Caries risk/susceptibility assessment: its value in minimum intervention oral healthcare

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In brief

Suggests appropriate caries management has to be planned at the patient susceptibility level and not at the lesion level as it is in traditional operative restorative dentistry.

Highlights that caries susceptibility assessment still has the potential to enhance patient care by allowing the oral healthcare practitioner/team and the patient to understand the specific reasons for their caries activity and to tailor the care plan and recall interval accordingly.

Notes that various risk/susceptibility assessment protocols/models have been developed to assist the oral healthcare practitioner/team in a logical systematic approach to synthesising information about a disease that has a multifactorial aetiology.

This narrative review describes the intimate connection between minimum intervention (MI) oral healthcare and caries risk/susceptibility assessment (CRA). Indeed CRA is the corner stone of an MI care plan, allowing the determination of the appropriate interventions (non-invasive as well as invasive [restorative]) and recall consultation strategies. Various CRA protocols/models have been developed to assist the oral healthcare practitioner/team in a logical systematic approach to synthesising information about a disease that has a multifactorial aetiology. Despite the criticisms toward the lack of clear-cut validation of the proposed protocols/models, CRA still has great potential to enhance patient care by allowing the oral healthcare practitioner/team and the patient to understand the specific reasons for their caries activity and to tailor their care plans and recall intervals accordingly.

MI foundations and evolution

The foundations of minimum intervention (MI) dentistry (MID) were laid in the late 1980s and early 1990s in the UK and Australia. In 1992, Dawson and Makinson published the first manuscripts related to MID that can be found on PubMed.[1,2] They discussed a movement emerging in the UK, 'provocative' at this time and denouncing, based on clinical investigations, the inadequacy between patient needs and care provision in restorative dentistry. Indeed, in the UK, an extensive re-education programme had been initiated by the British Department of Health and Social Security in conjunction with the British Dental Association, based on those clinical investigations and the report of the Committee of Enquiry into Unnecessary Dental Treatment. The dental profession was also reminded of Smales' definition of dental health (written communication, 1988): 'Dental health can be considered in terms of a dentition that is functionally adequate, aesthetically pleasing, and free from discomfort and disease'. It was concluded that, within this definition, sound dental tissues constitute the basis of both functional and aesthetic dental systems.[2] In the light of present knowledge in cariology (from histology/microbiology/pathophysiology to decision-making and clinical procedures), this has led to the development of the ICCMS™ concept (International Caries Classification and Management System) based on the statement 'The ICCM is a health outcomes focused system that aims to maintain health and preserve tooth structure'.[3–5]

Elderton denounced the traditional restorative care concept as being ineffective for managing caries.[6–9] In 1996, his standpoint was that 'treatment should come to mean what it says, namely the curing of diseases – and much of this can only be accomplished by non-invasive means', and that 'restorative procedures should be seen simply as prosthetic, making up for lost tissues'.[9]

Aubrey Sheiham published the proceedings of a 1999 meeting devoted to MID (International Conference on Minimal Intervention Approach for Dental Treatment) in Kuwait.[10] Three fundamental reflections included:

1. 'An interventionist orientation to dental diseases leads to a spiral of damage'
2. 'As dentists think they are looking after a machine, which is constantly breaking down, they do not allow it to repair or heal because they do not consider the natural history of disease'
3. 'Limiting intervention to the absolute minimum and giving prevention the opportunity to work should be the basis for quality dental care'.

In 2000, Tyas *et al.* proposed the four guiding principles of MI: 1) the remineralisation of early lesions; 2) the reduction in cariogenic bacteria (in order to eliminate the risk of further demineralisation and cavitation); 3) the minimal surgical intervention of cavitated lesions, the repair rather than the replacement of defective restorations; and finally 4) the disease control.[11]

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Table 1 The different CRA protocols specific to children <6 years old and their variables (cont. on page 193)

CRA in children aged under 6 years old

CRA protocols (Chronologic order)	Factors/variables
CAMBRA, 2007[19] 0-5 years old	**Risk indicators (parent interview)**
	Mother/caregiver: active caries in the past 12 months
	Child: recent restorations
	Parent/caregiver: low socioeconomic status and/or low health literacy
	Child: developmental problems
	Child: no dental home/episodic dental care
	Risk factors (biological) (parent interview)
	Child: frequent (> three times daily) between-meal snacks of sugars/cooked starch/sugared beverages
	Child: saliva-reducing factors (medications and medical)
	Child: continually uses bottle – contains fluids other than water
	Child: sleeps with a bottle or nurses on demand
	Non-biological protective factors (parent interview)
	Mother/caregiver: decay-free last three years
	Child: dental home and regular dental care
	Biological protective factors (parent interview)
	Child: lives in a fluoridated community or takes fluoride supplements by slowly dissolving or as chewable tablets
	Child: fluoridated toothpaste (pea-size) daily
	Mother/caregiver: xylitol chewing-gum/lozenges 2-4× daily
	Risk indicators/factors (child clinical examination)
	Obvious white spots, decalcifications, or obvious decay
	Restorations in the last 2 years
	Obvious plaque on teeth and/or gums bleed easily
	Dental or orthodontic appliances (fixed or removable)
	Visually inadequate saliva flow (dry mouth)
ADA, 2011[20] 0-6 years old	**Contributing conditions**
	Child: fluoride exposure
	Child: sugary foods and drinks
	Child: eligible for Government programme
	Mother, caregiver and/or other siblings: caries experience
	Child: dental home
	General health conditions
	Child: special healthcare needs
	Clinical conditions (child clinical examination)
	Visual or radiographically evident restorations/cavitated lesions
	Non-cavitated (incipient) lesions
	Teeth missing due to caries
	Visible plaque
	Dental/orthodontic appliances
	Saliva flow

CRA protocols (Chronologic order)	Factors/variables
DCRAM, 2012[21]	**Data collection at age 1 for prediction at age 4:**
	d1mft >0 – 'any caries–risk' model
	Health visitor opinion of risk
	Deprivation category
	Parental smoking
	Breastfeeding
	Use of a dummy
	d3mft >0 – 'any caries–risk' model
	Health visitor opinion of risk
	Parental smoking
	Food or drink at night
	d1mft – 'high caries–risk' model
	Type of housing
	Use of a feeder cup
	d3mft – 'high caries–risk' model
	Type of housing
	Health visitor opinion of risk
	Use of vitamins
AAPD CAT, 2015 (last revision)[22]	**0-3 years olds (for physicians and other non-dental health care providers):**
	Biological factors
	Mother/caregiver: active cavities
	Parent/caregiver: low socioeconomic status
	Child: >3 between meal sugar-containing snacks or beverages per day
	Child: put to bed with a bottle containing natural or added sugar
	Child: special healthcare needs
	Child: recent immigrant
	Protective factors
	Child: optimally-fluoridated drinking water or fluoride supplements
	Child: teeth brushed daily with fluoridated toothpaste
	Child: topical fluoride from health professional
	Child: dental home/regular dental care
	Clinical findings
	Child: white spot lesions or enamel defects
	Child: visible cavities or fillings
	Child: presence of plaque

CRA: caries risk assessment; CAMBRA: caries management by risk assessment; ADA: American Dental Association; DCRAM: Dundee Caries Risk Assessment Model; AAPD: American Academy of Paediatric Dentistry; CAT: Caries-risk Assessment Tool.

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Table 1 The different CRA protocols specific to children <6 years old and their variables (cont. from page 192)

CRA in children aged under 6 years old			
CRA protocols (Chronologic order)	**Factors/variables**	**CRA protocols (Chronologic order)**	**Factors/variables**
AAPD CAT, 2015 (last revision)[22] (continued from page xx)	**0-5 years olds (for dental providers):**	MySmileBuddy[23,24]	Diet (for example, What did your child eat yesterday?) Feeding practices (for example, How often do you prechew your child's food?) Caregiver attitudes and beliefs (for example, How confident are you in reducing your child's risk for tooth decay) Fluoride use (for example, what type of toothpaste does your child most routinely use?) Family history (for example, Have you ever had an abscessed tooth?)
	Biological factors Idem as above		
	Protective factors Idem as above		
	Clinical findings Child: >1 decayed/missing/filled surfaces Child: active white spot lesions or enamel defects		
	Child: elevated mutans streptococci levels Child: presence of plaque		

CRA: caries risk assessment; CAMBRA: caries management by risk assessment; ADA: American Dental Association; DCRAM: Dundee Caries Risk Assessment Model; AAPD: American Academy of Paediatric Dentistry; CAT: Caries-risk Assessment Tool.

In 2002, the Fédération Dentaire Internationale (FDI) also joined the MI movement with the diffusion of policy statements related to caries management.[12] A decade later, Frencken *et al.* published a report of the FDI task group and drove home the message that the dental profession should move away from the surgical care approach and fully embrace the MID approach.[13] They put the emphasis on the fact that the chance for MID to be successful is thought to be increased if dental caries is not considered an infectious disease but instead a behavioural disease with a bacterial component.[13]

All the points cited above revolve around one axis – appropriate caries management has to be planned at the patient susceptibility level and not at the lesion level as it is in traditional operative restorative dentistry.[14] Demarco *et al.*[15] investigating the clinical efficacy of posterior composite resin restorations, demonstrated that one of the main reasons for failure in the long term are secondary carious lesions (contemporary terminology: CARS – caries associated with restorations and sealants) highlighting that patient factors such as caries activity should be monitored and managed. Targeted patient education and engagement towards achieving and maintaining a better oral health (oral hygiene and diet counselling), modification of oral flora (from infant early colonisation to elderly), primary prevention (fluoridated agents and dental sealants), favouring the oral conditions allowing the remineralisation of early carious lesions (from adequate saliva buffering capacity to fluoridated agent regimen) and tooth preserving restorative managements are the backbone of patient-focused, case-by-case customised, personalised care plans.[16–18] A recently developed comprehensive and integrated package related to caries management, from detection and classification to detailed clinical procedure recommendations, is the ICCMS™.[5] Based on contemporary scientific evidence, it proposes a comprehensive assessment and personalised caries care plan based around four different steps: history (patient-level caries risk/susceptibility assessment [CRA]), classification (caries staging and activity assessment), decision-making (synthesis and diagnosis) and management (personalised-caries prevention, control and tooth preserving operative care).

Patient-level caries risk/susceptibility assessment is the corner stone of an MI care plan, the only rational and ethical way to manage caries, both the process and lesions, in the light of current scientific knowledge. Indeed CRA allows determining the appropriate interventions – the non-invasive as well as the invasive (restorative) – and the recall intervals. Risk assessment can be carried out at the population/patient level whereas the oral healthcare team will implement protocols to help ascertain the individual patient's susceptibility to disease.

Caries risk assessment models

Caries risk factors and indicators have been incorporated into various risk/susceptibility assessment protocols/models assisting the oral healthcare practitioner/team in a logical systematic approach to synthesising information about a disease that has a multifactorial aetiology.

Some CRA protocols/models are specific to infants and children under 6 years old (Table 1):

- Caries management by risk assessment (CAMBRA) system – age <6[19]
- System of the American Dental Association (ADA) – age 0-6[20]
- Dundee Caries Risk Assessment Model (DCRAM) (data collection at 1 for caries prediction at 4)[21]
- Caries-risk Assessment Tool (CAT) of the American Academy of Paediatric Dentistry (AAPD) – age 0-3 for physicians and other non-dental health care providers; age 05 for dental providers[22]
- MySmileBuddy (MSB) (for early childhood caries).[23,24]

Some protocols are for children aged 6 and over, adolescents and adults:

- Cariogram[25]
- CAMBRA[26,27]
- Caries Risk Pyramid (CRP)[28]
- System of the American Dental Association (ADA)[20,29,30]
- Caries-risk Assessment Tool (CAT) of the American Academy of Paediatric Dentistry (AAPD).[22]

They all combine similar variables that can be grouped in various ways as shown in Tables 1 and 2. It can be noticed that the terminology slightly differs from one system to another. Indeed, the presence of previous restorations may be considered as a disease indicator (CAMBRA) or as a clinical condition/

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Table 2 The different CRA protocols for children ≥6 years old, adolescents and adults and their variables

CRA in children ≥6 years old, adolescents and adults

CRA protocols (Chronologic order)	Factors/variables
Cariogram, 2005[25]	**Caries experience**
	DMFT, DMFS
	New caries experience in the past 1 year
	Related diseases
	Medical history
	Medications
	Diet, contents
	Diet history
	lactobacillus test count
	Diet, frequency
	Questionnaire results, 24 h recall or dietary recall (3 days)
	Plaque amount (plaque index)
	Mutans streptococci
	Fluoride programme
	Fluoride exposure
	Interview patient
	Saliva secretion (stimulated test)
	Saliva buffer capacity
CAMBRA, 2007[27]	**Disease indicators**
	Visible cavities or radiographic penetration of the dentin
	Radiographic proximal enamel lesions
	White spots on smooth surfaces
	Restorations last 3 years
	Risk factors (biological predisposing factors)
	MS and LB both medium or high
	Visible heavy plaque on teeth
	Frequent snack (>3× daily between meals)
	Deep pits and fissures
	Recreational drug use
	Inadequate saliva flow by observation or measurement
	Saliva reducing factors (medications/radiation/systemic)
	Exposed roots
	Orthodontic appliances
	Protective factors
	Lives/work/school fluoridated community
	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 topical fluoride in last 6 months
	Chlorhexidine prescribed/used one week each of last 6 months
	Xylitol gum/lozenges 4× daily last 6 months
	Calcium and phosphate paste during last 6 months
	Adequate saliva flow (>1 ml/min stimulated)
CRP, 2011[28]	Level 1: Psychosocial, behavioural, genetic
	Level 2: biological: host, bacteria, sugar
	Level 3: biochemical (acid/alkali)
	Level 4: pH
ADA, 2011[20,29,30]	**Contributing conditions**
	Fluoride exposure
	Sugary foods and drinks
	Caries experience
	Dental home
	General health conditions
	Special healthcare needs
	Chemo/radiation therapy
	Eating disorder
	Medications that reduce saliva flow
	Drug/alcohol abuse
	Clinical conditions
	Cavitated, non-cavitated carious lesions or restorations
	Teeth missing due to caries in past 36 months
	Visible plaque
	Unusual tooth morphology that compromises oral hygiene
	Interproximal restorations
	Exposed root surfaces
	Restorations with overhangs and/or open margins; open contacts with food impaction
	Dental/orthodontic appliances
	Severe dry mouth (xerostomia)
AAPD CAT, 2015 (last revision)[22] ≥ 6 years old	**Biological factors**
	Socio-economic status
	>3 between meal sugar-containing snacks or beverages per day
	Special healthcare needs
	Recent immigrant
	Protective factors
	Optimally-fluoridated drinking water
	Daily use of fluoridated toothpaste
	Professional topical fluoride application
	Additional home measures (xylitol, MI paste, antimicrobial)
	Dental home/regular dental care
	Clinical findings
	>1 interproximal lesions
	Active white spot lesions or enamel defects
	Low saliva flow
	Defective restorations
	Intraoral appliance

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finding (ADA; AAPD CAT) (Table 2); in the same manner, frequent in-between meal snacks may be listed as part of the biological factors (CAMBRA; CRP; AAPD CAT) or as part of the contributing conditions (ADA) (Table 2). Socioeconomic status is a common factor taken into account in children aged under 6 (CAMBRA, ADA, DCRAM, AAPD CAT), nevertheless in adults, it is only considered in the AAPD CAT. It is interesting that Cariogram does not address this factor directly; indeed Bratthall *et al.*[25] explained that social factors do not directly act on the tooth surface but that they can often explain reasons for factors such as neglected oral hygiene and increased sucrose consumption, factors that are already included in the Cariogram, the same reason that socioeconomic status was eliminated from the 6 year through adult CAMBRA CRA form.

The somewhat apparently arbitrary risk categorisation varies markedly among the protocols: risk levels (from 2 to 4 categories – low, moderate, high and extreme for CAMBRA, ADA and AAPD CAT), presence of risk (yes/no for DCRAM), pH (acidic in favour to demineralisation and alkaline in favour to remineralisation for the CRP) and percentage of chance to avoid further carious lesions (Cariogram) (Table 3). At a practice level, it is suggested that all members of each oral healthcare team are calibrated among each other (using test clinical scenarios and group discussion/consensus), so that risk levels obtained are meaningful across the team and to the patient and any future changes can be monitored and documented over time.

The Cariogram is the only one to propose a computer programme in which the factors/variables are entered after being given a score according to a predetermined scale.[25] According to its built-in formula, the programme presents a pie diagram in which a green sector shows an estimation of the 'chance of avoiding caries'; this chance, and conversely the risk of caries, are expressions for the same process but illustrated inversely. The other cited protocols are structured forms that may help in the systematic assessment of multiple caries risk factors in practice and aid in objective record-keeping over time.[31] Most recently CAMBRA has become available as an algorithm driven App for mobile devices called 'MyCAMBRA' (https://www.mycambra.com/).

Value of risk assessment

Twetman reviewed the evidence behind CRA in children and concluded that CRA should be carried out at the child's first dental visit and reassessments should be carried out throughout childhood and that multivariate models offer improved accuracy over those using single predictors.[32] Tellez *et al.*[33] published a critical review toward the evidence for the prediction of caries using Cariogram, AAPD CAT, CAMBRA and ADA systems. Based on 14 prospective cohort studies and randomised controlled trials, they concluded that the evidence on the validity for those CRA protocols is limited. It is unknown if the identification of high-risk individuals can lead to more effective long-term patient management that prevents lesion initiation and arrests or reverses the lesion progression. There is an urgent need to develop valid and reliable methods for CRA that are based on best evidence for prediction and disease management rather than opinions of experts. Tellez *et al.* (2015) reported that when using the CAMBRA protocol, the incidence risk ratio was not significantly higher for the moderate caries risk group compared with the low caries risk group.[34] Thus, they suggested that low-risk and moderate-risk categories may not be sufficiently and distinctively different in predicting increasing risk of future caries and that a calibrated re-evaluation of the number of risk categories (four at the moment, namely low, moderate, high and extreme) is recommended.

When faced with issues highlighting the difficulties in identifying with any certainty at-risk patients and considering the evidence of the effectiveness of preventive measures for individuals at high risk is not always strong, Fontana *et al.* considered that caries susceptibility assessment still has the potential to enhance patient care by allowing the oral healthcare practitioner/team and the patient to understand the specific reasons for their caries activity and to tailor the care plan and recall interval accordingly.[35,36] Moreover, studies have shown that the most important factor in predicting future risk is recent caries experience and current disease activity.[35,36] However, a careful analysis of all risk and protective factors will allow the oral healthcare team and patient to understand the specific reasons for the caries disease progress and thus will allow them to tailor the care plan and recall interval specifically to the patient's needs.[35]

Indeed, more important than overall risk level determination is the specific identification of individual pathological and protective, 'susceptibility' factors in order to plan customised preventive strategies adapted to individual needs and ability of compliance; a customised preventive care plan aims to cou terbalance individual pathological factors by strengthening individual protective factors.[37] Structured protocols and forms may help in the systematic assessment of such multiple caries susceptibility factors in practice and aid in appropriate care planning and in objective record-keeping over time.[31,38] Afuakwah and Welbury also showed that improving documentation positively influences the patients' adherence to their individualised protocol for preventive care.[39]

Recently, clinical outcomes studies have been published on the use of CAMBRA in the university teaching clinic setting. Doméjean *et al.* presented data on 2,571 patients over a period of six years who returned for follow up.[40] The proportion of patients who went on to have new cavities in each of the risk categories was 24, 39, 69 and 88% for low, moderate, high and extreme risk respectively, demon strating validation of the risk/susceptibility assessment procedure. A subsequent outcomes

Table 3 The different risk level categorisation used in the CRA protocols for children, adolescents and adults

System/concept	Risk categorisation
Cariogram, 2005[25]	Chance (%) to avoid caries
CAMBRA, 2007[19,27]	Low versus Moderate versus High versus Extreme risk
CRP, 2011[28]	Acidic pH (demineralisation/caries) versus Alkaline pH (remineralisation/health)
ADA, 2011[20,29,30]	Low versus Moderate versus High risk
DCRAM, 2012[21]	At risk: Yes versus No
AAPD CAT, 2015 (last revision)[22]	**0-3 years old (for physicians and other non-dental health care providers)** Low versus High risk
	0-5 years old child (for dental providers) and older patients Low versus Moderate versus High risk

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assessment in the same clinic in 2,724 patients produced similar validation.[41] Further, that study reported a 20% reduction in caries for those high-risk patients who used a combined chlorhexidine/fluoride therapy versus those who did not accept the therapy. In a subset of the same population who were on public assistance and used the products there was a 38% reduction in caries versus those who did not.

CRA

The gap between fundamental science and clinical practice

Several questionnaire studies assessing the use of risk/susceptibility assessment in everyday clinical practice highlighted that CRA has been poorly implemented into practice.[42–45] One undertaken among a randomised sample of French general dental practitioners (GDPs) showed that, in 2015, approximately 38% of the respondents claimed not to use any form of CRA routinely.[44] Those results compare regrettably to the 31% obtained among a network gathering of American and Scandinavian practitioners.[42] The situation in Japan seems to be even worse with 74% of Japanese dentists claiming not to use CRA.[45]

The use of CRA in everyday clinical practice seems to be influenced by the oral healthcare practitioners' demographic characteristics. The French survey showed that CRA was used more by GDPs who had recently participated in a CPD course, those who read scientific articles on the topic and females.[44] Despite structured protocols/forms to help systematic CRA in practice, and to aid in appropriate care planning, among those French GDPs who claimed that they assessed the caries risk of their patients, less than 5% used such forms.[44] This compares unfavourably to the 17% reported by Riley *et al.* in the USA and Scandinavia for adult patients, but is below the 31% recorded among Japanese GDPs.[42,45]

In the discipline of caries management and MID, the gap between science and practice is not limited to risk/susceptibility assessment, but includes an early restorative threshold for lesions that could have benefited from non-invasive preventive therapies, lack of therapeutic sealant placement in non-cavitated lesions and iatrogenic dentine excavation in deep carious lesions.[46] The lack of implementation of CRA into routine practise may be multifactorial. It can be hypothesised that the lack of clear-cut validation of any CRA protocol/system may disincentivise their routine use. Despite the evidence being weak, it can be argued that the lack of financial recognition/incentive may discourage oral healthcare professionals to change their clinical behaviour with respect to MID concepts in general.[47]

Conclusions

CRA is an essential component of the individualised MI oral healthcare care plan. The development and the validation of risk/susceptibility assessment models/protocols are needed to help oral healthcare practitioners to customise their care plans according to the individualised needs of their patients, case by case. Moreover, proper documentation may help enhance the patients' compliance with the protocol for preventive care plans. The specifications of the 'ideal' caries risk/susceptibility assessment protocol are:

- The capacity of predicting the occurrence of new carious lesions and the progression of existing ones, in various clinical settings and populations (different ages: children, adolescents, adults, elderly; different health conditions; different caries prevalence regions/countries)
- The capacity to educate and engage the patient and thus motivate them to take responsibility of and value their long term oral healthcare and enhance his/her adherence to preventive care plans (the time devoted to CRA at chair-side is a time for communication, explanation and engagement about deleterious behaviours in terms of dental caries)
- To be an affordable/inexpensive, quick, user-friendly, and easy to understand tool.

There is a need for prospective clinical studies demonstrating that such assessments improve care planning outcomes in terms of a reduction of the occurrence of new carious lesions and the progression of existing ones with associated healthcare economics in different clinical practice settings and in different populations/countries. However, such randomised controlled trials (the highest form of evidence-base) will always be complex, if not impossible, to be carried out due to the large numbers of variables to control and the time taken to observe changes in risk/susceptibility in populations and individuals. Outcome assessments will likely be the strongest evidence available upon which to build and strengthen clinical practice. The limited results already available support CRA concept dissemination and CRA implementation into clinical routine practice to target the individualised needs of each patient in terms of care planning and provision (from prevention to restorations). Further studies are likely to provide even stronger support for this major change in clinical practice for the improved oral health of our patients.

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