in the developing data set, but also in an external data set.

We generated CART-based models using standard approaches for CART (including use of the Gini index and entropy method, along with specification of misclassification cost) (25,26). We found that models performed similarly with or without specification of misclassification cost and, thus, we chose the model with the lowest relative cost as the candidate model. In creating the candidate model, we first generated eight prediction models that considered self-reported information, body composition measurements, blood pressure measurements and biomarker predictors. Second, we generated a separate set of models without considering blood pressure measurements and biomarker information. We used the CART analysis method to rank each candidate predictor's importance based on its overall contribution to the prediction model. Usually the first variable in the prediction model is the most important predictor (26,29).

We assessed the performance of the final model by using standard measures of sensitivity, specificity, the Akaike information criterion and the Hosmer-Lemeshow goodness-of-fit test. Our prediction model recommended for dental care providers is intended to be a clinical guideline that is easy to follow. To help select the final prediction model, we used 10-fold cross-validation methods and performed internal and external validation by applying the best-fitted model to the NHANES III testing data set and the NHANES 2003-2004 data set. We chose the best model on the basis of the trade off between accuracy and complexity (29,31). To further examine the prediction accuracy of the final model, we also varied cutoff points at probability 0.04, 0.06 and 0.08. We conducted all analyses for this study by using statistical software (SAS, Version 9.2, SAS Institute, Cary, N.C.; TreeNet, Salford Systems, San Diego; and CART, Salford Systems).

Results

Selection of variables

We initially considered 55 predictors on the basis of our literature review. According to the TreeNet analyses, 20 of these predictors were important predictors (Box 1). Models with predictors in continuous form performed similarly to models based on dichotomizing predictors into binary variables (receiver operating characteristic [ROC] = 0.76 and 0.77, respectively). Therefore, we transformed continuous variables into binary variables on the basis of optimal points that we identified by using the CART method. These variables were 90 centimeters and 97 cm for waist circumferences; 30, 36 and 45 years for age; 150 pounds for self-reported weight; and six for the number of decayed, missing and filled permanent surfaces. We gave self-reported oral health status a value of 0 if patients reported that their oral health status was "poor" and 1 if they reported otherwise.

Descriptive analyses

A total of 15,785 participants of the 20,050 in the NHANES III data set had data available for both the results of the fasting plasma glucose test and the answer to the question »Have you ever been told by a physician that you have diabetes?« Among these participants, 1,314 (8.3 percent) reported being told by a physician that they had diabetes, and 456 (2.9 percent) had undiagnosed diabetes. After we excluded participants for whom we had no dental information and those who were younger than 20 years or pregnant at the time of examination, 15,090 participants remained. We then split the NHANES III data into two equal-sized data sets (training and testing data sets). We used the former for model development and the latter for internal validation. Table 1 shows the mean number and percentages of candidate predictors in the training data set, the internal validation set (NHANES III testing data set) and the external validation data set (NHANES 2003-2004 data set). The prevalence of undiagnosed diabetes was 2.6 percent (194 of 7,545 participants) in our training data set, 3.3 percent (247 of 7,545 participants) for the internal validation data set and 2.1 percent (51 of 2,400 participants) for the external validation data set.

CART analysis

Both the Gini index and the entropy method yielded similar prediction models, with or without specification of misclassification costs. The models we generated that included biomarkers performed slightly better than did models generated without biomarkers (areas under the curve [AUCs] were 0.78 and 0.74, respectively). Predictors such as C-reactive protein, however, require blood tests and may be relatively expensive to collect. For the ease of implementation in dental practices, we only considered models that were generated without biomarkers. Even though we used different prediction rules, when we used the CART method, we consistently identified similar variables as important predictors, including waist circumference, age, self-reported weight, self-reported oral health status and self-reported race or ethnicity. The candidate prediction models were in a tree format; they had similar tree structures and differed only in terms of the final branches. After validation, the AUCs reduced slightly, ranging from 0.68 to 0.72 (Table 2). We selected the prediction model with the best face validity as the best model, as all eight models performed similarly and only differed in terms of size. The extra information needed was self-reported information, which was easy to collect in the model we selected compared with other candidate prediction models. The final model included the five predictors: waist circumference, age, self-reported oral health status, self-reported weight and self-reported race or ethnicity (Fig. 1). The *P* value from the Hosmer-Lemeshow goodness-of-fit test was close to 1.0 for both the internal and external validation data. We used the CART method to identify periodontal disease as an important predictor, but it was not retained in the final prediction model.

Fig. 1 shows the questions that dental care providers need to ask and in what sequence. The process of implementing the clinical guideline begins with asking the participant to self-measure or self-report his or her waist circumference to see if it is greater than 90 cm. If the answer is »Yes,« the next question is »Is the patient older than 45 years?« If the answer is »Yes,« this patient

BOX 1

List of final predictors selected by means of a statistical software program (TreeNet, Salford Systems, San Diego).

- Periodontal disease
- Self-reported race or ethnicity
- Self-reported weight
- Self-reported oral health status
- Self-reported age
- Poverty income ratio
- Education level
- Time since last medical visit
- Congestive heart failure
- Hypertension
- Time since last visit to a dentist or dental hygienist
- Physical activity
- Body mass index (kilograms per square centimeter)
- Waist circumference (cm)
- Standing height (cm)
- Sum of decayed, missing and filled permanent surfaces
- Serum cholesterol (milligrams per deciliter)
- Serum triglycerides (mg/dL)
- Serum high density lipoprotein cholesterol (mg/dL)
- Serum C-reactive protein (mg/dL)

BOX 2

Clinical guideline for predicting undiagnosed diabetes.

STEP ONE

Obtain patient information on the following:

- self-reported or self-measured waist circumference
- self-reported age
- self-reported weight
- self-perceived oral health status
- self-reported race or ethnicity

STEP TWO

Using this patient information, follow the flowchart (Figure) to determine the patient's risk of having undiagnosed diabetes

STEP THREE

To facilitate clinical referral, also determine the following:

- the patient's level of periodontal disease
- the patient's family history of diabetes

STEP FOUR

Perform a screening test or refer the patient to a physician for a screening test

STEP FIVE

Enter the screening test results into the patient's chart and counsel the patient accordingly on how to control his or her diabetes

CLINICAL IMPLICATIONS

This clinical guideline could help dentists identify patients with undiagnosed diabetes, resulting in the early identification of dental patients who require treatment for diabetes and, thus, reduce morbidity and health care costs.

belongs to the subset population with 5.0 percent risk of having undiagnosed diabetes. If the patient's waist circumference is less than 90 cm but he or she is older than 36 years and has poor self-reported oral health, he or she belongs to the subset population with 3.0 percent risk of having undiagnosed diabetes. Furthermore, if the patient weighs more than 150 pounds, his or her risk of having undiagnosed diabetes increases from 3.0 to 7.0 percent.

We originally identified periodontal disease as one of the important predictors on the basis of its overall contribution to the regression model. However, the results of analysis via the CART method indicated that we should not include it in the final model because it is correlated with other variables that we did include in the final model. If a dental care provider knows a patient's periodontal disease status, he or she could use this information to help identify patients at high risk of having undiagnosed diabetes. In each subgroup, we further compared the risk of having undiagnosed diabetes between participants with periodontal disease and those without periodontal disease. In the following two subsets of the study population, participants with periodontal disease had a much higher risk of having undiagnosed diabetes than did healthy people (those without periodontal disease): participants who had a waist circumference of greater than 97 cm, were younger than 45 years and identified as nonwhite (estimated risks were 6.7 percent for people with periodontal disease and 3.2 percent for people without periodontal disease) and participants who had a waist circumference of between 90 and 97 cm, were younger than 45 years and were identified as nonwhite (estimated risks were 4.6 percent for people with periodontal disease, and 0.7 percent for those without periodontal disease). Besides asking the questions shown in Fig. 1, we also recommend asking patients about their families' histories of diabetes since the answers have important clinical implications.

Discussion

We developed a clinical guideline to help dental care providers identify undiagnosed diabetes in their dental patients. Given the overall low prevalence of undiagnosed diabetes (2.6 percent) in our study population, the predicted probability was relatively low (the estimated risk ranged from 0.1 to 9.1 percent) (Fig. 1). The prediction model, however, can differentiate well among participants with different risks of having undiagnosed diabetes, with a

TABLE 1

Descriptive analysis of the training and testing data sets.

PREDICTOR VARIABLE	TRAINING DATA SET (N = 7,545) (MEAN NO. [%])	INTERNAL VALIDATION DATA SET (N = 7,545) (MEAN NO. [%])	EXTERNAL VALIDATION DATA SET (N = 2,400) (MEAN NO. [%])
Undiagnosed Diabetes			
Yes	194 (2.6)	247 (3.3)	51 (2.1)
No	7,351 (97.4)	7,298 (96.7)	2,349 (97.9)
Age (Years)			
> 30	5,914 (78.4)	5,919 (78.4)	1,536 (64.0)
≤ 30	1,631 (21.6)	1,626 (21.6)	864 (36.0)
> 36	4,988 (66.1)	4,939 (65.5)	1,316 (54.8)
≤ 36	2,557 (33.9)	2,606 (34.5)	1,084 (45.2)
> 45	3,842 (50.9)	3,800 (50.4)	1,088 (45.3)
≤ 45	3,703 (49.1)	3,745 (49.6)	1,312 (54.7)
Have Congestive Heart Failure			
Yes	301 (4.0)	254 (3.4)	NA*
No	7,244 (96.0)	7,291 (96.6)	NA
Have Hypertension			
Yes	2,123 (28.1)	2,078 (27.5)	NA
No	5,422 (71.9)	5,467 (72.5)	NA
Have Periodontal Disease			
Yes	2,315 (30.7)	2,251 (29.8)	NA
No	5,230 (69.3)	5,294 (70.2)	NA
Self-Reported Weight (Pounds)			
> 150	4,710 (62.4)	4,727 (62.7)	1,660 (69.2)
≤ 150	2,835 (37.6)	2,818 (37.3)	740 (30.8)
Physical Activity Levels of Men or Women of the Same Age			
Same level			
Yes	3,379 (44.8)	3,397 (45.0)	NA
No	4,166 (55.2)	4,148 (55.0)	NA
Less			
Yes	1,628 (21.6)	1,654 (21.9)	NA
No	5,917 (78.4)	5,891 (78.1)	NA
More			
Yes	1,628 (21.6)	1,654 (21.9)	NA
No	5,917 (78.4)	5,891 (78.1)	NA
Poverty Income Ratio			
> 0.9	5,411 (71.7)	5,372 (71.2)	NA
≤ 0.9	2,134 (28.3)	2,173 (28.8)	NA
Sum of Decayed, Missing and Filled Permanent Surfaces (No.)			
> 6	4,780 (63.4)	4,823 (63.9)	NA
≤ 6	2,765 (36.6)	2,722 (36.1)	NA
Body Mass Index (Kilograms per Square Centimeter)			
> 27	3,564 (47.2)	3,673 (48.7)	NA
≤ 27	3,981 (52.8)	3,872 (51.3)	NA
Height (cm)			
> 162	5,050 (66.9)	5,075 (67.3)	NA
≤ 162	2,495 (33.1)	2,470 (32.7)	NA
Waist Circumference (cm)			
> 97	2,767 (36.7)	2,783 (36.9)	1,090 (45.4)
≤ 97	4,778 (63.3)	4,762 (63.1)	1,310 (54.6)
> 89	4,274 (56.6)	4,304 (57.0)	1,514 (63.1)
≤ 89	3,271 (43.4)	3,241 (43.0)	886 (36.9)

TABLE 1 (CONTINUED)

PREDICTOR VARIABLE	TRAINING DATA SET (N = 7,545) (MEAN NO. [%])	INTERNAL VALIDATION DATA SET (N = 7,545) (MEAN NO. [%])	EXTERNAL VALIDATION DATA SET (N = 2,400) (MEAN NO. [%])
Time Since Last Dental Visit (Years)			
> 1	2,965 (39.3)	3,027 (40.1)	NA
≤ 1	4,580 (60.7)	4,518 (59.9)	NA
Self-Reported Oral Health Status			
Excellent, good or fair	5,418 (71.8)	5,453 (72.3)	1,958 (81.6)
Poor	2,127 (28.2)	2,092 (27.7)	442 (18.4)
Self-Reported Race or Ethnicity			
Non-Hispanic white			
Yes	3,175 (42.1)	3,139 (41.6)	1,181 (49.2)
No	4,370 (57.9)	4,406 (58.4)	1,219 (50.8)
Non-Hispanic black			
Yes	2,040 (27.0)	2,058 (27.3)	546 (22.8)
No	5,505 (73.0)	5,487 (72.7)	1,854 (77.2)
Mexican American			
Yes	2,017 (26.7)	2,059 (27.3)	534 (22.2)
No	5,528 (73.3)	5,486 (72.7)	1,866 (77.8)
Other			
Yes	313 (4.1)	289 (3.8)	69 (2.9)
No	7,232 (95.9)	7,256 (96.2)	2,331 (97.1)
Education Level			
Highest grade or year of regular school			
> 6	6,355 (84.2)	6,372 (84.5)	NA
≤ 6	1,190 (15.8)	1,173 (15.5)	NA
> 12	2,137 (28.3)	2,151 (28.5)	NA
≤ 12	5,408 (71.7)	5,394 (71.5)	NA
Time Since Last Medical Visit (Years)			
> 1	1,388 (18.4)	1,466 (19.4)	NA
≤ 1	6,157 (81.6)	6,079 (80.6)	NA

* Not applicable

TABLE 2

Performance of the clinical guideline in training and testing data sets.

MEASURES OF MODEL PERFORMANCE	TRAINING DATA SET	10-FOLD CROSS-VALIDATION	INTERNAL VALIDATION DATA SET	EXTERNAL VALIDATION DATA SET
Sensitivity	91.2	82.4	79.8	82.4
Specificity	52.2	51.8	52.1	52.8
Area Under the Receiver Operating Characteristic Curve	0.74	0.68	0.70	0.72

sensitivity of 82.4 percent, a specificity of 52.8 percent and an AUC of 0.72. Among five selected predictors in the prediction model (that is, waist circumference, age, self-reported oral health status, self-reported weight and self-reported race or ethnicity), age and waist circumference were the most important predictors. We used the CART method to identify periodontal disease as an important predictor, but it did not remain in the final prediction model. However, in certain subgroups such as nonwhite participants

Clinical guideline for predicting undiagnosed diabetes

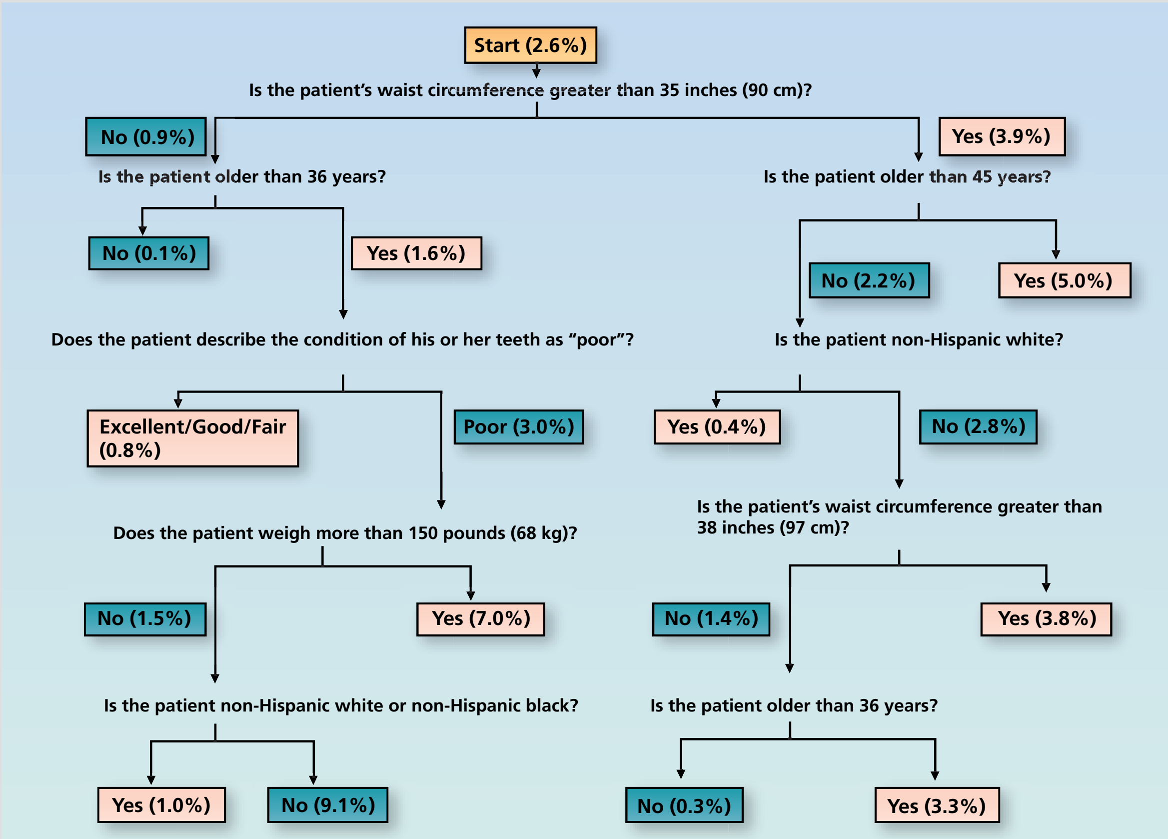

Fig. 1. *Clinical guideline for predicting undiiagnosed diabetes in the general population. Percentages in parentheses are the average risk of having undiagnosed diabetes in each subset of the population. cm: Centimeters. kg: Kilograms.*

younger than 45 years with a waist circumference greater than 90 cm, participants with periodontal disease had a much higher risk of having undiagnosed diabetes compared with participants without periodontal disease.

Box 2 is a summary of our proposed clinical guideline for predicting undiagnosed diabetes. We based steps one and two on our CART analysis results, and steps three, four and five are our recommended clinical procedures. Self-reported or self-measured waist circumference has a high correlation with measured waist circumference (r = 0.7-0.9) (32,33). Therefore, we recommend using self-reported or self-measured waist circumference for practical reasons. Although using them might affect the prediction accuracy, the amount of bias likely would be minimal owing to the high correlation between self-reported and measured waist circumference. The results of our study helped us create a clinical guideline that dental care providers can use to identify patients with undiagnosed diabetes by means of a periodontal disease examination, as well as asking questions about self-reported or self-measured waist circumference, self-reported age, self-reported weight, self-reported oral health status, self-reported race or ethnicity and family history of diabetes. Rather than choose potential risk factors a priori, we collected reported risk factors for diabetes on the basis of our literature review. Using CART can help investigators avoid the difficulty of including higher order interaction terms that often occur in traditional logistic regression models. We also considered a wider range of variables, such as demographic, socioeconomic, dietary and health-related variables, as well as biomarker and body composition measurements. Compared with previous studies, we considered using more clinical dental variables such as self-reported oral health status; the World Health Organization caries diagnostic criteria for decayed, missing and filled surfaces; and time since last dental visit. We considered family history of diabetes as one of the potential predictors in the beginning of our study, but results of analysis via the CART method did not include it in the final prediction model. Given the clinical importance of the medical history, however, dental care providers still should determine if there is a family history of diabetes (34).

To date, few studies' investigators have generated prediction models for a diabetes screening program specifically for the dental setting (8,14). However, the investigators in these studies did not consider waist circumference as one of the predictors for their models that could be used to identify undiagnosed diabetes specifically in the dental setting (8,14). Waist circumference has been shown in previous studies to be associated with a risk of developing diabetes, independently of body mass index (35,36). It is not surprising that waist circumference and age were the most important predictors in our model, given the obesity epidemic in the United States (37,38). Several studies' investigators have used CART methods to predict undiagnosed diabetes in the general medical care setting, but these studies' investigators did not consider oral health components (5-7,39,40). In a recent survey of a random sample of general dentists in the United States, the results showed that 76.6 percent of responding dentists thought it was important to conduct a screening for diabetes, and 83.4 percent of responding dentists were willing to conduct a medical screening that might yield immediate results (41). Our clinical guideline outlined in Fig. 1 and Box 2 could serve as a tool to help a dentist's decision-making process.

The main limitation of our study was the relative low specificity of the prediction model. A test with relatively low specificity usually leads to higher numbers of false-positive results. Even though we found most of the undiagnosed diabetes cases in the high-risk group, we still may have a few people who have undiagnosed diabetes but are classified as not having undiagnosed diabetes per our flowchart (false-negative diagnosis). Given the low cost of this prediction model and the consequences to patients of having undiagnosed diabetes, we recommend using a prediction model to determine a patient's risk of having undiagnosed diabetes that has a relatively high sensitivity and that could be used in combination with the screening test for diabetes (4). More work is needed to improve the prediction model, such as the use of reclassification measures to evaluate and compare predictive models, a change in cutoff points or the incorporation of questions related to family history of diabetes and periodontal disease (42). A false-positive diagnosis, however, will lead only to the patient's undergoing a screening test for diabetes and not an invasive procedure.

Another limitation is that we may have underestimated the predictability of our model, since the prevalence of periodontitis in both NHANES 2003-2004 and NHANES III, which represent the general population and are known to use conservative protocols to measure the prevalence of periodontitis, has been shown to be lower than it is in the actual dental patient population (43). Therefore, in dental patients, especially among patients with periodontal disease, the prevalence of undiagnosed diabetes can be expected to be higher. A fasting plasma glucose test has 58 percent sensitivity and 77 percent specificity, with cutoff points for both sensitivity and specificity at 89 mg/dl (44). Hence, we may have misclassified some patients with undiagnosed diabetes, which could have compromised the predictability of this model.

Other limitations to our study were that the analyses did not use weights to account for the clustered sampling in the study design, and that NHANES III is a national survey and all of the information was collected by means of a cross-sectional design. Further validation studies using larger longitudinal data sets are needed to reconfirm our model, especially the predictability of obesity-related variables in patients who may have undiagnosed diabetes and for the effects of periodontal disease in patients who are of normal weight and those who are obese.

Lastly, there still are some barriers to incorporating diabetes screening into routine dental practice. In previous studies (41,45,46), patients' willingness and their dentists' lack of adequate education and knowledge were reported as major concerns. There is an ongoing debate regarding dentists' responsibilities and the scope of future dental practice (10,37,47,48). The correlation between dental patients' overall general health and oral health, however, is a major trend in dentistry, and the identification of diabetes would fit within that trend. Dentists need to be more active in helping their patients control chronic systemic disease because it can help patients control chronic dental diseases.

Conclusions

We developed a clinical guideline that predicts the probability that a dental patient has undiagnosed diabetes. At the initial dental visit, the patient's self-reported waist circumference, age, oral health status, weight and race or ethnicity are collected and interpreted by following the guidelines in our flowchart. The guideline has a sensitivity of 82.4 percent and a specificity of 52.8 percent. It is inexpensive and noninvasive. In addition to considering periodontal disease status from the patient examination and family history of diabetes, dental care providers can determine whether to refer patients to physicians or conduct a screening test in the office.

Early diagnosis of diabetes in the dental setting can help improve the patient's oral health and overall health status by helping patients avoid or reduce complications from diabetes. If a clinical guideline such as ours could be used in dental practice settings, the resulting early treatment for diabetes and control of risk factors for diabetes by dental care providers could improve the general health status of patients with diabetes, thus reducing morbidity and health care costs. n

Disclosure. None of the authors reported any disclosures.

Dr. Li was supported by a traineeship in Oral Health Research Statistics by the Task Force on Design and Analysis in Oral Health Research (»www.taskforceondesign.org/index.php«) and was supported partly by a presidential scholarship from Harvard School of Public Health.

Acknowledgement

The authors thank Nancy Cook, ScD, and E. Francis Cook, ScD, both of the Department of Epidemiology, Harvard School of Public Health, Boston, for their kind support and insightful advice regarding this project.

Abstract (dansk)

Udvikling af klinisk retningslinie for forudsigelse af udiagnosticeret diabetes hos patienter I tandlægepraksis

Baggrund – i 2007 blev 17.9 millioner mennesker i USA diagnosticeret som diabetikere, og 5.7 millioner havde udiagnosticeret diabetes. Forfatterne udarbejdede klinisk retningslinie som hjælp til tandlægers mulighed for at identificere patienter med udiagnosticeret diabetes.

Metoder – Forfatterne benyttede klassifikation- og regressionstræ (CART) metoder for at udvikle forskellige modeller til at forudsige diabetes ved brug af data fra Den Tredje Nationale Sundheds- og Ernæringsundersøgelse (NHANES III) (1988-1994) og data fra NHANES 2003-2004 som ekstern validering. De klassificerede deltagere, som svarede nej til spørgsmålet, »har en læge nogensinde fortalt dig, at du har diabetes?« og som havde et fastende plasma glukoseniveau, der var større end eller lig med 126 mg pr. dl, til at have udiagnosticeret diabetes. Forfatterne benyttede orale undersøgelsesdata vedrørende tilstedeværelse eller fravær af marginal parodontitis og taljemål, såvel som data om deltagernes selvrapporterede mundhulestatus, vægt, alder, slægtshistorie, race og etnicitet. Forfatterne valgte den bedste prædiktionsmodel vha. 10-fold kryds validering samt interne og eksterne valideringsmetoder, der vurderede hver prædiktionsmodel ved at sammenligne sensitivitet, specificitet og areal under ROC-kurve (N=7,545).

Resultater – Forfatternes endelige kliniske retningslinie til forudsigelse af udiagnosticeret diabetes hos tandlægepatienter havde en sensitivitet på 82,4 procent, en specificitet på 52,8 procent og et areal under ROC-kurve på 0,72. De fandt, at taljemål, alder, selvrapporteret tandsundhed, selvrapporteret race og etnicitet, selvrapporteret information om vægt kunne bruges til at forudsige risikoen for udiagnosticeret diabetes (variationsbredde 0,1 til 9,1 procent).

Konklusion – Tandlægepraksis kunne overveje at bruge en klinisk retningslinie, som inkluderer følgende prædiktorer: taljemål, alder, egen opfattelse af tandsundhed, egen opfattelse af vægt og selvrapporteret race eller etnicitet såvel som enhver yderligere information vedrørende parodontal status og slægtshistorie vedrørende diabetes.

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