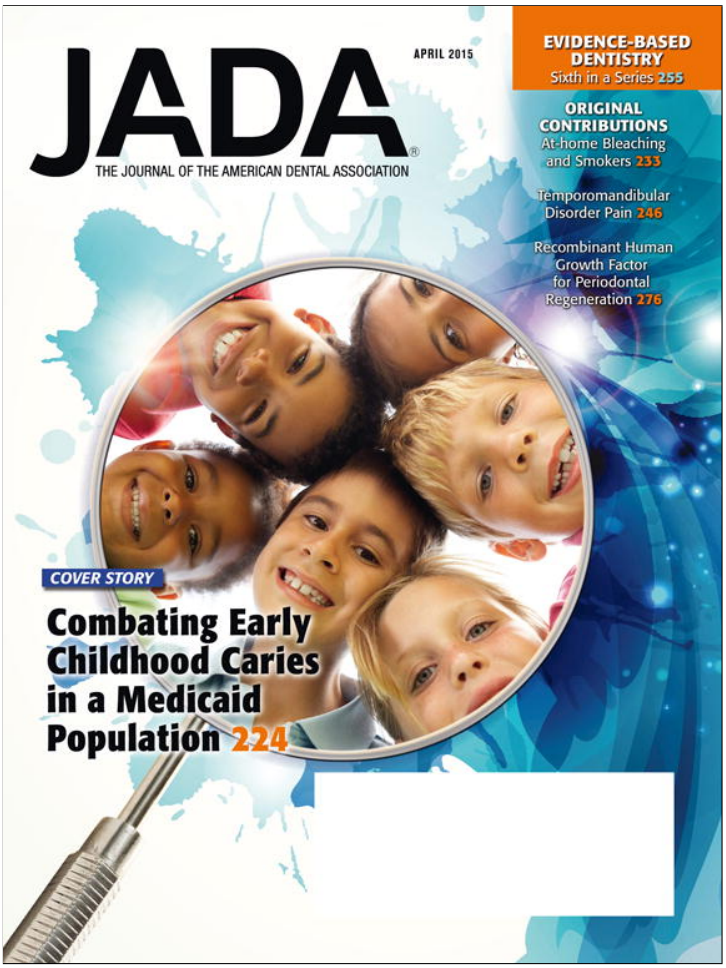

ADA CE Program ARTICLE 1

COVER STORY

Reducing early childhood caries in a Medicaid population

A systems model analysis

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ABSTRACT

Background. Despite early childhood caries (ECC) being largely preventable, its repair accounts for a disproportionate share of Medicaid expenditures. In this study, the authors model disease reductions and cost savings from ECC management alternatives.

Methods. The authors apply system dynamics modeling to the New York State Medicaid population of young children to compare potential outcomes of 9 preventive interventions (water fluoridation, fluoride varnish, fluoride toothpaste, medical screening and fluoride varnish application, bacterial transmission reduction, motivational interviewing, dental prevention visits, secondary prevention, and combinations) and the effect of defluoridating New York City.

Results. Model simulations help project 10-year disease reductions and net savings from water fluoridation, motivational interviewing, and fluoride toothpaste. Interventions requiring health professionals cost more than they save. Interventions that target children at high risk, begin early, and combine multiple strategies hold greatest potential. Defluoridating New York City would increase disease and costs dramatically.

Conclusions. The variety of population-level and individual-level interventions available to control ECC differ substantially in their capacity to improve children's oral health and reduce state Medicaid expenditures.

Practical Implications. Using Medicaid and health department dollars to deliver ECC preventive and management interventions holds strong promise to improve children's oral health while reducing state dental expenditures in Medicaid.

Key Words. Caries; Medicaid; dental care for children; preventive dentistry; fluoridation; models; economic.
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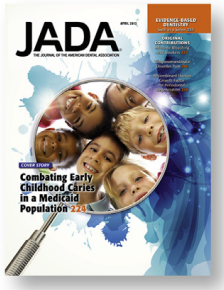
Medicaid's Early and Periodic Screening, Diagnostic and Treatment benefit for children and the Children's Health Insurance Program both mandate comprehensive dental benefits[1] for the nearly one-half of US children enrolled at any time during the year. In the United States, early childhood caries (ECC)—tooth decay among children younger than 6 years—is highly prevalent[2] and strongly associated with children eligible for public insurance.[3] ECC treatment consumes a disproportionate share of Medicaid and Children's Health Insurance Program dental expenditures because its conventional remedy often requires extensive and expensive dental repair with patients under general anesthesia in medical facilities.[4] Although dental repair restores function and esthetics, it does not arrest disease progression[5] because it does not affect underlying determinants of this chronic disease. A number of public health, behavioral, educational, and pharmacologic approaches to ECC have been proposed to prevent and suppress caries activity, particularly among children of low income whose cavities frequently go untreated.



We previously reported findings of system dynamics modeling to assess the potential for chronic disease

This article has an accompanying online continuing education activity available at: http://jada.ada.org/ce/home.

management to reduce ECC occurrence and progression among Colorado preschoolers of all income levels.[6] System dynamics modeling is a computer simulation technique that allows the user to anticipate the effect of interventions in complex situations with interdependent variables.

It is not predictive of the future but does "allow policy makers and program managers to consider resolutions of complex, multilayered, interactive issues in an organized way."[6] Determination of Medicaid investments in disease management for young children is 1 such complex issue. Our Colorado findings helped us project 10-year intervention costs and associated savings, noting that interventions would yield the greatest benefit if they target the youngest children, would yield the greatest return on public investment if they target children at highest risk, and would be most effective with use of combinations of interventions that address multiple stages of ECC's genesis and progression. Although some interventions saved more in dental repair than their cost, all produced substantial reductions in disease occurrence and associated repair costs. Building on these Colorado findings for all young children, we assess in this study the potential for ECC interventions to reduce cavity occurrence in toddlers and preschoolers who are poor and of low income in New York State (NYS) and help project savings that may accrue to the NYS Medicaid program through ECC management.

METHODS

Our approach is predicated on the natural history of caries progression in young children. Children become at risk for ECC from birth as teeth erupt and children acquire caries-associated bacteria. They vary in caries risk and experience according to hereditary, familial, environmental, dietary, and developmental factors. Caries risk and activity increase with age from no disease; to the establishment of caries activity; to the development of visible cavities; and, if untreated, to the occurrence of symptoms and infections. This progression can be arrested and, to a limited degree, reversed. The nature of the disease and the population affected mean that children vary over time in at least 3 dimensions accommodated by the model: they grow from birth to age 6 years, their disease progresses through recognized stages at different rates related to risk, and their level of caries activity is affected by preventive and disease-suppressive interventions.

In our baseline model, we considered caries progression in the absence of any intervention for the 450,000 children younger than 6 years eligible for NYS Medicaid (56% in New York City [NYC]) on the basis of family incomes less than 133% of the federal poverty level. We then modeled interventions that change the rates of progression from 1 stage of disease to the next for their putative capacity to reduce cavity prevalence and associated repair costs. The model provides intervention-specific costs, associated savings in avoided dental repair, and net savings (reduced costs for repair minus the cost of the intervention), thereby allowing practitioners and policy makers to consider the potential benefit in dollars saved for Medicaid and disease avoided for beneficiaries.

To allocate these children among groups of low, moderate, and high caries risk, we used NYS parental reports of the condition of their children's teeth from the National Survey of Children's Health 2007,[7] apportioning 62.9% to low risk on the basis of parents reporting "excellent or very good" dental condition, 25.8% to moderate risk on the basis of parents reporting "good" dental condition, and 11.3% to high risk on the basis of parental reports of "fair or poor" dental condition.

To allocate cavity occurrence within each risk group, we selectively adjusted National Survey of Children's Health 2007 parent reports of children having "decay or cavities in the last six months" by clinical caries examination findings from the 1999-2002 National Health and Nutrition Examination Survey (NHANES),[8] thereby ensuring that overall caries prevalence equated to the 35% in the NHANES report. This method resulted in estimates of 18.1% cavity occurrence among young children at low risk, 57.3% among young children at moderate risk, and 77.9% among young children at high risk in NYS Medicaid.

We additionally extrapolated proportions of cavities that were untreated and the extent of cavities from NHANES. We estimated precavitation caries prevalence by using procedures described in the Colorado study.[6] We validated rates of dental treatment among affected children by using data from the 2004 Medical Expenditure Panel Survey.[9]

Data from NYS Medicaid and from the state's all-payer hospital data set (Statewide Planning and Research Cooperative System) revealed that dental office restorative care for young children costs $486 and that 2.6% of children additionally had obtained care in a hospital emergency department at a cost of $375.[10] Approximately one in seven (13.8%) young children required treatment in the hospital operating room at an aggregate cost of $4,630, composed of facility cost at $3,128 after adjusting for cost-to-charge ratio of 0.429,[11] dental at $866 (Jayanth Kumar, DDS, MPH, email communication, October 2013), anesthesia at $485 (Jayanth Kumar, DDS, MPH, email communication, October 2013), and preoperative physical and laboratory expenses at $151.[12]

For demographic trends, we used actual NYC and rest-of-state birth rates for preschoolers who were

ABBREVIATION KEY. **CWF:** Community water fluoridation. **ECC:** Early childhood caries. **MI:** Motivational interviewing. **NHANES:** National Health and Nutrition Examination Survey. **NYC:** New York City. **NYS:** New York State.

TABLE 1

Projected outcomes, costs, and net savings attributable to early childhood caries interventions.

	OUTCOME MEASURE 1: PREVALENCE OF CHILDREN WITH CAVITIES	
	Percentage of Children With Cavities	Percentage of Reduction in Children With Cavities Compared With Baseline
BASELINE	27.3	NA*
1. Community Water Fluoridation		
1.1 Maximally fluoridating rest of state with cost and benefit allocated exclusively to rest of state Medicaid preschoolers	26.4	3.3
1.2 Defluoridating NYC† with cost and benefit allocated exclusively to NYC Medicaid preschoolers	31.0	−13.6
2. Fluoride Varnish for Preschoolers Receiving Medicaid Throughout New York State		
2.1 Applied to children aged 6 months to 6 years assuming 40% reduction in rate of new and recurrent cavities	18.7	31.5
2.2 Applied to children aged 2 to 6 years assuming 40% reduction in rate of new and recurrent cavities	24.0	12.1
2.3 Applied only to children at high risk aged 2 to 6 years assuming 40% reduction in rate of new and recurrent cavities	26.7	2.2
2.4 Applied to children aged 6 months to 6 years assuming 22% reduction in rate of new and recurrent cavities	22.8	16.5
2.5 Applied to children aged 2 to 6 years assuming 22% reduction in rate of new and recurrent cavities	25.6	6.2
2.6 Applied only to children at high risk aged 2 to 6 years assuming 22% reduction in rate of new and recurrent cavities	27.0	1.1
3. Toothbrushing With Fluoridated Toothpaste at Various Reports of Effectiveness for Children Aged 2 and 3 Years		
3.1 All Medicaid preschoolers assuming a 50% increase in toothbrushing over NYC baseline of 43%	25.6	6.2
3.2 All Medicaid preschoolers assuming a 50% increase in toothbrushing over Iowa baseline of 36%	25.9	5.1
3.3 Preschoolers at high risk receiving Medicaid assuming a 50% increase in toothbrushing over NYC baseline of 43%	27.1	0.7
4. Screening for Children at High Risk by Primary Medical Care Providers Followed by 4 Fluoride Varnish Applications per Year		
4.1 Screening for high-risk group combined with 4 prevention visits per year that include fluoride varnish application	26.2	4.0
5. Reducing Cariogenic Bacteria Transmission From Mother or Caregiver to Preschoolers Receiving Medicaid Aged 6 Months to 2 Years		
5.1 Reduce transmission among preschoolers receiving Medicaid between birth and 24 months	17.9	34.4
5.2 Reduce transmission among only preschoolers at high risk who are receiving Medicaid	25.8	5.5
6. MI‡ at Various Reports of Effectiveness		
6.1 MI assuming 63% cavity reduction with intervention at 6 months	15.0	45.0
6.2 MI assuming 63% cavity reduction with intervention at age 2 years	21.7	20.5
6.3 MI assuming 46.5% cavity reduction with intervention at 6 months	18.5	32.2
6.4 MI assuming 38.3% cavity reduction with intervention at 6 months	20.2	26.0
6.5 MI assuming 46.5% cavity reduction when applied only to preschoolers at high risk who are receiving Medicaid at 6 months	25.8	5.5
7. Dental Prevention Visits		
7.1 Preventive visits reaching 32% of preschoolers receiving Medicaid	26.7	2.2
7.2 Preventive visits reaching 100% of preschoolers receiving Medicaid	23.5	13.9
7.3 Preventive visits reaching 100% of preschoolers at high risk who are receiving Medicaid	26.7	2.2
8. Secondary Prevention and Reduction in Expensive Cases		
8.1 Treating white-spot lesions before cavitation more aggressively in children aged 6 months to 2 years and less aggressively in children aged 2 to 6 years	21.8	20.1
8.2 Treating white-spot lesions before cavitation equally aggressively in children aged 6 months to 2 years and in children aged 2 to 6 years	19.9	27.1
9. Selected Combined Interventions		
9.1 MI assuming 63.0% cavity reduction AND reduced cariogenic flora transmission among preschoolers receiving Medicaid between birth and 24 months.	9.1	66.7
9.2 All preschoolers at high risk who are receiving Medicaid receive preventive visits AND MI (assuming a 46.5% cavity reduction)	25.5	6.6
9.3 All preschoolers at high risk who are receiving Medicaid receive preventive visits AND MI (assuming a 46.5% cavity reduction) AND 50% increase in toothbrushing over NYC baseline of 43%	24.7	9.5

* NA: Not applicable.
† NYC: New York City.
‡ MI: Motivational interviewing.

TABLE 1 (CONTINUED)

OUTCOME MEASURE 2: NUMBER OF AFFECTED TEETH		COSTS		OUTCOME MEASURE 3: TREATMENT SAVINGS	OUTCOME MEASURE 4: RETURN ON INVESTMENT	NET SAVINGS
Number of Affected Teeth	Percentage of Reduction in Number of Affected Teeth	Total Intervention Cost	Cumulative Cost of Repair	Savings in Cost of Repair	Dollars Saved in Dental Repair for Each Dollar Spent on the Intervention	Net Savings (Net Costs or Negative Savings)
625,406	NA	$0	$315,928,768	NA	NA	NA
605,576	3.2	$1,221,375	$303,727,648	$12,201,128	$9.99	$10,979,753
710,733	−13.6	−$1,745,709	$371,879,904	−$55,951,136	−$32.05	−$54,205,427
428,040	31.6	$241,786,256	$208,958,624	$106,970,152	$0.44	−$134,816,104
549,437	12.1	$170,385,376	$267,327,328	$48,601,440	$0.29	−$121,783,936
612,722	2.0	$19,247,422	$303,344,640	$12,584,128	$0.65	−$6,663,294
522,407	16.5	$241,786,256	$257,049,248	$58,879,520	$0.24	−$182,906,736
585,658	6.4	$170,385,376	$289,537,664	$26,391,112	$0.15	−$143,994,264
619,322	1.0	$19,247,424	$309,324,000	$6,604,786	$0.34	−$12,642,638
587,755	6.0	$15,071,346	$293,597,984	$22,330,792	$1.48	$7,259,446
594,731	4.9	$12,331,104	$297,664,032	$18,264,728	$1.48	$5,933,624
620,210	0.8	$1,702,680	$310,463,072	$5,465,688	$3.21	$3,763,008
599,573	4.1	$52,739,365	$293,883,392	$22,045,384	$0.42	−$30,693,981
409,338	34.5	$102,328,720	$238,042,272	$77,886,504	$0.76	−$24,442,216
591,912	5.4	$11,563,149	$295,592,736	$20,336,032	$1.76	$8,772,883
343,623	45.1	$78,259,232	$188,415,568	$127,513,200	$1.63	$49,253,968
497,353	20.5	$101,750,000	$238,140,000	$77,790,000	$0.76	−$23,960,000
424,597	32.1	$78,259,232	$220,735,632	$95,193,136	$1.22	$16,933,904
463,255	25.9	$78,259,232	$237,347,824	$78,580,944	$1.00	$321,712
592,277	5.3	$8,843,294	$290,859,520	$25,069,264	$2.83	$16,225,970
612,140	2.1	$29,336,728	$306,399,648	$9,529,120	$0.32	−$19,807,608
539,025	13.8	$182,790,432	$256,744,704	$59,184,072	$0.32	−$123,606,360
612,885	2.0	$20,650,690	$300,089,600	$15,839,168	$0.77	−$4,811,522
499,116	20.2	$47,631,232	$274,034,368	$41,894,408	$0.88	−$5,736,824
455,599	27.2	$70,300,320	$262,442,976	$53,485,792	$0.76	−$16,814,528
209,197	66.6	$192,090,656	$149,028,192	$166,900,576	$0.87	−$25,190,080
584,280	6.6	$31,454,200	$279,384,224	$36,544,536	$1.16	$5,090,336
566,415	9.4	$37,723,156	$269,575,360	$46,353,392	$1.23	$8,630,236

eligible for Medicaid and projected 10-year NYC population growth to nearly 280,000 and a slight population decrease in the rest of the state.

We calibrated the baseline model to determine rates of flow that would maintain constant equilibrium distributions among disease stages without further interventions over 10 years. The resultant baseline simulation provides a basis for comparing interventions. The 9 categories of interventions tested (Table 1) were community water fluoridation (CWF), 2 simulations, including defluoridating NYC's water as proposed by the chair of the City Council's Committee on Public Safety; fluoride varnish application for children covered by Medicaid, 6 simulations; toothbrushing with fluoridated toothpaste, 3 simulations; screening of children at high risk by primary care medical care providers followed by 4 fluoride varnish applications per year, 1 simulation; reducing transmission of caries-causing bacteria from mother to child between birth and 2 years, 2 simulations; motivational interviewing (MI) with parents, 5 simulations, including a sensitivity analysis at 3 effect sizes, reflecting recognized effect degradation over time[13]; preventive dental visits, 3 simulations; secondary prevention to reduce high-cost cases, 2 simulations; and selected combination strategies, 3 simulations—MI plus reduced cariogenic flora transmission, MI and preventive visits, and MI, preventive visits, and toothbrushing with fluoride toothpaste. Data on each intervention's effect and cost from the peer-reviewed literature and from experts informed the model (Table 2).[13-29]

RESULTS

Table 1 provides 10-year results for each of the 9 intervention categories and their subsets demonstrating a wide range of:

- net savings—from a negative savings of $182.9 million for fluoride varnish application to all Medicaid preschoolers assuming the lowest reported effect size (simulation 2.4) to a positive savings of $49.2 million for MI for families of all preschoolers receiving Medicaid at age 6 months (simulation 6.1);
- costs of dental repair—from an increased cost of care of $56.0 million for defluoridating the NYC water supply (simulation 1.2) to a savings of $166.9 million for the combined intervention of MI and reduced cariogenic flora transmission from mothers and caregivers to children younger than 24 months (simulation 9.1);
- cost-to-savings ratios—from 15 cents saved for each dollar invested for fluoride varnish application for all preschoolers receiving Medicaid (simulation 2.5) to $9.99 saved for each dollar invested for maximally extending CWF to the rest of the state (simulation 1.1);
- proportion of affected children—from 1.1% reduction from baseline for fluoride varnish applied only to children at high risk aged 2 to 6 years (simulation 2.6) to 66.7% for a combination intervention of MI assuming 63% cavity reduction effect size and reduced cariogenic flora transmission among preschoolers receiving Medicaid between birth and 24 months (simulation 9.1);
- number of affected teeth—from a 13.6% increase from baseline for defluoridating NYC (simulation 1.2) to a 66.7% reduction from baseline for combined intervention 9.1;
- savings in the cost of dental repair—from $5.5 million for toothbrushing with fluoride toothpaste for preschoolers at high risk who receive Medicaid assuming a 50% increase in the practice over the NYC baseline of 43% (simulation 3.3) to $166.9 million for the combined intervention (simulation 9.1).

Expanding CWF suggests net cost savings over 10 years (simulation 1.1), whereas defluoridation would result in multiple times greater net costs for increased dental repair (simulation 1.2) compared with savings on the cost of fluoridation. Toothbrushing with fluoridated toothpaste—another fluoride-mediated, low-cost, home- or community-based intervention—similarly helps project net cost savings (simulations 3.1-3.3). Health care professional interventions—fluoride varnish application (simulations 2.1-2.6), screening and intensive fluoride varnish application (simulation 4.1), dental prevention visits (simulations 7.1-7.3), and secondary prevention to treat incipient cavities (simulations 8.1-8.2)—reduce disease burden in young Medicaid beneficiaries, but each costs more than it saves in reparative care because of high input costs. MI, despite requiring the engagement of professionals, suggests net savings for all scenarios that initiate this intervention in children before age 2 years (simulations 6.1, 6.3, 6.4, and 6.5). Reducing cariogenic flora transmission, another high-cost intervention, holds promise to be cost saving when directed to families of young children at high risk (simulation 5.2) but not to all young children receiving Medicaid (simulation 5.1).

Among fluoride-based interventions, the lowest unit cost and most passive intervention, CWF, holds the greatest promise for both disease reduction and cost savings while equitably reaching all young children receiving Medicaid regardless of their caries risk. This finding held even when discounting CWF's effectiveness by one-half of the benefit reported in a Cochrane review as reflected in Table 2 to reflect other sources of fluoride exposure.[12] Toothbrushing with fluoride toothpaste similarly demonstrates positive outcomes for all 4 outcome measures—percentage of children with cavities, numbers of affected teeth, savings in dental repair, and ratio of dollars saved in repair to dollars spent on interventions—for all toothbrushing simulations (3.1-3.3). The greatest return on toothbrushing program costs ($3.21 per $1.00 expended) is evident when the intervention is directed exclusively to children at high risk (simulation 3.3), whereas the greatest cumulative net cost

TABLE 2

Data sources and cost assumptions used in modeling each of 30 interventions within 9 intervention categories.

INTERVENTION	DATA SOURCES	COST ASSUMPTIONS
Community Water Fluoridation	25% disease reduction from Kumar and colleagues,[14] 2010 (representing about one-half the reported effect size from Marinho and Colleagues,[15] 2003); 38.2% of rest-of-state population, and 16% of the Medicaid preschool population, is served by nonfluoridated community water systems amenable to fluoridation	$1.58 per child per year from Griffin and colleagues,[16] 2007, and Centers for Disease Control and Prevention,[17] 1999
Fluoride Varnish Application	40% disease reduction from Marinho and colleagues,[15] 2003; 22% disease reduction from Weyant and colleagues,[18] 2013; modeling based on Weintraub and colleagues,[19] 2006	$30 per fluoride varnish application paid by New York State Medicaid
Primary Care Pediatric Dental Prevention Visit With Quarterly Topical Fluorides	65.3% disease reduction from Ng and colleagues,[20] 2012; modeling based on Pahel and colleagues,[21] 2011	$14 screening cost at age 2 years from J. Kumar, DDS, MPH, Director, New York State Bureau of Dental Health, email communication, October 2013; $30 per fluoride varnish application paid by New York State Medicaid
Reducing Transmission of Caries-Causing Bacteria From Mother to Child by Using Parental Education and Xylitol by Mother for 12 Months	88% colonization reduction from Söderling and colleagues,[22] 2001; 64% colonization reduction from Köhler and colleagues,[23] 1983; 73% disease reduction from Isokangas and colleagues,[24] 2000, and Köhler and Colleagues,[25] 1994	$114 per mother or caregiver from K. Thomas, Managing Partner, Elevate Oral Care, email communication, September 2014
Motivational Interviewing	63% disease reduction from Weinstein and colleagues,[26] 2004; adjusted for effectiveness degradation over time from Hettema and colleagues,[13] 2005	$100 assumed for 1 motivational interviewing session
Toothbrushing With Fluoridated Toothpaste	21% to 38% disease reduction from Marinho and colleagues,[15] 2003 bracketing 31% from Santos and colleagues,[27] 2013; 35.9% and 43.4% brushing prevalence among preschoolers from unpublished reports by the Iowa Fluoride Study and New York City Department of Health and Mental Hygiene	$17 per child from K. Thomas, Managing Partner, Elevate Oral Care, personal communication
Preventive Dental Visits	23% reduction in the numbers of children requiring dental repair and 55% reduction in the numbers of procedures for children with a preventive visit before 42 months of age from Beil and colleagues,[28] 2012	$56 per preventive visit from New York State Medicaid
Secondary Prevention	20% reduction in cavities with less aggressive intervention focusing more heavily on affected children with intervention at 6 months to 2 years and less on those aged 2 to 6 years; 27% reduction in cavities with more aggressive intervention that targets children aged 6 months to 2 years and 2 to 6 years equally from Manski and Brown,[26] 2007	$242 per caries management intervention determined as the midpoint in costs for a pediatric preventive and restorative visit reported in Medical Expenditure Panel Survey from Manski and Brown,[29] 2007, and inflation adjusted
Selected Combined Interventions	Data sources described above	Funding sources described above

savings is evident when applied to all preschoolers receiving Medicaid (simulations 3.1 and 3.2). When fluoride is delivered by means of professionally applied varnish, positive findings remain for all outcomes, but the relatively high cost of delivery substantially reduces the ratio of dollars saved for repair to dollars spent on interventions and, unlike CWF and toothbrushing, cumulative intervention costs consistently exceed savings in dental repair across all models. The reported effect sizes for fluoride varnish vary by nearly a factor of 2, as do the resultant disease reductions and ratio of savings.

As with fluoride varnish, interventions requiring health care professionals—medical screening followed by intensive fluoride varnish application (simulation 4.1), dental prevention visits (simulation 7.1-7.3), and arrest of lesion progression by treating incipient lesions (simulations 8.1-8.2)—improve all outcomes but at a negative cumulative cost. Greatest disease reductions are associated with arresting lesion progression among children with early physical signs of disease (simulations 8.1-8.2), whereas prevention visits for all children receiving Medicaid is among the most costly (simulation 7.2).

MI and counseling mothers and caregivers in limiting the transmission of cariogenic flora both result in improvements across all 4 outcome measures. All except 2 simulations for educational interventions—starting MI at age 2 years rather than earlier (simulation 6.2) and limiting transmission for all children rather than for only children at high risk (simulation 5.1)—also help project net cost savings. MI simulations are presented at 3 effect sizes (simulations 6.1, 6.4, and 6.5) to provide a sensitivity

analysis commensurate with the understanding that the effect of MI decreases over time. Beginning with the 63% effect size reported by Weinstein and colleagues,[26] the potential for MI[15] was reduced to 46.5%, assuming a decrease in effect after 1 year to 33%, and was reduced to 38.3%, assuming a decrease in effect after 2 years to the same level. We made no assumption about the professional qualifications of the MI provider and applied the same intervention cost to all MI simulations.

System dynamics allowed us to anticipate that combinations of interventions will be greater than single interventions (simulations 9.1-9.3) but that their effects on outcomes will not be additive. Instead, we factored the complexity in children's movement by age, risk, and treatment, as well as overall population dynamics, into the model to derive unique outcomes for each combination. The only negative intervention modeled was the defluoridation of NYC's water supply (simulation 1.2) that allows us to anticipate negative effects on all 4 outcome measures (13.6% increase in the percentage of children with cavities and number of cavities, decreased savings on dental repair, and loss of $32.05 for each dollar saved from discontinuance), as well as substantial net cost.

DISCUSSION

Our findings are consistent with those of a US surgeon general's 2000 Workshop on Children and Oral Health that proposed strategies for caries control in young children.[30] These strategies are starting interventions early in children's lives; engaging all who come in contact with young children; empowering families and enhancing their capabilities to prevent and suppress disease; and "fixing public programs," including Medicaid, by prioritizing prevention and disease management on the basis of the best available science.[30] Authors of a 2013 US Preventive Services Task Force review noted the need for greater evidentiary studies of high quality.[31] They also support a number of our simulations in reporting high sensitivity (0.76) for pediatricians correctly identifying the presence of ECC, confirming the effectiveness of fluoride varnish, and reconfirming the effectiveness of fluoride supplementation.

Overall, as in our Colorado study,[6] interventions that begin early in children's lives or that affect early stages of caries development anticipate greater disease reductions compared with baseline than do interventions that target the children at highest risk. Interventions that depend on professionals are universally salutary but, with the exception of MI and toothbrushing instruction, which also can be delivered by lay health workers, cost more than they save in reparative dentistry costs. Nonetheless, the value of professional dental visits extends beyond the individual interventions modeled herein because professional visits address oral health considerations beyond caries development, including orofacial development, soft-tissue health, occlusion, and dental defects related to trauma and dental development. They also reinforce educational messages about personal caries management strategies, including dietary control and home fluoride use. Given that children from families of low income with Medicaid coverage experience higher rates of ECC; that ECC is consequential to them, their families, and the Medicaid program itself[32]; and that they experience fewer dental visits than do children of higher income, continued efforts to increase use of preventive dental services is warranted.

In this study, we considered 2 important interventions not previously modeled for ECC: toothbrushing with fluoridated toothpaste and defluoridation of the city's water supply. Toothbrushing is important because it is a low-cost, home- or community-administered intervention with wide public acceptance that currently is underused among young children of low income despite the strong encouragement of professional and trade associations through the Ad Council's *2min2X* campaign.[33] Unlike professional application of fluoride varnish, toothbrushing, like CWF, projects net cost savings. Although toothbrushing reduces the percentage of children with cavities more modestly than does CWF, its adoption by one-half of all young children receiving Medicaid not currently brushing with fluoridated toothpaste can be expected to result in comparable reductions in the numbers of affected teeth. We did not include costs associated with instruction and promotion of toothbrushing in the cost estimation, but we assumed they were provided in routine dental care.

The proposal to defluoridate NYC water is important because fluoridation is well established as safe and effective[34] and has been in place in NYC since 1964.[35] However, the City Council has entertained a bill for its removal and has not endorsed using Medicaid funds to support fluoridation infrastructure as a cost-saving measure. System dynamics help anticipate that defluoridating the NYC water supply would increase reparative dentistry costs by $55.9 million for young children receiving Medicaid alone. The overall effect would be far greater, given that CWF additionally benefits young children in families above Medicaid eligibility as well as the entire state's residents across their life spans.[16] Defluoridation also fails to address human costs in terms of young children's impaired oral health status, their seeking care at hospital emergency rooms for caries-related complications, and the imposition and risks of general anesthesia.

System dynamics modeling facilitates clinical and policy decision making by demonstrating the relative value of competing options. As Medicaid, public health, and dental policy makers work to balance scarce resources against competing public needs, system dynamics modeling provides information helpful in

maximizing usefulness and efficiency. Results reported must be understood within the model's assumptions and limitations in the availability of authoritative cost data for some of the simulations. Results also need to be considered within the context that we model only benefits to children younger than 6 years enrolled in Medicaid, whereas older children and children from higher-income families also may benefit from tested strategies.

This work supports a number of policies that hold promise to reduce the ECC epidemic and its associated programmatic costs, including the following:

- Retaining CWF in NYC.
- Expanding CWF in the rest of the state.
- Promoting and supporting the development and implementation of widespread MI, minimizing cariogenic bacterial transmission, and combined interventions on ECC prevention and suppression targeted to parents of young children of low income. Parents of such children at high risk can be reached through early intervention; Women, Infants and Children; Head Start; and regulated day-care programs, as well as through community and faith-based groups.
- Promoting and supporting the development and implementation of toothbrushing programs that encourage regular use of fluoride toothpaste among young children receiving Medicaid.
- Continuing to pay for fluoride varnish applications by pediatric medical care providers and dental care providers with prioritization of youngest children at highest ECC risk. Most state Medicaid programs now reimburse nondentists to apply fluoride varnish,[36] and training programs are available through multiple professional organizations and state oral health programs.
- Incentivizing providers financially, socially, and educationally to prioritize care of the youngest children at highest risk to deliver intensive preventive care, control disease progression, and use multiple interventions in the suppression of caries activity. Examples include the Washington State Access to Baby and Child Dentistry Program,[37] the Iowa I-Smile Dental Home Program,[38] the North Carolina Into the Mouth of Babes Program,[39] and the Maine From the First Tooth Program.[40]

Although highly prevalent, consequential, and costly to Medicaid relative to other pediatric dental expenditures, ECC is overwhelmingly preventable. System dynamics modeling provides support to Medicaid and health policy makers to take action that holds strong potential to reduce disease occurrence and thereby improve the health and welfare of children who are poor or of low income. ■

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