Community Dent Oral Epidemiol 2008; 36: 357–362

Community Dentistry and Oral Epidemiology

Exploring the contributions of components of caries risk assessment guidelines

James D. Bader[1], Nancy A. Perrin[2], Gerardo Maupomé[3], William A. Rush[4] and Brad D. Rindal[4]

[1]School of Dentistry and Sheps Center for Health Services Research, University of North Carolina, Chapel Hill, NC, [2]Center for Health Research, Kaiser Permanente, and Oregon Health & Science University, Portland, OR, [3]Oral Health Research Institute, Indiana University School of Dentistry, Indianapolis, IN, [4]HealthPartners Research Foundation, Minneapolis, MN, USA

Bader JD, Perrin NA, Maupomé G, Rush WA, Rindal BD. Exploring the contributions of components of caries risk assessment guidelines. Community Dent Oral Epidemiol 2008; 36: 357–362. © 2007 The Authors. Journal compilation © 2007 Blackwell Munksgaard

Abstract – *Objective:* To examine the relative contribution of current caries activity, past caries experience, and dentists' subjective assessment of caries risk classifications. *Methods:* Administrative data from two dental plans were analyzed to determine dentists' risk classification, as well as current caries activity and previous caries experience at the time of the classification. The performance of these predictors in identifying patients who would experience subsequent caries was then modeled using logistic regression. *Results:* In both plans, current caries activity alone had relatively low sensitivity and high specificity in identifying patients who would experience subsequent caries. Sensitivity improved, but at the cost of specificity when previous caries experience was included in the models. Further improvement in sensitivity accrued when dentists' subjective assessment was included, but performance was different in the two plans in terms of false-positives. *Conclusions:* Consideration of previous caries experience tends to strengthen the predictive power of caries risk assessments. Dentists' subjective assessments also tend to improve sensitivity, but overall accuracy may suffer.

Key words: caries experience; caries risk assessment; dental caries; dental outcomes

Jim Bader, Sheps Center for Health Services Research, University of North Carolina, 725 MLK Blvd, Chapel Hill, NC 27514, USA.
Tel: +1 919 966 5727
Fax: +1 919 966 3811
e-mail: Jim_bader@unc.edu

Submitted 17 December 2006;
accepted 15 March 2007

Increasingly over the past decade dentists have been urged to perform caries risk assessments (CRA) in their practices to increase the probability that patients will receive appropriate caries preventive treatment (1–5). While dentists have probably always undertaken informal, i.e. unrecorded assessments of risk of future caries in individual patients, how dentists have made these assessments is generally not well understood. Current methods for caries risk assessment include a range of objective and subjective methods. At one extreme are complex formulae requiring a variety of objective clinical and microbiological information that yield a risk score (6–9). At the opposite extreme are simple approaches that require only a dentist's subjective assessment of risk level offering little guidance for making that assessment (10).

An approach gaining in popularity represents a middle ground between complex, rigidly objective and completely subjective methods. In this approach dentists' subjective risk classifications are guided by suggestions of how current caries experience and recent caries experience, and other specific risk factors such as diet, fluoride exposure, and salivary flow, might be considered in classifying an individual patient's risk level. We have recently reported that dentists using two versions of this criteria-based, guideline-driven approach successfully classify their patients into low, moderate, and high caries risk groups (11). Our criterion for successful classification was that patients classified as being at higher risk for caries recorded higher rates of caries-related restorative services in the years subsequent to the classification, controlling for any preventive treatment.

While these findings would seem to be the validation necessary to advocate dissemination and adoption of this simple approach to CRA, some key questions about the effectiveness of its various components remain unanswered. The

doi: 10.1111/j.1600-0528.2007.00399.x

specific guidelines that we evaluated rely primarily on a classification keyed to current caries activity and prior caries experience, with all other caries risk factors used as modifiers to be applied at the dentist's discretion. An obvious question is whether consideration of prior caries experience in addition to current caries activity affords any increase in accuracy in predicting subsequent caries activity. One guideline asks dentists to consider only a patient's current caries activity, i.e. the presence or absence of non-cavitated and cavitated lesions. The other guideline asks dentists to consider both current caries activity and recent caries experience. From the extensive literature supporting caries experience as a principal risk indicator for future caries lesions (11), it is not clear which of these two considerations of a patient's caries experience will result in more accurate classifications.

Two additional related questions arise with respect to the 'dentist added' component of the caries risk assessment guidelines, i.e. the subjective assessment that may cause a dentist to depart from the risk classification that would result from a strict application of a guideline's caries experience criteria. First, are the dentists' caries risk assessments more accurate than classifications based solely on caries experience? Secondly, if indeed dentists' classifications are more accurate, what additional information are dentists considering when altering the classification that would be assigned based only on caries experience. The implication of the answers to these questions is obvious, and addresses the need for direct dentist involvement in CRA.

The purpose of this study was to explore these three questions through further analyses of the data first described in our assessment of the predictive validity of the two applications of the simple, guideline-driven approach to CRA (11).

Methods

We studied two closed-panel dental group practices organized as sole providers of dental services to two health management organizations (HMOs) in the US. The caries risk assessment guidelines were independently developed by clinical dentists working in each practice, or plan. Both risk assessment guidelines have been in place for a number of years and patient risk classifications have been routinely included in the plans' administrative data systems. Both plans' guidelines are relatively simple and constitute official clinical policy within the dental group practices, although it is within the purview of the individual dentist to make exceptions based on clinical judgment. The major difference between the two plans is the use of previous history of caries in the determination of risk. Dentists at plan A are expected to use both previous caries experience and current caries activity in determining caries risk, while dentists at plan B are expected to use only current caries activity to determine risk (Table 1).

Plan A is a staff model group practice consisting of 60 general dentists and specialists providing both pre-paid and fee-for-service dental and oral-care services in 16 dental clinics located throughout the Twin Cities metropolitan area of Minnesota. Plan A provides care for approximately 100 000 members in a fluoridated community. About 70% of the dentists' compensation is salary, with the

Table 1. Summary of caries risk assessment guidelines at the two sites

Caries risk assessment (CRA)	Plan A guidelines	Plan B guidelines
Low risk	No caries in the last 3 years	No active caries No or non-progressive incipient caries detected
Moderate risk	Main criteria: 1–2 caries in the last 3 years Cariogenic diet Active orthodontic treatment Modifiers to be considered: Exposed root surfaces Restoration with overhangs and open margins Physical disability	Evidence of 1-5 lesions including: Incipient caries requiring remineralization Caries requiring restorative procedures
High risk	Main criteria: 3 or more lesions in the last 3 years Suboptimal fluoride Xerostomia or salivary gland hypofunction	Rapidly progressing caries or evidence of 6 or more lesions including: Incipient caries requiring remineralization Caries requiring restorative procedures

remainder being related to production and other plan incentives, including adherence to clinical guidelines as determined through administrative reports and chart audits. Plan B is also a staff model group practice consisting of 120 full-time general dentists and specialists. Plan B provides dental services through 14 dental clinics located in southeast Washington State and northern Oregon, with approximately 180 000 dental members in a largely non-fluoridated area. At the time of this study, incentives linked to adherence to clinical guidelines represented a small fraction of practitioners' overall salaries. This study's design and conduct followed the regulations for human subjects' protection at the two dental groups (plans A and B) where data collection took place.

Data

We used the dental plans' administrative data from adult patients for the analyses. Members of both dental plans have a broad range of socioeconomic backgrounds from public assistance members to blue collar and professional occupations. Inclusion criteria for the analyses described here were at least 25 years of age, receipt of a CRA during a specified reference period, and continuous enrollment in the dental plan for at least 1 year prior to, and 2.5 years following, the CRA. Each patient's reference date was the date of the most recent CRA during the reference period. The reference periods for the two plans differed to insure that the CRA had been in use for at least 2 years and fully implemented at each site. The reference period for plan A was January 1, 1998 to June 30, 1999 and that for plan B was January 1, 2000 to December 31, 2000.

The date of the CRA defined a reference date for each patient. Data were collected during the year prior to the reference date (prior period), the 6 months following the reference date (current period), and the 2 years following the 6-month current period (follow-up period) from the administrative data systems. Variables representing the number of teeth with any caries-related treatment procedure and receipt of caries preventive treatment were created for each of those three periods. At plan A, existing diagnostic codes were used to identify restorative, endodontic, and surgical procedures to treat caries. At plan B, existing reason-for-treatment codes were used for the same purpose. The restorative procedures were limited to intra-coronal restorations. Endodontic procedures were limited to first endodontic therapy and surgical procedures were limited to simple extractions. The distributions of these three types of caries-related treatment procedures were 95.9% restorative, 1.2% endodontic, and 2.9% surgical in plan A, and 96.7% restorative, 0.4% endodontic, and 2.9% surgical in plan B. Crowns were not included in these counts of procedures for either plan because of the high percentage of missing data, principally reason-for-treatment codes (10.9% compared with less than 1% for all other procedures) at plan B. However, only 3.5% of crowns with associated codes had a caries diagnosis. Reason-for-treatment codes are an indirect measure of caries activity and it is possible that some caries-related restorations could have been done for reasons other than existing caries, such as a dentist's assessment of the potential for caries. However, a preliminary study of the reliability of the dentists' assessment of reason-for-treatment codes in plan B was reported previously, and found to be reasonable, with kappa = 0.69 (12).

The number of teeth with a caries-related treatment procedure in the current period represented the caries activity seen by the dentist at the time of the caries risk assessment. For purposes of the analyses reported here, we assigned a CRA score according to guidelines using only current caries to each patient (0, if no caries in the current period; 1, if at least one caries-related procedure). Similarly, the number of teeth with such procedures in the prior period represented previous caries experience. Thus, we assigned a CRA score according to guidelines using both previous caries experience and current caries activity to each patient (0, if no caries activity in the prior and current period; 1, if at least one caries-related procedure in either period). Note that because of data restrictions, the prior period in these analyses is shorter than the 3-year period specified for retrospective consideration of caries experience in plan A. The CRA that the dentist actually assigned at the reference date was coded as 0 for low risk and 1 for moderate or high risk. The number of teeth with caries-related treatment procedures in the follow-up period represented the caries activity that the CRA attempted to predict and was dichotomized (none versus one or more caries-related procedure).

At plan A (serving a mostly fluoridated community), a preventive procedure was defined as a formal recommendation for an in-home fluoride product, reflecting the predominant practice pattern in that plan. At plan B (serving a mostly non-fluoridated community), a preventive procedure was defined as the application of in-office fluoride, again reflecting plan B's predominant practice pattern. In addition to these variables, we collected patient age (at the time of the CRA) and gender.

Analyses

Logistic regression was used to determine the degree to which CRA based on current caries activity, CRA based on prior caries experience and current caries activity, and dentists' actual CRA predict any caries activity in the follow-up period. Sensitivity, specificity, and positive and negative likelihood ratios for each of the three types of risk assessment were computed. Logistic regression was also used to determine the factors other than caries activity that contribute to dentists' assigned CRA. All analyses were conducted separately for the two plans.

Results

Table 2 summarizes the sample characteristics for plan A and plan B. Patients were similar in age and gender, but differed somewhat in distributions of dentists' actual CRA scores. Plan B had a greater percentage of patients at moderate risk, and a smaller percentage at high risk. The sample size for the plan A analysis was 14 859 and for plan B was 30 834.

Hierarchical logistic regression was used to test whether guidelines using current caries activity and prior caries experience in determining caries risk were more predictive of future caries than guidelines using current caries activity alone. CRA based on current caries activity only was entered in the first step of the model and CRA based on previous caries experience and current caries activity was entered in the second step predicting future caries activity. At plan A current caries activity alone explained approximately 2.5% of the variance (Nagelkerke R^2) in future caries activity ($\chi^2 = .256.36$, df = 1, $P < 0.001$), while previous and current caries activity was significant above and beyond the CRA based on current caries activity alone ($\chi^2 = 308.55$, df = 1, $P < 0.001$) and the model explained approximately 5.5% of the variance in future caries activity. The results for plan B were similar. Current caries activity alone explained approximately 4.9% of the variance in future caries activity ($\chi^2 = 1123.61$, df = 1, $P < 0.001$). CRA based on both previous and current caries activity was significant above and beyond the CRA based on current caries activity only ($\chi^2 = 503.45$, df = 1, $P < 0.001$) and the model explained approximately 6.9% of the variance in future caries activity.

Dentist's actual caries risk assessments were then entered in the models to test if they added useful information for predicting future caries activities beyond the previous caries experience and current caries activity. At plan A, dentists' CRA was predictive of future caries activity above and beyond CRAs based on previous caries experience and current caries activity ($\chi^2 = 740.46$, df = 1, $P < 0.001$), with the model explaining 8.2% of the variance. Dentists' CRA was not as strong a predictor at Plan B. Dentists' CRA was predictive of future caries activity above and beyond CRAs based on previous caries experience and current caries activity ($\chi^2 = 932.02$, df = 1, $P < 0.001$). However, the model explained less variance (4.1%) than guidelines based on previous caries experience and current caries activity alone.

Table 3 shows distributions of patients in plans A and B for each of the three CRAs. Table 4 shows predictive performance statistics for the three types of assessments for the two plans. As can be seen in Table 4, when compared with current caries activity alone for both plans, sensitivity increased with the addition of an assessment of previous caries

Table 2. Study population characteristics

	Plan A	Plan B
Total n	14 859	30 834
Male	42%	44%
Average age (SD)	49.8 (13.1)	50.5 (13.4)
CRA = Low	60.5%	54.9%
CRA = Moderate	28.5%	41.1%
CRA = High	11.0%	4.0%

Table 3. Number of patients correctly and incorrectly predicted to have future caries based on three different caries assessments

	Future caries			
	Plan A		Plan B	
CRA criteria	Yes	No	Yes	No
Guidelines – current caries only				
Moderate/high	930	1427	4320	3946
Low	2895	9607	7050	15 518
Guidelines – previous and current caries				
Moderate/high	1603	2386	6060	5879
Low	2222	8648	5310	13 585
Dentists' assessment				
Moderate/high	2276	3591	6425	7496
Low	1549	7443	4945	11 968

Table 4. Performance statistics for three different caries assessments

CRA criteria	Plan A	Plan B
Current only		
Sensitivity	0.24	0.38
Specificity	0.87	0.80
Likelihood ratio+	1.85	1.90
Likelihood ratio−	0.87	0.78
Previous and current		
Sensitivity	0.42	0.53
Specificity	0.78	0.70
Likelihood ratio+	1.91	1.77
Likelihood ratio−	0.74	0.67
Dentists' assessment		
Sensitivity	0.60	0.57
Specificity	0.67	0.61
Likelihood ratio+	1.82	1.46
Likelihood ratio−	0.60	0.70

experience and increased again with the addition of the dentists' CRA. These increases occurred at the expense of specificity in all instances. Positive likelihood ratios tended to remain the same in plan A, while negative likelihood ratios improved. In plan B, positive likelihood ratios weakened when dentists' CRA was added, while negative likelihood ratios remained relatively constant.

As dentists' CRAs were more predictive of future caries activity than guideline CRAs based on previous and current caries activity, the factors that are predictive of dentists' CRA assessments were investigated. Table 5 presents the results of the logistic regression predicting dentists' CRA. The model was significant at plan A (χ^2 = 4953.55, df = 6, $P < 0.001$, Negelkerke $R^2 = 0.384$) and plan B (χ^2 = 3625.72, df = 6, $P < 0.001$, Negelkerke R^2 = 0.148). At both plans, in addition to having any caries activity in the prior or current periods, dentists were more likely to assign an elevated caries risk to those patients who are older, who received prior preventive treatment, and who have larger numbers of caries-related procedures in the prior period and in the current period.

Discussion

The results suggest that, among patients in these plans, inclusion of a consideration of prior caries experience improves the sensitivity of a caries risk assessment compared with the use only of current caries activity. Furthermore, dentists' caries risk assessments have greater sensitivity but less specificity than assessments based on current activity and past caries experience alone. Before considering the implications of these findings, however, it is important to consider the extent to which they can be generalized.

There are three caveats that may limit generalization. The first caveat, already noted, is that in plan B, reason-for-treatment codes were used to identify caries-related procedures. These codes, while similar to diagnostic codes, are not nearly as specific. Thus, it is possible that some 'caries-related procedures' in plan B were not performed in the presence of a lesion, but either in anticipation of or as longer-term repair of a lesion. This 'indirect' measure of caries activity was used both in determining independent variables (current caries activity and prior caries experience) and the dependent variable of future caries experience. While this situation probably also occurs in plan A, the more explicit diagnostic codes are assumed to reduce its frequency. The second caveat is that the criterion employed for both current caries activity and past caries experience was receipt of one or more caries-related restorative, endodontic, or surgical procedures. Thus, the current activity and past experience assessments were simplistic, either none or some. It is quite possible that the relative advantage of using both current activity and past experience may be different if current activity is assessed through quantitative evaluations of caries experience. The final caveat is that only 1 year of prior caries experience was available for the analyses. Plan A, for example, specifies that caries

Table 5. Results of logistic regression examining factors that predict dentists' CRA of low versus moderate or high

	Plan A		Plan B	
	Odds ratio	95% CI	Odds ratio	95% CI
Previous & current caries	2.140	1.772–2.583	1.311	1.207–1.423
Prior preventive treatment	6.637	5.993–7.350	0.836	0.786–0.889
Gender (1 = female)	0.957	0.883–1.038	0.888	0.846–0.931
Prior no. teeth with caries	2.066	1.806–2.365	1.189	1.140–1.241
Current no. teeth with caries	2.806	2.452–3.212	1.899	1.814–1.988
Age in 10-year increments	1.115	1.082–1.149	1.245	1.223–1.268

experience over the prior 3 years should be considered.

Consideration of previous caries experience in addition to current caries activity increased the proportion of caries active patients identified by the CRA. For plan A this increase can be expressed as 176 patients per 1000 caries-active patients (i.e. those who actually experience new caries), or 45 patients per 1000 examined patients. In plan B these figures are 153 and 56, respectively. However, an additional 87 patients per 1000 non-caries-active patients are incorrectly identified as being at elevated risk in plan A, and 99 of 1000 in plan B. These figures may be useful in economic analyses of a CRA program.

The effect of allowing dentists to modify the CRA based on current caries activity and previous caries experience was different in the two plans. In plan B, a greater proportion of the additional patients identified by the dentists' CRAs as caries-active were false-positives, thereby attenuating the overall effectiveness of the additional information. This attenuation of overall predictive accuracy may be related to the lack of a consideration of previous caries experience among the suggested criteria in plan B, although the analysis of predictors of dentists' CRAs would suggest otherwise, as the prior number of teeth with caries contributed significantly to the model. Curiously, prior preventive treatment was a strong predictor of dentists' elevated CRAs in plan A, but operated to reduce the likelihood of such an elevated assessment in plan B. It may be that dentists in plan B expected that receipt of fluoride treatment in the office would result in a subsequent reduction in patient's risk of caries.

The implications of the results for the design of simple CRA programs are not entirely clear. It seems that patients' prior caries experience should be included in any set of CRA criteria, but the decision to encourage dentists to modify the criteria-driven assessment is less sure. In all likelihood, the sensitivity of the assessment will increase, but the 'cost' in terms of false-positives may be greater than desired. Further research to tease out the relative contributions of clinical strategies used by dentists to improve CRA performance might identify those areas amenable to intervention and training to further improve dentists' accuracy in caries risk assessments.

Acknowledgments

This study was supported by grant R01-HS-013 339 from the Agency for Healthcare Research and Quality.

References

1. American Dental Association, Council on Access, Prevention, and Interprofessional Relations. Caries diagnosis and risk assessment: a review of preventive strategies and management. J Am Dent Assoc 1995;126(Suppl):1S–24S.
2. Powell L. Caries risk assessment: relevance to the practitioner. J Am Dent Assoc 1998;129:349–53.
3. Pitts N. Risk assessment and caries prediction. J Dent Educ 1998;62:762–70.
4. National Institutes of Health. Diagnosis Management of Dental Caries throughout Life. NIH Consensus Statement. 2001;181:1–30.
5. Featherstone J, Adair S, Anderson M, Berkowitz R, Bird W, Crau J et al. Caries management by risk assessment: consensus statement, April 2002. J Calif Dent Assoc 2003;31:257–69.
6. Dodds M, Suddick R. Caries risk assessment for determination of focus and intensity of prevention in a dental school clinic. J Dent Educ 1995;59:945–56.
7. Benn D, Dankel D, Clark D, Lesser RT, Bridgewater A. Standardized data collection and decision making with an expert system. J Dent Educ 1997;61:885–94.
8. Hänsel-Petersson G, Twetman S, Bratthall D. Evaluation of a computer program for caries risk assessment in schoolchildren. Caries Res 2002;36:327–40.
9. van Palenstein Helderman W, van't Hof M, van Loveren C. Validation of a Swiss method of caries prediction in Dutch children. Community Dent Oral Epidemiol 2001;29:341–5.
10. Bader JD, Shugars DA, Kennedy JE, Hayden WJ Jr, Baker S. A pilot study of risk-based prevention in private practice. J Am Dent Assoc 2003;134: 1195–1202.
11. Bader JD, Perrin NA, Maupome G, Rindal B, Rush WA. Validation of a simple approach to caries risk assessment. J Public Health Dent 2005;65:76–81.
12. Bader J, White A, Olsen O, Shugars D. Dentist reliability in classifying disease risk and reason-for-treatment. J Public Health Dent 1999;59:158–61.