Published in final edited form as:
J Am Dent Assoc. 2012 July ; 143(7): 756–763.

Early childhood caries screening tools:

A comparison of four approaches

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Abstract

Background—Early childhood caries (ECC) is prevalent and consequential. Risk assessment tools have been proposed that can be used to identify children who require intensive interventions. In this study, the authors compare four approaches for identifying children needing early and intensive intervention to prevent or minimize caries experience for their accuracy and clinical usefulness.

Methods—The authors screened 229 predominantly low-income Hispanic children younger than 3 years with ECC and 242 without ECC by using the American Academy of Pediatric Dentistry's Caries-risk Assessment Tool (CAT) and the optional screening measure of culturing *Streptococcus mutans*. The authors compared four approaches (CAT, CAT minus socioeconomic status, CAT minus socioeconomic status plus mutans streptococci [MS] and MS alone) for accuracy and clinical usefulness.

Results—The results of the CAT demonstrated high sensitivity (100.0 percent) and negative predictive value (NPV) (100.0 percent) but low specificity (2.9 percent) and positive predictive value (PPV) (49.4 percent). The MS culture alone had the highest combination of accuracy and clinical usefulness (sensitivity, 86.5 percent; specificity, 93.4 percent; PPV, 92.5 percent; NPV, 87.9 percent). When we removed the socioeconomic status element, the CAT's performance improved.

Conclusions—Salivary culture of MS alone in a population of young, low-income Hispanic children outperformed the CAT and variations on the CAT for test accuracy (sensitivity and specificity) and clinical usefulness (predictive values).

Clinical Implications—Screening for ECC by using salivary MS cultures and variations on the CAT are promising approaches for identifying children who need early and intensive intervention to prevent or minimize caries experience.

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Disclosure. None of the authors reported any disclosures.

Keywords

Early childhood caries; risk assessment; pediatric dentistry; public health; community dentistry; Hispanic Americans

Prioritizing young children who have the greatest need of early dental intervention requires the use of a reliable and clinically useful risk assessment method. Since 1978, the American Academy of Pediatric Dentistry (AAPD) has proposed and refined its policy on classifications of, consequences of and preventive strategies for early childhood caries (ECC).[1] In 2006, AAPD introduced the Caries-risk Assessment Tool (CAT).[2] Cariologists,[3] other dental associations (for example, the American Dental Association[4]) and dental manufacturers (for example, CariFree[5]) have developed similar multifactorial clinical tools, demonstrating how actively the field of caries risk assessment is being adopted and used. The developers of these efforts seek to refine a trouble-free screening test to enable health care providers, Early Head Start staff members, Special Supplemental Nutrition Program for Women Infants and Children (WIC) staff members and others involved with young children to identify young children at risk of developing caries.

Any sign of dental caries in children younger than 3 years is defined as severe early childhood caries (S-ECC).[6] S-ECC is prevalent among U.S. children. An estimated one in 10 two-year-olds (10.9 percent) have frank caries[7] and a higher percentage of children have earlier signs of disease, such as visually evident enamel decalcifications or voluminous soft plaque accumulation. Caries experience increases with age; an aggregate of 28 percent of 2- to 5-year-olds have visually evident caries.[8] ECC can affect children's health and function and negatively affects families' welfare and communities' resources.[9] Intervention early in the disease process is desirable because timely and effective management can arrest the caries process and obviate, minimize or delay the need for restorative care. Restoring the teeth of young children who "lack cooperative ability"[10] owing to their developmental stage is challenging for clinicians, the children and their caregivers and often requires use of general anesthetic,[1,11] which can involve the "potential seriousness of anesthesia-induced developmental neurotoxicity."[12] Despite a high level of need, only a small percentage of children younger than 4 years (11.6 percent of U.S. children in 2007[13]) receive dental care. As a result of the difficulties of providing restorative care and limited access to care for young children, 73 percent of preschool-aged children in the United States who have had caries have untreated disease.[8]

A clinically useful screening test used to identify children at high risk of experiencing caries should be simple, rapid, inexpensive relative to the direct cost of the disease, usable by a variety of providers, valid and reliable, as well as sensitive and specific.[14] Although some conditions, such as streptococcal pharyngitis, may be identified quickly with a rapid antigen detection test, the multifactorial nature of caries as a biopsychosocial condition[15] and its multiple bacterial components limit the use of any single test for determining caries risk. Nonetheless, *Streptococcus mutans* is correlated highly with the caries process[16,17] and culturing mutans streptococci (MS) is included in the CAT as an optional screening measure. Biological evidence for MS specificity in caries initiation is evident in ecological modeling,[18] in the positive relationship between MS acquisition by infants and maternal salivary levels,[19,20] and in the finding that preventive measures in mothers that interrupt MS transmission decrease caries occurrence in children at 3 years of age[21] and across subsequent years of growth and development.[22,23] Nevertheless, microbiological screening for MS in saliva has been used to only a small degree in infants and toddlers compared with its use in older children, owing to the difficulties of collecting stimulated saliva.[24–28] In young children, however, collecting unstimulated saliva from the dorsum of the tongue

using a sterile tongue depressor for transfer of samples onto selective agar media is sufficient.[24,27]

The results of investigations of sensitivities, specificities and predictive values of such MS testing have established age as a clinically significant factor in the link between caries prevalence and MS levels, with younger children showing a stronger correlation between MS levels and caries.[29] Consistent with the findings of Baehni and Guggenheim,[30] specificity was higher than sensitivity, depending on MS cutoff levels, suggesting that cariogenic bacteria are a necessary but not sufficient condition for caries in young children.[29] Furthermore, the accuracy of MS testing (measured as sensitivity and specificity) decreases as age and MS cutoffs increase,[29] supporting the idea that the clinical usefulness of MS testing (measured as positive predictive values [PPVs] and negative predictive values [NPVs]) may be greatest in young children. In addition to MS, models of caries association and prediction typically are used to collect data regarding a variety of dietary, fluoride and social variables.[16] These more expansive models can demonstrate higher correlations with caries status and reduce the amount of variance explained by MS.

We conducted this study to examine the accuracy and clinical usefulness of four caries-risk assessment approaches: the CAT alone (without its optional MS screening measure), MS alone, the CAT excluding the socioeconomic status (SES) risk factor and the CAT excluding the SES risk factor supplemented with MS in screening children younger than 3 years for S-ECC.

METHODS

Setting, participant recruitment and eligibility

After obtaining study approval by the Columbia University Medical Center's Institutional Review Board, we prospectively recruited patients who were new to the pediatric dental clinic at the time of their initial nonurgent dental visit. The clinic serves residents of three communities with fluoridated water in the northern part of the New York City borough Manhattan (Harlem, Washington Heights and Inwood), which have predominantly low-income and Hispanic populations. Our inclusion criteria were that the child had never been seen by a dentist, was 3 years or younger and had all four maxillary primary incisors. The child's primary caregiver provided written informed consent before we began the dental examination. A pediatric dentist (R.K.Y.) fully explained the study to caregivers, including the study's risks and discomforts, as well as its benefits to the child.

Study procedures

The study visit consisted of a caregiver interview conducted by a dental assistant followed by a dental assessment conducted by the pediatric dentist. Using the CAT form and following instructions for its use provided by the AAPD, the dental assistant obtained the nonclinical information necessary to complete the CAT, including information about the child's general health, allergies, intake of medicines, between-meal sugar exposures, maternal caries activity, topical fluoride exposure and caregivers' SES. We obtained clinical information required to complete the CAT by means of the dental examination, in which we assessed visible plaque and evidence of decalcifications and caries and collected saliva samples for MS culturing. The pediatric dentist was masked to the nonclinical CAT assessment indicators at the time of the dental examination.

We scored plaque on the mesiofacial, straight facial and distofacial surfaces of four maxillary incisors by using a modified version of the Silness and Löe plaque index criteria.[31] On the basis of the mean plaque score of the four teeth, we classified a child as having a low (score 0–3), moderate (score 4–6) or high (score 7–8) plaque score. One

pediatric dentist (R.K.Y.) assessed the presence of caries by means of visual inspection and the use of a dental mirror and illumination after visible plaque was removed with a dry 2- by 2-inch cotton-filled gauze sponge. We documented decalcifications and frank caries for all incisor surfaces, and we classified the children as having or not having caries. Because only the pediatric dentist conducted all of the dental examinations, his techniques were not calibrated for the plaque and caries indexes. Instead, we obtained photographs of the first 20 patients' teeth and used these photographs to establish intrarater reliability of plaque and dental caries scoring.

To assess MS levels, we collected unstimulated saliva by pressing a sterile tongue depressor onto the dorsal surface of the patient's tongue and then impressed it onto an MS-selective agar medium (mitis salivarius, kanamycin, bacitracin agar, Fisher Scientific, Pittsburgh).[32–34] We incubated saliva samples for 48 hours at 98.6…F in a countertop incubator (Complete Culture Control Incubator, Model 132000, Boekel Scientific, Troy, Mich.) after we placed them in a tightly sealed plastic bag inflated with air exhaled by the pediatric dentist to establish a partially anaerobic environment. He evaluated each plate to determine the number of characteristic colony-forming units (CFUs) and categorized the MS on each plate as low (no detectable CFUs), moderate (1 to 50 CFUs), high (51 to 100 CFUs) or too numerous to count (more than 100 CFUs).

After the dental examination, we performed prophylaxis by using a toothbrush dipped in a chlorhexidine gluconate oral rinse, 0.12 percent. We then administered a topical fluoride treatment with acidulated phosphate fluoride, 1.23 percent. We treated children who had visually evident decalcifications by using sodium fluoride white varnish, 5 percent. On the basis of findings of the interview and examination, we informed primary caregivers about age-appropriate oral hygiene and preventive dental care and offered follow-up visits. We scheduled children categorized to be at high risk of experiencing caries by means of the CAT assessment for a follow-up appointment at three months. We scheduled those categorized at low to moderate risk for a follow-up appointment at six months. We scheduled children with dental caries for dental treatment as needed.

Sample size

Analysis of relative sensitivities (the percentage of people who are classified correctly as positive by means of a screening method) and specificities (the percentage of people who are classified correctly as negative by means of a screening method) required that we use tests that compared proportions of children with S-ECC and those without S-ECC who were identified correctly by means of each of the four screening methods. We selected a sample size to provide an α level of .05 and a statistical power of 0.80 to detect a 10 percent difference in proportions between any two tests and a 30 percent proportion of discordant pairs. On the basis of these assumptions, we determined that there needed to be 229 patients in the group with S-ECC and in the group without S-ECC. We recruited every child who met the study inclusion criteria to participate in our prospective cross-sectional study until we enrolled a minimum of 229 children in each group.

Statistical methods and analyses

We entered data into a database (Access 2003, Microsoft, Redmond, Wash.) and checked for entry errors. We stored the data on a password-protected computer that was backed up daily. We performed statistical analyses by using statistical software (SAS, Version 9.2, SAS Institute, Cary, N.C.). We used the Cohen κ statistic to test intrarater reliability in assessment of plaque and caries occurrence (presence, extent and pattern). We compared demographic characteristics of children with S-ECC and children without S-ECC by using χ^2 analyses. We calculated sensitivities, specificities and predictive values for each caries-

risk indicator and each risk assessment approach. We conducted a sensitivity analysis of predictive values by using prevalence rates ranging from 5 to 75 percent to examine the utility of each S-ECC approach for screening young children in communities with varying prevalence of S-ECC.

RESULTS

From August 2006 through September 2009, we enrolled 471 children younger than 3 years (36 months) (mean [standard deviation] age, 24.7 [6.6] months; age range, 1.9–36.0 months; 29 percent male and 71 percent female) in the study and included 229 children (48.6 percent) with S-ECC and 242 children (51.4 percent) without S-ECC. Most of the patients in the sample were Hispanic and were the children of recent immigrants, which reflected the population served by the clinic. We found no differences between the groups in terms of sex ($P = .32$). However, younger children (≤ 18 months) received a diagnosis of S-ECC less frequently than did older children (18.2 percent versus 10.9 percent; $P = .03$). Intrarater reliability of plaque and caries status for the first 20 patients was high ($\kappa = 0.87$).

Table 1 shows the CAT characteristics of the children with S-ECC and those without S-ECC and lists the risk factors in rank order of their occurrence. Most children with S-ECC had mothers with recent caries experience (57.2 percent), moderate or higher MS levels (86.5 percent) and gingivitis or visible plaque (94.8 percent). Children without S-ECC had fewer than three between-meal sugar exposures (86.4 percent) and had lower than moderate MS levels (93.4 percent). Both groups of children were part of families with low socioeconomic status (100 percent with caries, 97.5 percent without caries) and received topical fluoride exposure through the New York City fluoridated water system (92.6 percent with caries, 100 percent without caries).

Table 2 presents the sensitivity, specificity, PPV and NPV for each CAT risk element and each of the four risk assessment approaches. The CAT elements with the highest sensitivity were low SES (100.0 percent), gingivitis or visible plaque (94.8 percent) and moderate or higher MS level (86.5 percent). Elements with highest specificity were suboptimal fluoride exposure (100 percent), three or more between-meal sugar exposures (86.4 percent), having special health care needs (97.5 percent), poor salivary flow (99.2 percent), enamel hypoplasia (97.1 percent) and moderate or higher levels of MS (93.4 percent). Because demineralization is a precursor of cavitation, it may be considered either a risk factor for caries or an alternative outcome measure.

PPVs for the CAT elements were highest for suboptimal fluoride exposure (100 percent) and moderate or higher MS levels (92.5 percent), whereas NPVs were highest for low SES (100 percent), gingivitis or visible plaque (93.1 percent) and moderate or higher MS levels (87.9 percent). The CAT elements with the highest overall diagnostic performance for test sensitivity, specificity and predictive values were gingivitis or visible plaque and moderate or higher MS levels.

Test accuracy varied among the four caries-risk assessment approaches. Although the CAT risk assessment without the optional MS screening measure was highly sensitive (100 percent), it lacked specificity (2.9 percent). When we removed SES status as an assessment criterion, specificity improved (68.6 percent) but sensitivity decreased to 85.6 percent. Overall, clinical usefulness was highest for MS, with a PPV of 92.5 percent and an NPV of 87.9 percent.

Table 3 provides a sensitivity analysis for testing clinical usefulness for each of the four caries-risk assessment approaches when community caries prevalence rates range from 5 to 75 percent. The CAT's PPVs ranged from 5.1 percent at 5 percent S-ECC prevalence to 75.6

percent at 75 percent S-ECC prevalence. All NPVs for the CAT were 100 percent. Overall, MS had the highest PPVs.

DISCUSSION

In our study, we evaluated the accuracy and clinical usefulness of existing screening tools that have been developed to identify young children according to S-ECC risk and status. Our results confirm that caries screening has the potential to identify young children who may be at caries risk and support the value of separating population-level screening variables (for example, SES) from individual-specific screening variables (for example, between-meal sugar exposures).

Since 2002, AAPD has called for caries-risk assessment in infants, children and adolescents as "an essential element of contemporary clinical care" and has advanced the CAT as a "tool for assessing caries risk."[2] On the basis of "a set of physical, environmental, and general health factors,"[2] the CAT is offered to clinicians as an initial approach "toward incorporating available evidence into a concise, practical tool to assist both dental and non-dental health care providers."[2] This tool has not been tested, and no report of its usefulness as measured by means of accuracy (sensitivity, specificity) or clinical usefulness (predictive values under varying levels of disease prevalence) for either caries presence (association) or incidence (prediction) has been published previously. In 2011, the CAT was refined further by reconsidering fluoride exposure as being composed of fluoridated toothpastes, prescribed fluoride supplements and fluoridated water by including the presence of caries, as well as decalcification, as risk factors; by adding immigrant status as a risk factor; and by incorporating questions regarding bottle use in and establishment of a dental home for children younger than 3 years. These changes retain the basic form, concept and evidentiary base as in the original CAT and maintain the inclusion of multiple factors at individual, family and population levels.

Conceptually, the CAT provides a comprehensive and well-ordered educational framework; however, the CAT incorporates both population-level and individual-level factors and, therefore, is not practical to use in low-income populations because all children from low-income families are classified automatically as being at high risk. Thus, using the CAT in programs that exclusively serve low-income children such as Early Head Start and WIC would negate use of this variable. Epidemiologic evidence indicates that young children living in poverty have higher caries rates than do more affluent children, yet most of those living in poverty had not experienced ECC (58.7 percent) or S-ECC (81.4 percent).[7]

After we discounted visually confirmed demineralization as a tautology and low SES as universally present in the study population, the strongest risk factors in the CAT (without the optional MS screening measure) were gingivitis or visible plaque, between-meal sugar exposures, recent maternal caries experience and suboptimal fluoride exposure. MS assessment alone had the highest overall sensitivity (86.5 percent), specificity (93.4 percent) and predictive values (92.5 percent PPV and 87.9 percent NPV) of all factors, suggesting that it may be superior to the CAT for risk assessment, although not for educational value. Adding MS culturing to the CAT resulted in little improvement in overall CAT accuracy or usefulness because its influence was overshadowed by low SES for children with S-ECC and by suboptimal fluoride exposure in our fluoridated community for children without S-ECC. When we assessed the CAT after excluding caregivers' SES, its accuracy improved only slightly by adding MS.

There are limitations to extrapolating our findings to the general population. The study population was composed almost exclusively of low-income, minority (primarily Hispanic)

and immigrant children, which limits study generalizability to more diverse populations. Our study population of children younger than 3 years from August 2006 through September 2009 had a caries prevalence of 48.6 percent, which was higher than the national average for children of this age (31.4 percent in 2007)[7] and somewhat lower than the 66.0 percent community prevalence for 3- and 4-year olds noted during a 1995 to 1997 community survey.[35]

As clinicians consider findings of this study for their patient populations, they should be aware that measures of each risk assessment's sensitivity and specificity will not change across populations, but measures of its predictive values will change with the population's underlying S-ECC prevalence. According to Bayes theorem,[36] as S-ECC prevalence decreases, the PPV decreases and the NPV increases. Future research concerning tests of the caries risk models in more racially and ethnically diverse populations, as well as in nonclinical settings (for example, Early Head Start centers), is warranted.

Tanzer[16] substantiates salivary MS assay "as a surrogate for plaque monitoring" that is especially "attractive for the study of potentially uncooperative young children." Commercial kits that use selective growth media are available for measuring salivary MS levels semiquantitatively as low, moderate, high and very high. These categories reflect approximate logarithmic increments in MS titers in saliva. Various media and sampling techniques yield somewhat different levels of MS growth, and mitis-salivarius-bacitracin agar is regarded as a satisfactory growth medium.[32,33,37]

CONCLUSIONS

Because young children are vulnerable to caries initiation and progression, effective evidence-based screening strategies are needed to identify those at risk and to intervene effectively to prevent or limit cavitations and the associated pain, infection and dysfunction. On the basis of a comparison of the CAT without MS, the CAT without SES or MS, the CAT without SES but with MS, and MS alone, we identified MS as the best screening tool, both in terms of accuracy and clinical usefulness in a population of low-income children with a caries prevalence of 48.6 percent.

Acknowledgments

This study was supported by funding from the Northeast Center for Research to Evaluate and Eliminate Dental Disparities (National Institutes of Health, National Institute of Dental and Craniofacial Research grants U54 DE014264 and U54 DE019275, Raul Garcia, principal investigator) and from the National Institutes of Health, National Center on Minority Health and Health Disparities (grant 1 RC1 MD004257-01, Burton Edelstein, principal investigator).

ABBREVIATION KEY

AAPD	American Academy of Pediatric Dentistry
CAT	Caries-risk Assessment Tool
CFU	Colony-forming unit
ECC	Early childhood caries
MS	Mutans streptococci
NPV	Negative predictive value
PPV	Positive predictive value

S-ECC	Severe early childhood caries
SES	Socioeconomic status
WIC	Special Supplemental Nutrition Program for Women Infants and Children

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TABLE 1

Characteristics of the patients with and without severe early childhood caries (S-ECC).

CARIES-RISK ASSESSMENT TOOL HIGH-RISK ELEMENT	RISK FACTOR STATUS	S-ECC PRESENT, NO. (%) (n = 229)	RISK FACTOR, RANK*	RISK FACTOR STATUS	S-ECC ABSENT, NO. (%) (n = 242)	RISK FACTOR, RANK
Dental Interview						
Suboptimal fluoride exposure	Present	17 (7.4)	6	Absent	242 (100.0)	1
≥ 3 between-meal sugar exposures	Present	37 (16.2)	5	Absent	209 (86.4)	6
Low socioeconomic status	Present	229 (100.0)	1	Absent	6 (2.5)	9
Recent maternal caries experience	Present	131 (57.2)	4	Absent	53 (21.9)	8
Special health care needs	Present	6 (2.6)	8	Absent	236 (97.5)	3
Poor salivary flow	Present	2 (0.9)	9	Absent	240 (99.2)	2
Clinical Evaluation						
> 1 area of demineralization	Present	131 (57.2)	4	Absent	242 (100.0)	1
Gingivitis or visible plaque	Present	217 (94.8)	2	Absent	162 (66.9)	7
Enamel hypoplasia	Present	12 (5.2)	7	Absent	235 (97.1)	4
Supplemental Assessment						
***Streptococcus mutans* (moderate or higher)**	Present	198 (86.5)	3	Absent	226 (93.4)	5

*1 = most frequent; 9 = least frequent.

TABLE 2

Sensitivity, specificity and predictive values of individual Caries-risk Assessment Tool (CAT) elements and caries-risk assessment approaches.*

VARIABLE	SENSITIVITY (%)	SPECIFICITY (%)	POSITIVE PREDICTIVE VALUE (%)	NEGATIVE PREDICTIVE VALUE (%)
CAT Element				
Dental interview				
Suboptimal fluoride exposure	7.4	100.0	100.0	53.3
≥ 3 between-meal sugar exposures	16.2	86.4	52.8	52.1
Low socioeconomic status	100.0	2.5	49.2	100.0
Recent maternal caries experience	57.2	21.9	40.9	35.1
Special health care needs	2.6	97.5	50.0	51.4
Poor salivary flow	0.9	99.2	50.0	51.4
Clinical evaluation				
> 1 area of demineralization	57.2	100.0	100.0	71.2
Gingivitis or visible plaque	94.8	66.9	73.1	93.1
Enamel hypoplasia	5.2	97.1	63.2	52.0
Supplemental assessment				
***Streptococcus mutans* (mutans streptococci [MS]) (moderate or higher levels)**	86.5	93.4	92.5	87.9
Caries-risk Assessment Approach CAT	100.0	2.9	49.4	100.0
MS (moderate or higher levels) alone	86.5	93.4	92.5	87.9
CAT excluding socioeconomic status risk factors	85.6	68.6	71.0	83.4
CAT excluding socioeconomic status risk factor plus MS (moderate or higher levels)	95.2	65.7	72.4	93.5

* Based on the 48.6 percent caries prevalence in the sample.

TABLE 3

Sensitivity analyses of positive and negative predictive values of severe early childhood caries (S-ECC) risk scoring approaches.

ECC RISK SCORING	S-ECC PREVALENCE (%)							
	5		25		48.6*		75	
	PPV†	NPV‡	PPV†	NPV‡	PPV†	NPV‡	PPV†	NPV‡
Caries-risk Assessment Tool (CAT)	5.1	100.0	25.6	100.0	49.4	100.0	75.6	100.0
Streptococcus mutans (Moderate or Higher Levels) Alone	40.7	99.2	81.5	95.4	92.5	87.9	97.5	69.6
CAT Excluding the Socioeconomic Status (CAT-SES)	12.5	96.9	47.6	93.5	71.0	83.4	89.1	61.2
CAT-SES Plus Streptococcus mutans (Moderate or Higher Levels)	12.7	99.6	48.0	97.6	72.4	93.5	89.3	82.0

*Prevalence of caries in the population.

†PPV: Positive predictive value.

‡NPV: Negative predictive value.