

Assessing Risks of Early Childhood Caries in Primary Care Practice Using Electronic Health Records and Neighborhood Data

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ABSTRACT

Context: Early childhood caries (ECC) is a persistent public health challenge, affecting more than 56% of US toddlers and preschool-aged children. Despite this, ECC is largely preventable with routine oral hygiene practices, diet, and application of topical fluoride.

Objective: This study assessed the utilization of preventive oral health care in primary care practices and evaluated the variation in patient characteristic and geographic disparities.

Design: We conducted a retrospective study using electronic health records (EHRs) over a 2-year period. Patients' home addresses were geocoded and linked to census-based neighborhood statistics and fluoridated water accessibility. Multiple logistic regression modeling was used to assess the risk of ECC in patients with fluoride preventive care, controlled for demographics, comorbid conditions, and neighborhood risk factors.

Participants: Patients aged 6 to 71 months who had primary care providers at family medicine and general pediatric clinics in a large academic medical center.

Main Outcome Measure: The presence of dental caries based on diagnoses in EHRs.

Results: The study consisted of 10 836 patients: 17% treated with topical fluoride varnish (TFV), 12% prescribed oral fluoride supplement, 6.1% with both TFV and supplement, and 64% without fluoride treatment. Patients with fluoride treatment were 24% to 53% less likely to have ECC. Children living in rural and nonfluoridated water communities had 1.7 to 1.8 times greater risk of developing ECC. Minority, under/uninsured, and low-income patients also were at an increased risk of ECC.

Conclusion: Despite continuing efforts to improve access to dental care for vulnerable populations, substantial disparities remain among socioeconomically disadvantaged children. To address dental care shortage, primary care clinicians should serve as the safety net to care for vulnerable and underserved children who have no or limited access to oral health services. Future research into the collaboration between primary care and dental providers at the level of both practice and professional education should be considered.

KEY WORDS: dental caries, early childhood caries, fluoride, pediatric oral health, primary care

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Dental caries is the most common chronic disease of childhood.¹ Early childhood caries (ECC) is identified as the presence of 1 or more decayed, missing, or filled primary teeth in children younger than 6 years.² By 6 to 8 years of age, 56% of all US children have experienced dental caries affecting the primary teeth.³ Not only do pediatric dental caries cause pain⁴ but they can also lead to more severe infections and affect children's normal growth and development.⁵ Children who experience ECC are more likely to have oral health problems in adulthood, as well as sleep disruption, behavioral problems, chewing difficulty and long-term nutritional deficiencies, missed time at school, diminished ability to learn, as well as emergency

department visits and hospitalizations, resulting in extremely high treatment costs.^{1,6-8} The large scale of young children with ECC has raised challenges to our health care practice, highlighting the need for better knowledge of preventing dental caries in early childhood.

Given the resonant impacts, caries prevention is paramount for good overall health. Regular use of topical fluoride and oral fluoride supplements reduces dental caries.^{3,4} Since 2021, the World Health Organization (WHO) has included fluoride in the list of essential medications for the prevention of dental caries.⁹ Community water fluoridation (CWF) has been widely recognized as a safe and effective public health intervention to prevent dental caries. Children living in communities with fluoridated tap water have fewer cavities than children whose water is not fluoridated.^{10,11} Nonetheless, many communities do not have access to fluoridated water. For children who do not have access to fluoridated water, the US Preventive Services Task Force (USPSTF) recommends that primary care providers prescribe systemic fluoride starting at 6 months of age (grade B recommendation).¹²

The USPSTF also recommends that primary care providers apply topical fluoride varnish (TFV) to the teeth of children younger than 5 years starting at the age of primary tooth eruption (grade B recommendation),¹² and the American Academy of Pediatrics (AAP)/Bright Futures Periodicity Schedule recommends TFV application from 6 months of age up through 5 years of age to prevent dental caries.^{13,14} TFV is an easy, low-cost service that can be applied in less than 2 minutes. Thus, all children younger than 6 years should receive TFV for caries prevention and any children without access to fluoridated water should be prescribed fluoride supplements. While available research is generally in agreement about the increased risk of dental caries among individuals without access to fluoride, the extent to which fluoride treatment is effective in preventing dental caries for children living in communities without CWF has not been assessed.

Moreover, despite knowing the USPSTF recommendations, many primary care providers express limitations in providing ECC prevention strategies to their patients. These limitations include time during appointments, training, access to supplies, and knowing whether patients have fluoridated or nonfluoridated water and whether patients should receive topical fluoride and prescription fluoride supplements. Furthermore, little is known about whether children living outside of fluoridated water systems are receiving TFV. Prior literature has also identified that ECC prevalence and severity varied by race,¹⁵

insurance type,¹⁶ socioeconomic status,^{4,17} and rural residence.¹⁸ This study intends to assess the utilization of TFV and preventive oral health care in family and general pediatric practices and to evaluate the variation in patient characteristics and geographic disparities with respect to dental caries risk. We hope to bridge these knowledge gaps in order to gain better insights into the effectiveness of TFV and preventive dental care for children younger than 6 years, with the goal of laying the foundation for future interventions and clinical trials to maximize the quality and outcome of the integration of oral health in primary care, including oral health.

Methods

Study design and population

This research utilized a retrospective longitudinal design using data extracted from an enterprise electronic health record (EHR) data warehouse. The study population consisted of children aged 6 to 71 months who had primary care physicians (PCPs) in a large academic health center in central and southern Pennsylvania between January 2018 and December 2019. To be considered actively managed by the health system, eligible patients must be affiliated with their PCPs for more than 6 months and have at least 1 encounter with primary care providers at family medicine or general pediatric clinics during the study period. Patients who received TFV or fluoride supplements after diagnoses of dental caries were excluded from the analysis. This study was approved by the academic medical center's institutional review board.

Patient, environmental, and neighborhood characteristics

Patient characteristics included sex, age, race, ethnicity, insurance type, and special health care needs. The analysis categorized patients' race and ethnicity into 5 groups: Hispanic/Latino, non-Hispanic White, non-Hispanic Black, Asian, and Other. Individuals reported as American Indian, Pacific Islanders, and unknown races were aggregated into the Other race category due to their small numbers. The insurance type of the patient was assigned to one of the 3 categories: commercial, public insurance (eg, Medicaid and government assistance programs), and other (uninsured and self-pay). Whether a patient had special health care needs was determined on the basis of the presence of any of the following health conditions: attention-deficit/hyperactivity disorder, asthma, autism, cerebral palsy, cystic fibrosis, depression, diabetes mellitus, Down syndrome, epilepsy,

congenital heart diseases, learning disability, and childhood cancer. These health conditions shared a greater likelihood of more complicated oral health problems and were determined using the *International Classification of Diseases, Tenth Edition (ICD-10)* diagnosis codes.^{19,20} More details for procedure and diagnosis codes used in the study are available in Supplemental Digital Content Table S1 (available at <http://links.lww.com/JPHMP/B54>).

Primary care providers in the analysis were from 2 specialty areas: family medicine and general pediatrics. PCPs in each specialty might have different experiences in training and ambulatory workflows that affect the likelihood of using fluoride. The study considered the PCP specialty a covariate to address potential confounding effects due to the specialty variation.

Moreover, patients' home addresses were converted to geographic coordinates and then matched to a specific census block group code. Geospatial analysis was performed to identify whether patients lived in areas with fluoridated water by linking geographic coordinates to the CWF status map.²¹ Drinking water sources in areas outside of fluoridated water systems are well water or municipal water without fluoridation. The rural status of the patient was determined by linking geographic coordinates to the census urban and rural classification mapping file.²² All the geospatial analyses were performed using ArcGIS Pro version 2.5 (ESRI Inc, Redlands, California).

The score of the Area Deprivation Index (ADI) was obtained at the census block group level to serve as the proxy of the socioeconomic status of the patient in the neighborhood context.²³ An ADI is a composite measure of 17 census-based social determinants that factors in domains of poverty, education, employment, and housing quality.^{23,24} Areas with higher ADI scores represent neighborhoods experiencing higher poverty and greater socioeconomic disadvantage. To estimate the availability of dental care, the ratio of dentists per 100 000 population was also extracted on the basis of the county where patients resided.²⁵

Outcome measures and fluoride treatment

Dental caries is the localized destruction of calcified tissues, such as enamel, dentin, and cementum, known colloquially as tooth decay.⁴ The analysis determined the presence of dental caries based on *ICD-10* codes K02 and its subcategories. The risk of dental caries was the outcome of interest of the study.

The common preventive treatment of dental caries included TFV applications and dietary fluoride supplements. Essentially, whether patients received TFV

applications was determined on the basis of the presence of the *CPT (Current Procedural Terminology)* code 99188 during the study period. Dietary fluoride supplements prescribed to patients were identified through medication order records in EHRs. This study considered patients treated with fluoride when they received either TFV applications or dietary fluoride supplements during the study period. Otherwise, patients were considered to have no fluoride treatment. Our analysis did not include sealant data because sealants are uncommon before 6 years of age. Sealant applications are also not performed in primary care clinics. Unlike TFV, sealant application requires specialized dental training and resources that are not available in nondental clinical settings.

Statistical analysis

Descriptive statistics were computed to describe the characteristics of the patient population. Differences in continuous variables were compared using the *t* test for parametric or equivalent tests for nonparametric analyses. Proportion differences in categorical variables were evaluated using the chi-square test.

Multiple logistic regression modeling was used to assess the risk of dental caries, controlled for demographics, comorbid conditions, and neighborhood risk factors. The regression analysis was computed using the maximum likelihood estimation method, which provided regression coefficients, standard errors (SEs), adjusted odds ratio (aOR), Wald 95% confidence intervals (CIs) for the coefficients, and *P* values for each of the model variables. All statistical analyses were performed using PROC LOGISTIC procedure version 9.4 (SAS Institute Inc, Cary North Carolina).

Results

Overall population

A total of 10 836 patients aged 6 to 71 months met eligibility criteria between January 1, 2018, and December 31, 2019, including 6514 (60.1%) managed by PCPs at family medicine clinics and 4322 (39.9%) at general pediatric clinics. About 17.9% (*n* = 1939) of the study population was treated with TFV only, 12% (*n* = 1304) of the study population was prescribed oral fluoride supplement without TFV, 6.1% (*n* = 664) received both TFV and oral fluoride supplement, and 64% (*n* = 6929) had no fluoride treatment during the study period (Table 1). Children with dental caries tended to have a higher average age and ADI score. The percentage of patients with dental

TABLE 1
Patient Characteristics by Dental Caries Status^a

Characteristic	Having Dental Caries (N = 223)	No Dental Caries (N = 10 613)	Statistics
PCP specialty, n (%)			3.7
Family medicine	125 (56.1)	6389 (60.2)	
General pediatrics	98 (43.9)	4224 (39.8)	
Age, mean (SD), mo	57.5 (15.0)	45.3 (18.9)	94.0**
Sex, n (%)			1.4
Female	100 (44.8)	5156 (48.6)	
Male	123 (55.2)	5457 (51.4)	
Race/ethnicity, n (%)			34.1**
Non-Hispanic White	96 (43.0)	6157 (58)	
Non-Hispanic Black	36 (16.1)	1128 (10.6)	
Hispanic	29 (13.0)	1157 (10.9)	
Asian	20 (9.0)	442 (4.2)	
Other	42 (18.8)	1729 (16.3)	
Payer category, n (%)			29.5**
Commercial	74 (33.2)	5257 (49.5)	
Public insurance	122 (54.7)	4729 (44.6)	
Uninsured/self-pay	27 (12.1)	627 (5.9)	
Special care need, n (%)			1.4
Yes	46 (20.6)	2130 (20.1)	
No	177 (79.4)	8483 (79.9)	
Rural/urban area, n (%)			1.1
Urban	39 (17.5)	1711 (16.1)	
Rural	184 (82.5)	8902 (83.9)	
Fluoridated water, n (%)			6.8**
Yes	47 (21.1)	3102 (29.2)	
No	176 (78.9)	7511 (70.8)	
Area Deprivation Index, mean (SD)	56.8 (19.8)	54.3 (17.9)	7.2**
Dentist ratio, mean (SD)	50.4 (13.1)	50.3 (12.7)	0.4
Treatment			15.4**
TFV	25 (11.7)	1914 (18.0)	
Oral fluoride prescription	14 (8.1)	1290 (12.1)	
Both	12 (5.8)	652 (6.1)	
None	131 (74.4)	6798 (63.7)	

Abbreviations: N, total number of individuals in a treatment group; n, number of individuals in a study characteristic; PCP, primary care physician; TFV, topical fluoride varnish. **P* < .05; ***P* < .01.

caries also varied by race, ethnicity, health insurance payer category, fluoridated water zone, and provision of preventive dental treatment.

Risk of childhood dental caries

Table 2 presents the aORs of dental caries risk, controlled for demographics and neighborhood factors. The analysis shows that the risk of dental caries

increased by approximately 5% as the patient age increased each year (aOR = 1.05; 95% CI, 1.041-1.062). Non-Hispanic Blacks were 2 times more likely to develop dental caries than their non-Hispanic White counterparts (aOR = 2.05; 95% CI, 1.314-3.206), and the risk of dental caries for Hispanics was almost 4-fold higher than non-Hispanic Whites (aOR = 3.82; 95% CI, 2.214-6.600). Children in the Asian and Other groups showed a 61% to 84% greater

TABLE 2
Risk of Early Children Caries From Multiple Logistic Regression^a

Characteristic	aOR	95% CI	P
PCP specialty (ref: family medicine)	0.89	0.656-1.203	.44
Age, mo	1.05**	1.041-1.062	<.001
Female	0.90	0.679-1.198	.48
Race/ethnicity (ref: non-Hispanic White)			
Non-Hispanic Black	2.05**	1.314-3.206	.002
Hispanic	3.82**	2.214-6.600	<.001
Asian	1.84**	1.178-2.868	.007
Other	1.61*	1.084-2.395	.02
Payer category (ref: commercial)			
Public insurance	1.90**	1.361-2.641	<.001
Uninsured/self-pay	2.34**	1.371-3.997	.002
Special health care need	1.12	0.799-1.562	.52
Rural	1.65*	1.119-2.438	.01
Fluoridated water	0.54**	0.374-0.780	.001
Area Deprivation Index	1.01**	1.005-1.023	.002
Dentist ratio	1.01	0.994-1.019	.30
Treatment (ref: no treatment)			
TFV only	0.48**	0.321-0.721	<.001
Oral fluoride supplement only	0.76*	0.488-0.910	.02
Both	0.47**	0.251-0.098	.04

Abbreviations: aOR, adjusted odds ratio; CI, confidence interval; PCP, primary care physician; TFV, topical fluoride varnish.

^a*P < .05; **P < .01.

likelihood of having dental caries than non-Hispanic Whites.

Children who were uninsured or covered by public health insurance were more likely to develop dental caries versus those covered by commercial insurance. Children living in rural communities were also found to have a higher risk of dental caries than those living in urban areas (aOR = 1.65; 95% CI, 1.119-2.438). There was a 46% decrease in the odds of developing dental caries for children living in water fluoridation communities versus those living outside of CWF zones (aOR = 0.54; 95% CI, 0.374-0.780).

The ADI score is a composite measure representing the socioeconomic status of the patient at the neighborhood level. A higher ADI score indicates a greater level of poverty and social disadvantage. The regression analysis showed that the risk of dental caries also increased 1% as the ADI score increased by 1 unit (aOR = 1.01; 95% CI, 1.005-1.023), suggesting significant associations between dental caries, poverty, and social disadvantage.

A decrease in dental caries was found among children who received fluoride treatment. Individuals treated with TFV applications were 52% less likely to develop dental caries (aOR = 0.48; 95% CI, 0.321-0.721). There was a 24% decrease in the odds of having dental caries for children prescribed oral fluoride medications (aOR = 0.76; 95% CI, 0.488-0.910). The risk of dental caries reduced by 53% when children received both TFV and oral fluoride medications (aOR = 0.47; 95% CI, 0.251-0.098).

There was no significant difference in the risk of dental caries between patients managed by family physicians and those managed by general pediatricians. Dental caries risk also did not change by sex or whether patients had special health care needs. The dentist-to-population ratio did not affect the likelihood of developing dental caries in the study population.

Discussion

ECC among infants, toddlers, and preschool-aged children can lead to lifelong dental problems, nutritional deficiencies, poor school performance, and adulthood chronic health conditions.⁶⁻⁸ The persistence of ECC in these populations despite known methods of prevention (ie, fluoride) suggests the need for other ways of addressing this disease. This study provides an innovative approach to assess factors influencing risk of dental caries by linking clinical care records in EHRs to neighborhood characteristics through geospatial analysis. In general, children who are older, minority, under/uninsured, experiencing economic hardship, or living in rural or nonfluoridated water areas were at a higher risk of ECC. Thus, while primary care practices continue to advocate the use of TFV or oral fluoride supplement to prevent ECC from their patients, clinicians should be sensitive to economic, cultural, and environmental barriers and other health inequities faced by patients and communities.

Our analysis showed that offering fluoride treatment in routine primary care visits effectively reduced the risk of developing ECC for young children, regardless of whether patients were managed by family physicians or general pediatricians. This finding is consistent with evidence-based literature and national prevention recommendations regarding the health benefits of providing fluoride supplementation for children.^{12,26} It further demonstrates that primary care providers can serve as an important source of oral health care for vulnerable patients to improve their overall health. Yet, oral health has historically been left out of health professions school curricula. Students who do not learn about oral health during

their training are unlikely to integrate oral health into their practice. Future health professions training should consider fundamental oral health assessment and screening as part of standard curricula to enhance the proficiency of clinicians to conduct oral examinations and apply fluoride varnish in primary care practice.²⁷

Racial and ethnic minority children in this study were found to have a significantly greater risk of dental caries than their White counterparts, consistent with findings from nationally representative surveillance data. The Centers for Disease Control and Prevention's National Oral Health Surveillance Report in 2011-2016 indicated that 33% of Hispanic and 28% of non-Hispanic Black children aged 2 to 5 years had cavities in their primary teeth versus 18% of their non-Hispanic White counterparts.²⁸ Our study also revealed that children experiencing greater economic hardship were likely to have dental caries. Poverty has been considered a key factor associated with an increasing risk of dental caries. The literature has shown that oral health conditions disproportionately affect individuals with low economic status.²⁹ Low-income families have historically had an increased burden of dental disease and less access to dental care. Individuals in households with poverty have been shown to be associated with oral cancer, dental caries, tooth loss, periodontal disease, and poor oral health quality of life.³⁰ There have been increased concerns that children from racial and ethnic minority or low-income households often face the greatest burden of dental caries.^{15,31} Despite continuing efforts to improve access to dental care for vulnerable populations, substantial disparities remain among low-income populations and racial and ethnic minorities.

Access to oral health care was also identified as an important predictor for dental caries in the study. The lack of access to oral health services has often been linked to dental workforce shortage. To increase the capability of dental care delivery services, many states have authorized the development of school- or community-based dental therapist programs as a strategy to expand access to care for the underserved population.³² This analysis did not find a correlation between the risk of dental caries and the ratio of dentists to the overall population in our health system's catchment area. Nonetheless, our study found a much greater risk of dental caries in uninsured and publicly insured children. As of 2015, approximately 29% of the US population (children and adults) lacked dental insurance.³³ The passage of the Affordable Care Act in 2010 increased health insurance rates by mandating that all Americans purchase health insurance or face a penalty. However, dental

insurance remained optional and not one of the "essential health services" required by law.³⁴ Our study signifies the importance for primary care to serve as a safety net for children to receive necessary preventive dental care, as finding an oral health provider who accepts insurance or with affordable co-pays can be a challenge.

CWF has been a safe and cost-effective way to prevent tooth decay and cavities,^{10,11} although more than a quarter of the US population does not have access to fluoridated water.³⁵ The risk of oral health problems can be aggravated for individuals living in rural areas where there is a lack of access to both fluoridated water and dental care services. Our study confirmed that children in rural and non-CWF communities are at a greater risk of dental caries. The finding underscores the importance for primary care clinicians to prescribe fluoride care to those children.

Although the diagnoses classified as special health care needs in this study share a greater likelihood of more complicated oral health problems, they did not reveal a significantly increased risk for dental caries in comparison with the other risk factors. In keeping with the AAP oral health risk assessment recommended for use by PCPs, as well as caries risk assessment tools by the American Academy of Pediatric Dentistry (AAPD),^{13,36} American Dental Association (ADA),³⁷ and Caries Management by Risk Assessment (CAMBRA),³⁸ we grouped together all children with special health care needs. Current guidelines acknowledge the general lack of scientific evidence to support inclusion of specific disease markers as risk factors in these caries risk assessment tools. However, emerging research in precision dentistry recognizes that children with special health care needs are complex and heterogeneous, leading to variations in caries risk among and between special health care needs subgroups.³⁹ Therefore, it is possible that the heterogeneous complexity of children with special health care needs in this particular study (ie, their socioeconomic risk factors and neighborhood characteristics) posed a greater dental caries risk than the special health care needs themselves. In fact, multiple studies investigating dental caries risk and utilization of caries prevention in children with special health care needs populations showed variability in caries risk, prevention, and care utilization in their study populations for reasons still not well understood.³⁹⁻⁴¹ Given the vulnerability of this population segment and its comorbidities, we suggest that increased attention to their oral health status, and specifically their caries risk, is still in order. As such, more precise exploration of the heterogeneity within this subpopulation as it relates to dental caries risk should be an area for future study.

Strengths and Limitations

Our study included several limitations. First, despite a large sample size, the study population was based on a single academic health care center, potentially limiting the findings' generalizability. Second, the analysis was unable to include individual-level socioeconomic indicators because those data were not collected in the EHRs. Nonetheless, the study used neighborhood-level census statistics derived from the home location of patients as proxies for these characteristics. Census data are aggregated statistics representing the overall sociodemographic nature of a small neighborhood area. These data may not capture all the variations among individuals, possibly diluting predictive power.³¹ Third, our analysis assumed that children living in CWF areas had access to fluoridated water. However, there might be families using nonfluoridated bottled water. Our result would not be able to account for this situation. Fourth, the ratio of dentists to the population was used as a proxy to represent the availability of the dental care services. The ratio might overestimate the proportion of the dentist workforce available for underserved children. Future study should include statistics representing the shortage of dentists participating in Medicaid or the Children's Health Insurance Program (CHIP) as a workforce shortage factor. Fifth, patients might have received fluoride treatment from their dentists outside of the health system's network. Care information from dentist visits was not available in the health system's EHRs, resulting in underestimation of the number of children receiving preventive fluoride care during the study period. Sixth, clinicians might have not consistently documented dental caries in EHRs during primary care visits. The prevalence of children with dental caries could also be underestimated and underrepresented in the analysis. Thus, future training of oral health for primary care providers would provide more comprehensive care for young patients.²⁷

Conclusions

ECC remains a public health challenge, although this chronic condition is largely preventable through TFV, oral fluoride supplements, and community fluoridated water. This study analyzing EHRs, neighborhood statistics, and geospatial data demonstrates that children who are identified as racial and ethnic minorities, under/uninsured, experiencing economic hardship, or living in rural or nonfluoridated water areas are at a higher risk of developing dental caries. Despite continuing efforts to improve access to dental care for vulnerable populations, substantial disparities

Implications for Policy & Practice

- Large racial and geographic disparities in dental caries exist among toddlers and preschool-aged children. Public health and health care professionals should be sensitive to economic, cultural, and environmental barriers and other health inequities faced by patients and communities when determining policies and procedures as they relate to preventing and reducing dental caries risk, particularly regarding access to care.
- Primary care clinicians can serve as the safety net to care for children with no or limited access to oral health care. Similar research beyond one health system should be considered. Further investigation into ways of strengthening collaborative care and eventually integration of oral health care into primary care should also be considered.

remain among socioeconomically disadvantaged children. Fluoride is relatively inexpensive, noninvasive, easy and fast to apply, and reimbursable by insurance companies. Our research suggests that fluoride application or prescription by primary care clinicians may decrease the incidence of dental caries, particularly for populations most affected by the disease. Future research beyond one health system should be considered to further characterize clinician prescribing practices as well as barriers to the use of fluoride. Additional investigation into the collaboration between primary care and dental providers at the level of both practice and professional education should be considered.

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