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INVITED REVIEW

Caries Risk Assessment: A Critical Look

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ABSTRACT

Caries risk assessment (CRA) is a concept that is firmly grounded on the well-known fact that dental caries is a disease. Steady accumulation of evidence under cariology has placed this concept as the pivotal point in management of caries disease. Although existent for decades, the CRA concept has not yet become the mainstream practice or training in India. Whatever is being practiced or taught does not seem to be proportionate enough to match its paramount importance in patient service. The reasons may be that it is still being overshadowed by the robust technical and technological growth of restorative dentistry that focuses only on restoring a carious lesion; or it does not possess enough evidence to be emphatic; or it does not provide the expected outcome reliably. The following review attempts to dissect various aspects of CRA in the realm of current evidence and propose certain future directions toward its effective adoption.

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INTRODUCTION

Caries risk assessment is a concept that is firmly grounded on the well-known fact that dental caries is a disease. Steady accumulation of evidence under cariology has placed this concept as the pivotal point in management of caries disease. Although existent for decades, the CRA concept has not yet become the mainstream practice or training in India. Whatever is being practiced or taught does not seem to be proportionate enough to match its paramount importance in patient service. The reasons may be that it is still being overshadowed by the robust technical and technological growth of restorative dentistry that focuses only on restoring a carious lesion; or it does not possess enough evidence to be emphatic; or it does not provide the expected outcome reliably.

The following review attempts to dissect various aspects of CRA in the realm of current evidence and propose certain future directions toward its effective adoption.

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WHAT IS CRA?

Risk is defined as the probability that a harmful or unwanted event will occur.[1] Disease risk assessment could be defined as the systematic evaluation and identification of risk factors responsible for a disease, estimation of risk levels, and finding possible ways to counter the onset and progression of a disease within the population.[2] Caries risk assessment denotes the process of establishing the probability for an individual patient to develop new enamel or dentin lesions over the near future.[3] It also involves assessing the probability of existing lesions to continue to establish itself in size and activity.[4]

WHY CRA?

Dental caries is the localized destruction of susceptible dental hard tissues by acidic by-products from bacterial fermentation of dietary carbohydrates.[5] It is a result of dynamic interactive process at the biofilm–tooth interface over time. Two types of disturbances in homeostasis/physiological equilibrium ensue due to this interaction that are dependent and consequential to each other: (a) shift in the microbial homeostasis in the biofilm, leading to maturation of cariogenic organisms; (b) alteration of the mineral homeostasis between the tooth and the oral fluid, due to demineralization of the enamel under acid attack.[6]

If frequent sugar attack, matured cariogenic biofilm, reduced salivary flow, and acidic pH of the biofilm liquid continue to persist locally, the resulting demineralization can progress from a noncavitated incipient lesion to an established cavitated one. These factors that are directly responsible for the onset of disease are collectively called determinants or risk factors. There are other factors that are not directly etiological but can influence the course of the disease process. These are called the confounders or risk indicators (predictors).[5,7,8] Socioeconomic status, knowledge, oral health awareness attitudes are such factors that act as confounders and influence the risk status of the patient to the disease. These are the factors that are responsible for the variations in the risk status between two individuals with similar causative factor/s as well as the variations in the causative factor/s between two individuals with similar risk status.[9] Figure 1 represents the risk factor and risk indicator variables in dental caries disease.

Being a multifactorial disease, dental caries requires a medical model of management rather than the long-practiced surgical model of restorations. In this model,

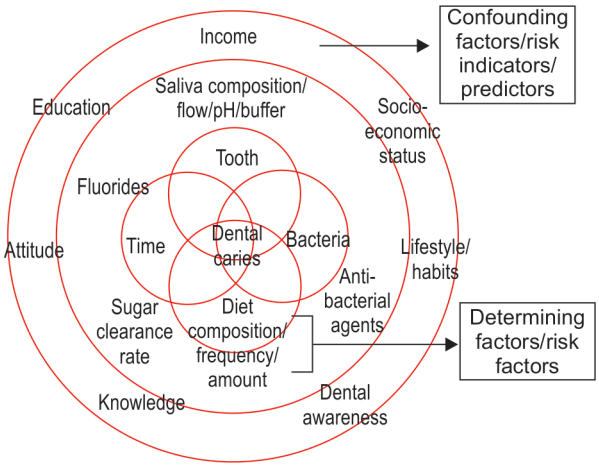

Fig. 1: Diagrammatic representation of the determining (risk factors) and confounding factors (risk indicators/predictors) in dental caries disease (adapted from references[5,8])

patients who are at risk are identified, factors that are directly or indirectly responsible for the disease are eliminated/reduced, and measures are taken to prevent future disease. Dental caries is also considered as a lifestyle-based disease. Factors, such as habits, socioeconomic status, attitude, etc., strongly influence its process and progress. Therefore, it does not suffice to only restore the lesions; it should be effectively controlled for lifetime, with preventive strategies and modifications in the confounding factors. Such a control mandates a longitudinal follow-up through periodic recalls.[10]

The purpose of CRA can thus be summarized as follows:

- Identify the risk factors, or combination of factors, that cause dental caries
- Identify the risk indicators that influence the risk status of the patient and prognosis of the lesion
- Plan a patient-centered prevention strategy based on the risk factors and risk predictors
- Plan a lesion-centered operative and/or nonoperative treatment decision based on risk, activity, and prognosis
- Decide the use of additional diagnostic procedures
- Decide the frequency of recall appointments and actions to be taken at the recalls.[1,4,11,12]

HOW TO PERFORM CRA?

An ideal CRA tool should possess questions on one or more of the following variables responsible for the disease, namely, social, behavioral, microbiologic, environmental, and clinical.[13] Table 1 presents the variables and the subvariables that are used in CRA forms. These are based on evidences obtained either from cross-sectional or from longitudinal studies. Cross-sectional studies identify the risk factors that are responsible for the past or current caries status or severity, whereas longitudinal studies elicit the predictive factors that indicate the possibility of future new caries development.[14] The evidences for these factors, however, vary from weak to strong as represented in Table 2.[1] The data on various

Table 1: Risk factors and risk indicators (causative/noncausative variables and subvariables) in caries risk assessment (adapted from references[1,12,15-17,19,22])

Risk factors	
Cariogenic microflora	Thick plaque/plaque pH
	Streptococcus mutans and *Lactobacilli* count in stimulated saliva
Diet	Frank sugar intake in diet
	Quantity/frequency of intake
	Balanced diet
	Medications that are sugar based
Tooth	Susceptible tooth morphology
	Freshly erupted tooth
	Presence/absence of pit and fissure sealant
Saliva	Salivary flow/buffer/pH/viscosity
	Medications/salivary gland disease or treatments/chemotherapy/radiotherapy that alter salivary flow
Fluoride/other caries protective agents' exposure	Fluoridated community
	Fluoridated toothpaste
	Brushing frequency/dosage of fluoride
	Fluoridate mouthwash/topical fluorides
	Calcium phosphate-containing toothpastes
	Antibacterial mouthwash/topical applications
	Xylitol-based chewing gums
Risk indicators	
Clinical indicators	Active cavitated carious lesions/white spot lesions (detectable visually or radiographically)
	Premature extractions for carious reasons
	Multiple restorations for carious reasons
	Caries in anterior teeth, proximal surfaces, and in smooth surfaces that are not prone for caries usually
	Oral hygiene index (plaque/calculus and gingival bleeding index)
	History of repeated restorations
	Defective restorations (overhanging/open margin/open contact)
	Orthodontic treatment
	Fixed partial dentures
	Exposed root surfaces
Socioeconomic status	Socially deprived
	Education
	Economic status
	Familial history of caries in siblings
General health	Medically compromised (mental/physical health issues)
Attitude	Dental awareness
	Motivation toward oral health care
	Irregular attendance to dental clinic
Lifestyle habits	Snack/sweet intake in-between meals
	Irregular working hours
	Smoking/alcohol/tobacco/recreational drug use
	Sugar-based chewing gums/mouth fresheners/lozenges

Table 2: Evidence on some variables as single predictors for caries risk (adapted from references[1,3])

Strong evidence	Past/current caries experience
	Young permanent dentition
Weak evidence	Sugar intake
	Cariogenic bacteria
	Visible plaque/oral hygiene
	Fluoride exposure in preschool children
Based on expert opinion	Salivary flow rate/buffering capacity

factors are elicited from history, clinical examination, diet charts, salivary examination for salivary flow, pH, buffer, and cariogenic organisms.[15,16]

Various professional organizations and universities have developed different CRA tools. All of them seem to converge on majority of the risk/predictor factors, but diverge only slightly to suit the local population characteristics, the caries prevalence, and age of the patient.[17] They can be broadly categorized as reasoning-based and algorithm-based tools. In reasoning-based models, important risk factors and indicators are collected in a checklist and the risk is qualitatively assessed. In algorithm-based tools, the risk is quantitatively calculated to improve the objectivity and diagnostic accuracy.[18] Currently, the widely researched reasoning-based risk assessment tools available are CAMBRA (caries management by risk assessment),[9] tools devised by ADA (American Association of Dentistry)[19] and AAPD (American Association of Paediatric Dentistry).[20] Recently introduced one is ICCMS (International Caries Control and Management System) that is based on CAMBRA.[21] Cariogram is a popular computerized, algorithm-based program, which analyzes the combination of risk factors in a weighted manner and project the likelihood of avoiding development of new lesions in percentage.[22] Similar one is newly devised by National University of Singapore for pre-school children.[18] The readers are encouraged to refer to the exhaustive reviews on these tools for explicit and lucid details.

IDEAL PREREQUISITE OF CRA

The ideal prerequisite of a CRA, as described by Stamm et al[23] is that "To be useful, a working [caries prediction1 model should produce a sensitivity level of 0.75 or higher and specificity level of at least 0.85 or higher." They further elaborated that "any model, regardless of its ultimate accuracy, would have to be based on a data collection system that is relatively quick, inexpensive, requires a limited armamentarium, and be acceptable to those to whom it is applied."[23]

The following section will dissect the CRA tools to understand if they fulfil these prerequisites.

Is Caries Risk Assessment a Quick Process?

General perception among the clinicians/learners about CRA process is that obtaining data is a lengthy process. Collection of wholesome data on all the causative and noncausative variables as discussed above would indeed make an accurate tool, but tends to make the process anything but quick. Thus, recent studies have been conducted on the diagnostic accuracy of few/single predictor factors against analysis of multiple factors.

It has been stated that the presence of clinical indicators, namely, carious lesions, restorations or missing teeth, termed together as "past caries experience," has a good predictor capability even as a single factor.[24] But it should be emphasized here that these are only indicators for an established disease in the patient, which is not adequate to achieve the goal of predicting and preventing the disease before it even occurs. Dental caries being multifactorial, taking into consideration a combination of other interactive causative factors should give more insight into the future. For example, it has been stated that cariogenic diet and biofilm might have weak evidence as single risk/predictor factors,[1] but in combination, they become strong causative factors.[22]

Elimination of variables that lack evidence to hasten the process might pose a risk of compromising on the diagnostic accuracy. From yet another different perspective, an exhaustive CRA data collection form can also serve as an excellent pedagogy tool in making the students understand the role of all the factors in dental caries.

Some of the current CRA tools seem to differ in the length of the data collection form. On closer look, it will become evident that factors are not eliminated but have been condensed under broad headings. For example, CAMBRA tool has 25 factors enlisted, whereas Cariogram program elicits only 9 factors. Table 3 shows that fluoride exposure factor in Cariogram is equivalent to seven questions that need to be individually assessed under the same

Table 3: Comparison between cariogram and CAMBRA showing the factors elicited under heading of fluoride exposure

CAMBRA	*Cariogram*
Lives/work/school fluoridated community	Estimation of to what extent fluoride is available in the oral cavity over the coming period of time
Fluoride toothpaste at least once daily	
Fluoride toothpaste at least 2× daily	
Fluoride mouthrinse (0.05% NaF) daily	
5,000 ppm F fluoride toothpaste daily	
Fluoride varnish in last 6 months	
Office F topical in last 6 months	

heading in CAMBRA. While it is explicit and elaborate in CAMBRA, in Cariogram it is implicit and in-built based on the conviction that the clinician is aware of soliciting various kinds of fluoride exposure by their clinical knowledge. Although comparatively less in number, Cariogram is contextually same as CAMBRA. Being algorithm-based, Cariogram might quicken the process of deduction of the risk status, but the data collection process is invariably as long or quick as any other reason-based form. Hereby, it also becomes apparent that the role of the clinician in risk assessment is of surmount significance, irrespective of the type of tool being used. Not only the knowledge and awareness but also the clinicians' skill in interpreting the collected data and categorizing the risk status plays a pivotal role, albeit that it tilts the concept toward subjectivity.[3]

To summarize, risk assessment and prediction can take into consideration of evidence on single predictor factors for risk assessment, but it is prudent to do a combined analysis of multiple causative and confounding factors. Therefore, it is better to be an inclusive multifactorial model.

Is Caries Risk Assessment an Inexpensive Process That requires Less Armamentarium?

Being a microbial disease, to target specific antimicrobial therapy, microbiological assessment of cariogenic organisms in saliva/plaque becomes significant in CRA. Numerous laboratory and chairside assessment methods are available for this purpose. Cost factor of a CRA tool increases with these analyses; especially if the risk should be assessed for a whole population. Domejean-Orliaguet et al,[25] while studying CRA in an educational environment, concluded that payment for bacterial assessment is one of the barriers to successful implementation.

To address this issue, studies have analyzed the influence of this assessment in caries prediction and thereby questioned the absolute necessity of this in a CRA tool. Weak evidence is available for the predictor value of salivary microbial assessments (Table 2). Evidence suggests that the accuracy of salivary tests of *Streptococcus mutans* for caries prediction is less than 50% in whole population. In population with lower caries prevalence, the predictive capacity is even lower. The prediction of low caries risk appears to be more reliable than for estimating high caries risk. In addition, the correlation is more with *S. mutans* count than with *Lactobacilli*. Therefore, it has been stated that salivary bacterial count might not have a profound impact on the predictive power of a CRA tool.[4,26]

But, as has been repeatedly reiterated in this article, eliminating any risk variable from a tool might compromise its diagnostic accuracy. This has been shown in a study by Petersson et al[27] where the accuracy of caries prediction was assessed by a "Reduced Cariogram" model, where the microbial assessment was not done. It was found that the collective sensitivity and specificity of Cariogram dropped from 1.3 to 1.1. Gao et al[28] also concluded similarly in their study. They had devised and proposed a questionnaire model for children, and assessed the caries prediction with and without the biological tests. They found that the "full-blown model" that included the biological test, showed a sensitivity/specificity of 90/90%, signifying improved accuracy, whereas the screening model with just a questionnaire and the clinical examination, produced a sensitivity/specificity of 82/73%.

However, they concluded with a logical suggestion that the initial "screening model" without the microbiological test be used for identifying the potential high-risk patients, and later the risk can be assessed accurately for specific clinical decisions, with a "full-blown model" that included those tests. Cost-effectiveness of CRA would thus be improved.

Bratthall and Hänsel Petersson[22] expound on the significance of differentiating a CRA tool, either as a risk model or as a predictor model. Predictor model can identify the patient who is at high risk for developing caries by taking into consideration past caries experience and socioeconomic status. Risk model assesses the biological causative factors, such as the level of cariogenic organisms and other parameters of saliva. This model enables a tailor-made treatment with a specific target. A risk model is also predictive of future caries. But the analysis of the saliva makes the model more time-consuming and expensive. Based on this, they have suggested that the choice of the model depends on if the risk assessment is done for public at large or for an individual's clinical decision. It has been suggested that the predictor model would be appropriate for a larger population and the risk model would be so for an individual patient.

To summarize, to make CRA cost-effective, expensive salivary microbial tests in a risk model of CRA can be selectively prescribed only for individual patients who are identified as high risk, with the objective of identifying the biological factors causing the disease.

Are the Current CRA Tools Sensitive, Specific, and Accurate?

The validity of any screening test is based on its accuracy in identifying diseased and nondiseased persons. Sensitivity of a tool denotes how accurate the screening test is in identifying disease in people who truly have the disease, and specificity denotes the accuracy of the test in correctly identifying the truly nondiseased people. It has been stated that a diagnostic tool should have a

collective sensitivity and specificity of 160 to be considered as accurate.[29]

Exhaustive reviews have concluded that consistent evidence is lacking in terms of good longitudinal prospective studies supporting any of the recent CRA tools to possess such a dependable accuracy.[3,11,14,24,30] This makes it difficult to choose the correct one for clinical use.

The weak evidence has been attributed to variations in the study design, age factor, and outcome measures of the study. More importantly, it was observed that a tool constructed for a specific population taking into cognizance the baseline caries risk/prevalence of the population has better outcome and accuracy, compared with the same tool being used for a different population. In addition, the subjectivity around the interpretation of data and the way high/low risk has been defined by each tool have also been pointed out as reasons for weakness of evidence. In the current scenario, the algorithm-based CRA systems that evaluate the factors in a "weighted way" are claimed to be more objective and possess better accuracy.[18,22] However, the "gut feeling" of the clinician in interpretation of the data still seems to have profound influence on the diagnostic accuracy and this aspect is intricately woven in all the CRA tools.[27,30]

Zero et al[11] had given an insight on how to choose a CRA tool with a given sensitivity/specificity based on the outcome needs. They stated that in a population-based risk assessment, it is important for a tool to have high specificity to rule out those who are at less/no risk. By being highly specific, false positives would be reduced, then unnecessary use of resources on prevention for a large-scale population would also be minimized. On the contrary, they stated that in a clinical-based risk assessment for an individual patient a high sensitivity is desirable. It is considered acceptable to err on the false-positive side with a sensitive tool, since for an individual patient, nonoperative preventive managements are not harmful but protective in the long run.

It can be summarized that being a lifestyle-based disease, it might not be entirely correct to extrapolate a particular CRA tool constructed for a specific population/age/caries prevalence to another setting. This can compromise on the diagnostic accuracy. It is highly recommended to take into account local adaptations and age.[21] A tool with high specificity can be recommended for risk assessment of large population and one with high sensitivity for an individual risk assessment.

FUTURE SUGGESTIONS

It is not indeed difficult to understand that the CRA is an important step toward caries management, but it is not yet into the mainstream of education or practice, not because the current CRA tools are ineffective. It is just that the mounting evidences are still "not sufficient" enough given the complexity of the disease itself. To make it effective, with available evidence, it is essential that a given CRA tool be adapted to suit the local population needs and preferences. Especially for a country as diverse as India, with wide spectrum in culture, socioeconomic status, food habits, oral hygiene habits, and caries prevalence, this local adaptation assumes a paramount significance. The lack of sufficient robust evidence can easily be overcome by further good-quality, longitudinal prospective studies in the specific population for which the tool is devised.

A wide chasm that exists in the objectives of dental education, clinical practice, and research with regard to dental caries must be mended with seamless knowledge and skills. If the "gut feeling, or clinical judgment" of a clinician is the ultimate decision factor in deciding the accuracy of any CRA tool, then education, clinical training, and assessment should align in their objectives, to empower the professionals with such a holistic clinical acumen. This might require an integrated and comprehensive cariology curriculum, with restorative dentistry being merely one of its many integral parts. This is a suggestion that deserves an in-depth reflection later, as implementation of such a curriculum might be far-fetching. Chaffee and Featherstone[31] while assessing the CRA implementation at the University of California state similarly that "In dental education, transition to a risk-based, prevention-focused curriculum may require a long-term commitment."

Attitudinal shift among the patients and the professionals is also the need of the hour to diffuse the misconception that CRA is ineffective or unimportant. Although absence of reimbursement for preventive services has been pointed as one of the reasons for a tardy adoption of CRA in other parts of the world,[25] in India, this might not be a completely applicable reason. Probably such a palpable monetary benefit might enable a small change among both stakeholders. Lack of awareness on caries prevention is still prevailing among the patients despite efforts taken by the professionals and the government. Therefore, it must be constantly reiterated to them through patient education and motivation that dental caries might not be a life-threatening disease, but when left unattended can compromise the quality of oral health and thus the quality of life. The professionals have to break free of the comfort zone of the long-practiced restorative dentistry and express an extended sense of responsibility in helping the patients achieve the same.[32]

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