Cost-effectiveness of a disease management program for early childhood caries

Mihail Samnaliev, PhD[1]; Rashmi Wijeratne, BS, MPH[2]; Eunhae Grace Kwon, DDS[3]; Henry Ohiomoba, BDS, MPH[4,5]; Man Wai Ng, DDS, MPH [2]

1 Clinical Research Center, Boston Children's Hospital, Boston, MA, USA
2 Department of Dentistry, Boston Children's Hospital, Boston, MA, USA
3 Pediatric Dentistry, University of the Pacific, Menlo Park, CA, USA
4 Harvard School of Dental Medicine, Boston, MA, USA
5 Boston Children's Hospital, Boston, MA, USA

Keywords
early childhood caries; disease management; prevention; cost; cost-effectiveness.

Correspondence
Mr. Mihail Samnaliev, BCH, Clinical Research Center, 21 Autumn Room 322, Boston, MA 02115. Tel.: 857-218-4726; Fax: 857-218-4726; e-mail: Mihail.Samnaliev@childrens.harvard.edu. Mihail Samnaliev is with Clinical Research Center of Boston Children's Hospital. Rashmi Wijeratne and Man Wai Ng are with the Department of Dentistry, Boston Children's Hospital. Eunhae Grace Kwon is with Pediatric Dentistry, University of the Pacific. Henry Ohiomoba is with Harvard School of Dental Medicine and Boston Children's Hospital.

Received: 11/12/2013; accepted: 06/13/2014

doi: 10.1111/jphd.12067

Journal of Public Health Dentistry •• (2014) ••–••

Abstract

Objectives: To assess the cost-effectiveness of a pilot disease management (DM) program aimed at preventing early childhood caries among children younger than 5 years.

Methods: The DM program was implemented in the Boston Children's Hospital-based dental practice in 2008. Health care costs were obtained from the hospital finance department and non-health care costs were estimated through a parent survey. The measure of effectiveness was avoided hospital-based visits for restorative treatment or extractions. Incremental costs (2011 US$) and effectiveness were estimated from a health care system, societal, and public payer perspectives over 3, 6, and 12 months, by comparing DM participants ($n = 395$) to a historical comparison group ($n = 123$) using generalized linear models. Bootstrapping and other sensitivity analyses were used to incorporate uncertainty in the analyses.

Results: The DM program was associated with a reduction in societal costs of $20 ($p = 0.85$), $215 ($p = 0.24$), and $669 ($p < 0.01$) per patient and a reduction in the number of hospital-based visits for restorative treatment or extractions by 0.44 ($p < 0.01$), 0.42 ($p < 0.01$), and 0.45 ($p < 0.01$) per patient over 3, 6, and 12 months, respectively. The probability of it being less costly and more effective was 61.5 percent, 81.9 percent, and 98.6 percent over 3, 6, and 12 months, respectively. Consistent results were observed from a health care system and public payer perspectives.

Conclusions: The DM program appears cost-effective and has the potential to reduce health care costs. Our results justify a multicenter trial to evaluate the DM program on a larger scale.

Introduction

Early childhood caries (ECC) is the most common chronic pediatric disease in the United States estimated to affect almost 28 percent of all children ages 2 to 5 years (1). Treatment is often initiated in hospital emergency departments (2,3) and commonly requires expensive treatment in operating room (OR) settings (4-10). More broadly, ECC leads to increased morbidity, pain, and discomfort, negatively affecting quality of life (11-13), restricting activity (14), and causing significant economic and social burden on children, their families, and society (14-16).

Over the past few decades, governmental agencies have devoted a great deal of attention to preventive dental care aimed at improving the oral health of Americans. The Oral Health focus area of Healthy People 2010 sets several objectives toward that goal, including reducing the proportion of children who have dental caries experience in their primary teeth and reducing untreated dental decay (16). It is now accepted that surgical and restorative treatment of caries alone does not address the disease. Instead, the balance between pathological and protective factors can be altered through care that prevents, halts, or reverses the caries process (17). In line with this approach, the National Call to Action to

Promote Oral Health called for the expansion of “plans, activities, and programs designed to promote oral health and prevent disease” (18).

In 2008, Boston Children’s Hospital (BCH) and Saint Joseph Hospital (SJH) in Rhode Island implemented a pilot demonstration disease management (DM) program aimed at preventing the occurrence and recurrence of ECC among children younger than 5 years. To our knowledge, this was the first program in the country implemented in a hospital-based dental practice. It has been previously reported that the DM program is associated with a lower incidence of pain and new cavitations and fewer referrals to the OR (19). This study evaluates the cost and cost-effectiveness of the DM program at BCH (SJH declined to participate in this analysis).

Methods

Cost-effectiveness analyses are widely used to inform decision makers about the value of new health programs and interventions. Interventions that are more costly and more effective than existing alternatives are considered cost-effective or “good value for money” if they cost less than the societal (or payer’s) willingness to pay for an additional unit of effectiveness. Interventions that are less costly and more effective than alternatives are always cost-effective.

Study site and enrollment

Although the DM program was implemented as a quality improvement project, institutional review board approval was sought and obtained. The DM program was implemented in the BCH Dental Clinic between March 2008 and September 2010. Parents of children younger than 60 months were randomly approached and asked to participate and subsequently included in the study if they met all of the following criteria: a) their child had active caries or a history of caries; b) provided informed consent and agreed to follow the DM protocol and receive care based on the caries risk determined during each visit through the use of a caries risk assessment tool (see section on DM protocol); c) returned for at least two subsequent visits ensuring a reasonable degree of DM protocol fidelity; and d) had complete data on utilization, background characteristics, and costs. All but one who were approached agreed to participate and signed an informed consent. Of 475 participants who consented, 403 returned for at least two follow-up visits and 395 had complete data. There were no statistically significant differences in terms of demographics characteristics between these 395 patients and the ones excluded because of the above criteria.

DM protocol

The DM protocol incorporated a caries risk assessment tool adapted from the American Academy of Pediatric Dentistry (20) and Caries Management by Risk Assessment (21) and included both an in-office and an at-home component. The protocol is outlined below; for a detailed description, see Ng and colleagues (19).

1. In-office management consisted of assessing the patient’s caries risk at each visit, applying fluoride varnish and setting self-management goals (SMGs) for home care. Parents of ECC patients were coached about the factors that lead to caries and informed of ways that tooth decay can be prevented and stopped. Providers and team members worked with parents to select SMGs to improve their child’s disease risk. A clinical examination was also performed, reassessing for the presence of new demineralization and cavitation along with remineralization. The periodicity for the DM visits was determined by the most recent caries risk assessed, in conjunction with the restorative or surgical treatment as needed by the patient and desired by the parent and provider. Patients deemed to be at high caries risk returned in 1-2 months, moderate-risk patients in 3-4 months, and low-risk patients in 6-12 months.

2. Parents were given the full options for restorative treatment, which might require pharmacologic management (nitrous oxide, sedation or general anesthesia) as adjunct.

3. If destruction of the tooth structure by the caries process was minimal, caries arrest was possible with remineralization of the tooth structure. The restorative treatment was deferred in patients if the caries had become inactive (by remineralization), especially in a child unable to cooperate for restorative treatment. However, close follow-up and preventive care based on caries risk were recommended to safeguard from relapse.

4. When the decay had progressed into dentin and caries arrest was not achieved, interim therapeutic restoration (ITR) was offered as an alternative treatment in young children with early cavitated lesions. Parents were informed that this approach is caries control rather than permanent restoration.

5. For the at-home protocol, parents were presented with a menu of SMGs (19) to work on before the next visit. Such goals include basic caries control strategies such as more frequent tooth brushing, using topical fluorides at home, and modifying the diet to include less frequent intake of carbohydrates and sugars.

6. A 0.4 percent stannous fluoride (1,000 ppm fluoride) was recommended to be applied judiciously two or three times per day by the parent after tooth brushing, followed by waiting 30 minutes before eating, drinking, or rinsing. Alternatively, parents may elect to use over-the-counter 1,000 ppm fluoride toothpaste. A few parents who had concerns about fluoride were apprised of xylitol, casein phosphopeptide, and calcium phosphate products.

Baseline comparison group

Historical control (baseline) data were obtained of patients younger than 60 months of age who initiated conventional dental treatment at BCH between 2004 and 2006. We used a computer-generated randomized scheme to identify patients and subsequently reviewed their billing records. Patients were included in the comparison group if they met the same criteria above (had active or history of caries, returned for follow-up visits, and had complete data), except criteria 2 related to the implementation of the DM protocol. We elected to use a historical instead of a concurrent control group because of concerns that the latter may lead to design contamination. Specifically, because the DM protocol was instituted as a quality improvement project, where the protocol was recommended to patients beyond those who gave informed consent, it seemed likely that dental provider would apply elements of the DM protocol even to patients who were not enrolled in the study. Our sample size (395 in the DM group and 123 in the comparison group) gave us the power ($P = 0.8$) to detect a difference of 10 percent or greater in costs and effectiveness (alpha = 0.05).

Perspective and timeframe of the evaluation

Base case analyses were conducted from the health care system and societal (incorporating patient non-health costs as well at home fluoride treatment costs) perspectives and over 3, 6, and 12 months from the day of the first treatment episode at BCH. Additionally, subgroup analyses (shown in the text) were conducted from a public payer perspective, using only patients with Medicaid coverage.

Resource utilization and costs

We first obtained the BCH charges for all treatment completed in the dental clinic and the OR, including anesthesia. While the DM protocol was pilot in nature and implemented at no additional cost to patients at BCH, it was still associated with added resource utilization. We used the average time for DM treatment – 30 minutes if scheduled as a separate visit, or 15 minutes if added on to other visits – and applied the respective charges for preventive dental care at the BCH dental clinic. Total per patient charges were then aggregated over 3, 6, and 12 months and converted to costs. In the analyses adopting the societal and health care system perspectives, we multiplied charges by 0.447, which was the ratio between average BCH dental care charges and costs to BCH (estimated for accounting purposes). In the analyses from the public payer perspective, costs were estimated multiplying each hospital charge for the dental care by a Medicaid cost to charge ratio, which was available by type/location of service (OR, DM, ITR and restorative/surgical treatment). The estimated cost for the at-home protocol was $0.83 per month and was based on the cost incurred at our dental clinic to purchase a tube of 0.4 percent stannous fluoride gel ($5), which lasts 6 months on average. In order to account for the differential timing in resource utilization, all costs were inflation-adjusted to USD 2011, using the consumer price index of the US Bureau of Labor Statistics. DM protocol costs for the subgroup of patients who initially consented but did not return for at least two subsequent visits were spread over all 395 study participants as these costs can be expected to be incurred in real-world settings. Study-driven costs (e.g., patient tracking and data collection) were not included as they would not be incurred otherwise.

Non-health costs

A survey among a random sample of parents ($n = 72$) who came with their child to the BCH dental clinic for a dental visit was used to estimate lost productivity, travel, and formal caregiving costs. The survey was administered during any visit; we did not believe that non-health costs correlate with whether it is a first or a subsequent as all visits were planned and prescheduled. The survey questions were designed by our team and reviewed for content and consistency by a survey methodologist in our institution. Parents were asked about the number of hours taken from work to come to their appointment. The number of hours was multiplied by the gender-blended 2011 wage rate for Massachusetts. Labor theory also suggests that patients value their time even if they are not working, although there is little guidance in the literature as to the actual amounts that should be used to value that time. In our study, the time costs for parents who did not take time from work (51.4 percent) were assumed to be between the average and the minimum 2011 Massachusetts wage with the midpoint used in the base case. Parents who drove to their appointment were asked whether they paid for tolls and parking and the number of miles driven; the latter was multiplied by the 2011 standard mileage rate, set by the Internal Revenue Service, and often used as a proxy for the total costs of operating an automobile in the United States. Parents who took public transportation were asked how much they paid for a one-way fare to BCH. Travel costs were doubled to estimate the cost of a return visit. Finally, parents were asked whether they had hired caregivers (e.g., for other siblings) in order to be able to make their appointment; associated costs were estimated using the average 2011 child care wage for Massachusetts. Time costs for the implementation of the home component were not tracked; however, sensitivity analyses explored the impact of assigning such costs based on the expected additional time to carry out fluoride treatment.

Effectiveness

Our measure of effectiveness was the number of avoided (reduced) restorative or surgical treatment visits in the ambulatory dental clinic or OR at BCH. Such intermediate outcomes are often used in cost-effectiveness analysis, provided that they have an expected impact on patient health, utility, and quality of life (22). In our case, the DM program has been shown to be linked with reduced restorative or surgical treatment and improved oral health outcomes such as reduced rates of new cavitation and pain (19). Preventing dental caries has also been linked with increased quality of life in several studies summarized in a 2008 review of the literature (11). Furthermore, preventing ECC significantly decreases the likelihood of caries in the permanent teeth (23).

Analyses

Baseline descriptive characteristics of patients were compared using χ^2 tests, except for the average age, which was compared via the nonparametric Mann–Whitney *U*-test. Incremental costs and effects (avoided restorative or surgical treatment visits in the dental clinic or in the OR) were estimated separately from the health care system and societal perspectives, and for each evaluation period as well as for the subgroup of Medicaid beneficiaries ($n = 361$). The base-case analyses relied on generalized linear models with a log (for costs) and Poisson (for effectiveness) link. These models adjusted for patient age, gender, race, ethnicity and for variables that might be linked with access to care (spoken language and type of dental insurance). To explore uncertainty related to the choice of model, we examined the effects of each confounder (and we observed little change in the main effects in a stepwise inclusion of confounders). In addition, as an alternative, we estimated incremental costs and effects using a 1:1 propensity score matching of DM and baseline patients. Regression models were chosen for the main analyses to avoid loss in sample size and because the two groups were relatively balanced in their background characteristics; results based on the matched pairs are summarized in the text.

A common way to incorporate statistical uncertainty in economic evaluations is through nonparametric bootstrapping (22), a type of probabilistic sensitivity analysis allowing estimation of the joint variance around the incremental cost-effectiveness ratio (ICER). We drew 1,000 random sample replicates from the original data and estimated the ICER for each sample. As the large majority of ICER replicates fell in quadrant IV of the cost-effectiveness plane, we report the proportion of samples where the DM program was less costly and more effective (i.e., dominates) than the baseline. All analyses were conducted with SAS 9.3® (SAS Institute Inc., SAS 9.1.3, Cary, NC, USA).

Results

Base case analyses

Description of patients in the baseline ($n = 123$) and the DM group ($n = 395$) are shown in Table 1. Patients' age, gender, type of dental insurance, and spoken language did not differ between the two groups. Overall, average age was about 39 months and patients were slightly more likely to be female. A relatively large proportion spoke a language other than English (21.9 percent baseline and 28.1 percent DM group). There were differences in the distribution of race and ethnicity ($P = 0.006$), which were driven in part by the increased proportion of "not known" (typically representing refusal to answer) responses in the DM group.

Table 2 shows the costs associated with the DM program, other diagnostic and preventive treatment, restorative treatment in the dental clinic and the OR, and OR facility and anesthesia costs. Non-health care costs are presented in Table 3. On average, they were $114.58 per patient, most of which were because of lost work productivity ($53.72) and other time costs ($37.05), followed by transportation ($19.76) and caregiving costs ($4.05).

Table 4 presents a summary of the incremental cost and effectiveness of the DM program, estimated via generalized linear models (the full models from societal perspective over

Table 1 Description of Patients Receiving Dental Treatment at Boston Children's Hospital

	Baseline group	Disease management (DM) group	
	n = 123	*n* = 395	*P*-value
Age in months, mean (SD)	38.6 (12.0)	39.0 (11.7)	0.511
Age category, *n* (%)			
<36 months	51 (41.5)	161 (40.7)	0.939
36-48 months	44 (35.8)	148 (37.5)	
48-60 months	28 (22.7)	86 (21.8)	
Female, *n* (%)	54 (43.9)	193 (48.9)	0.336
Male, *n* (%)	69 (56.1)	202 (51.1)	
Insurance, *n* (%)			
Public (Medicaid)	81 (65.8)	280 (70.9)	0.289
Private	42 (34.2)	115 (29.1)	
Language, *n* (%)			0.716
English	96 (78.1)	284 (71.9)	
Other/not known	27 (21.9)	111 (28.1)	
Race/ethnicity, *n* (%)			0.006
Asian	12 (9.8)	29 (7.3)	
Black or African American	31 (25.1)	66 (16.7)	
Hispanic or Latino	26 (21.1)	68 (17.2)	
White	33 (26.8)	99 (25.1)	
Other	8 (6.5)	49 (12.4)	
Not known	13 (10.6)	84 (21.3)	

SD, standard deviation.

Table 2 Costs (2011 US$) Associated with Dental Treatment at Boston Children's Hospital

Location and types of treatment	Mean (SD)	Median
Ambulatory dental clinic at BCH		
Disease management (DM) protocol	$45 (13)	$44
DM when added to other treatment	$23 (0)	$23
Diagnostic and preventive (not including DM)	$88 (32)	$81
Interim therapeutic restoration (ITR)	$135 (93)	$94
Restorative/surgical treatment	$196 (125)	$173
Operating room (OR) at BCH		
Restorative/surgical treatment	$1,963 (768)	$2,035
OR facility	$4,990 (1,516)	$5,119
General anesthesia in the OR	$1,073 ($301)	$1,093
Home component		
Fluoride treatment (per month)	$0.83 (0)	$0.83

BCH, Boston Children's Hospital; SD, standard deviation.

12 months are presented in Appendix I). DM program participation was associated with fewer hospital OR and dental clinic visits to receive restorative or surgical treatment within 3, 6, and 12 months ($P < 0.001$). In sub-analyses (not shown), this reduction in restorative/surgical treatment visits was observed in both the OR (44.8 percent reduction for DM versus baseline group) and in the ambulatory dental clinic settings (45.5 percent reduction for DM versus baseline group). Because of the high costs of restorative and surgical treatment, especially when provided in OR settings, these reductions resulted in savings, which offset the added cost of the DM program. Overall, DM program participation was associated with net savings that increased in magnitude over time and became significant in the 12-month evaluation for both the health care system ($752, $P = 0.003$) and societal ($669, $P = 0.009$) perspectives. The differences in costs and effectiveness appeared to remain unchanged in longer evaluation periods (not shown). When conducted from a Medicaid perspective ($n = 361$), savings associated with DM program participation amounted to $89 ($P = 0.08$), $123 ($P = 0.10$), and $173 ($P = 0.07$) and hospital visits to receive restorative/surgical treatment in the dental clinic or in the OR decreased by 0.47 ($P < 0.001$), 0.47 ($P < 0.001$), and 0.51 ($P = 0.003$) per patient over 3, 6, and 12 months, respectively (Table 4).

Probabilistic sensitivity analyses

Table 5 displays the joint probability of the DM program being associated with both lower costs and fewer restorative or surgical treatment visits compared with baseline. When assessed from a health care system perspective, this probability was 64.5 percent, 86.5 percent, and 99.2 percent over 3, 6, and 12 months, respectively (Table 5). This probability was slightly lower when the analyses were conducted from the societal perspective – 61.5 percent, 81.9 percent, and 98.6 percent over 3, 6, and 12 months, respectively – because of the additional non-health costs associated with increased visits to BCH among DM program participants. The joint probability of the DM program being associated with both lower cost and less restorative or surgical treatment over 3 and 6 months

Table 3 Non-health costs (2011 US$) Associated with a Dental Visit to Boston Children's Hospital

Type		Cost	
Time costs		Unit cost	Aggregate
Average hours for appointment	4.2		
Took time from work	48.6%	$26.32 per hour*	$53.72
Did not take time from work	51.4%	$17.16 per hour†	$37.05
Caregiving			
Hired a child care provider	11.1%		
Number of hours	2.9	$12.60 per hour‡	$4.05
Transportation			
Used public transportation	29.2%	$15.30 return ticket	
Came by car	68.1%		
Number of miles driven	27.5	$.55 per mile	
Paid for parking	55.5%	$9.00¶	
Walked	2.8%	$0.00	
Total transportation costs§			$19.76
Total per visit			$114.58

* Average 2011 wage rate for Massachusetts (24).
† Assumed midpoint between 2011 Massachusetts minimum ($8.00/hour) and average (26.32/hour) wage.
‡ Average 2011 child care wage for Massachusetts (24).
¶ Validated 2011 parking rate at Boston Children's Hospital.
§ 0.292×$15.30 + 0.681×27.5×$0.55 + 0.555×9.00 + 0.028×$0.

Table 4 Incremental Costs (2011 US$) and Visits for Restorative/Surgical Treatment per Patient*

Months		Full sample $n = 518$			Medicaid beneficiaries $n = 361$	
		Health care costs	Societal costs†	Visits‡	Costs¶	Visits‡
3	Baseline	698	955	0.92	456	0.95
	DM program	677	935	0.48	367	0.48
	Difference	21 ($P = 0.84$)	20 ($P = 0.85$)	0.44 ($P < 0.001$)	89 ($P = 0.08$)	0.47 ($P < 0.001$)
6	Baseline	1,092	1,441	1.23	662	1.33
	DM program	889	1,255	0.81	539	0.86
	Difference	203 ($P = 0.17$)	215 ($P = 0.24$)	0.42 ($P < 0.001$)	123 ($P = 0.10$)	0.47 ($P < 0.001$)
12	Baseline	2,023	2,465	1.80	917	1.85
	DM program	1,271	1,796	1.35	744	1.34
	Difference	752 ($P = 0.003$)	669 ($P = 0.009$)	0.45 ($P < 0.001$)	173 ($P = 0.07$)	0.51 ($P = 0.003$)

* Adjusting for age, gender, race, ethnicity, type of dental insurance, and spoken language.
† Including non-health and at-home fluoride treatment costs.
‡ Number of restorative or surgical treatment visits in the ambulatory dental clinic or operating room at Boston Children's Hospital.
¶ Based on estimated Medicaid payments.
DM, disease management.

(93.4 percent and 93.0 percent, respectively) was greater from the Medicaid compared with societal or health care system perspectives. This probability was 96.3 percent in the 12-month evaluation. Appendix II presents the actual simulation results of the societal cost and effectiveness over each evaluation period.

Other sensitivity analyses

Our conclusions remain unchanged when 1:1 matching was used instead of generalized linear regression models. For example, the DM program was associated with reduced societal costs of \$50 ($P = 0.83$), \$611 ($P = 0.03$), and \$513 ($P = 0.23$) and reduced hospital-based restorative/surgical visits in the dental clinic or in the OR by 0.41 ($P < 0.01$), 0.49 ($P < 0.01$), and 0.46 ($P < 0.01$) per patient over periods of 3, 6, and 12 months, respectively. In addition, we conducted one-way sensitivity analyses around the mean assigned time cost (\$17.16/hour) for parents who did not take time from work. We used the minimum (\$8.00/hour) and average (26.32/hour) Massachusetts wage (24) as lower and upper bound. These results had negligible impact on our results (not shown). In other sensitivity analyses, we assigned time costs associated with implementation of the DM home component. When we added 30 minutes/month (e.g., 1-minute fluoride treatment every day in addition to usual brushing) and valued that time at the average hourly wage, societal costs became slightly (although not significantly) larger for the DM group (\$8, $P = 0.92$); lower societal costs in the DM group were still observed over 6 months (\$131 per patient, $P = 0.40$) and 12 months (\$555 per patient, $P = 0.03$).

Table 5 Probability* of DM Being Less Costly and More Effective†

	Perspective		
	Health care (%)	Societal (%)	Medicaid (%)
3 months	64.5	61.5	93.4
6 months	86.5	81.9	93.0
12 months	99.2	98.6	96.3

* Based on 1,000 nonparametric bootstraps with replacement.
† Effective is defined as DM requiring less restorative/surgical treatment visits compared with baseline.
DM, disease management.

Limitations

A limitation of this study is that randomization into the DM versus a control group was not possible and we relied on a pre- to post-comparison; therefore, the possibility of underlying secular trends in utilization cannot be ruled out. However, to our knowledge, there was no change in clinical practices or criteria for restorative treatment at BCH including the ones related to OR referral, which had the strongest impact on cost savings. Further, beside the DM program, no new policies or treatment guidelines related to dental care were implemented at our institution after 2004, which increase our confidence that observed changes were driven by the DM protocol. Another limitation is that we are unable to control for unobservable confounders (e.g., disease severity) and that may bias our results if they are associated with both DM participation and the main outcomes. As in most longitudinal evaluations, there was a certain loss to follow-up, which was greater in the DM group (2.7 percent, 18.6 percent, and 29.2 percent over 3, 6, and 12 months, respectively). Our confidence in this study's results, however, is increased by the fact that our findings were consistent across evaluation periods including 3 months where such loss to follow-up was minimal, and by the fact that distributions in age, gender, insurance type, and spoken language between patients lost to follow-up and the rest were not significant (except for race/ethnicity, $P = 0.02$). Further, it is plausible that dropping out of the DM program was associated with improved oral health, which would make our estimates conservative. Our data, however, do not allow us to verify that. Another limitation is that any dental care outside BCH that DM or baseline participants may have received was not available for analysis. Therefore, our results should be viewed with caution because of the possible bias that the above limitations may introduce. Finally, this DM protocol was pilot in nature and implemented on a small scale; our hospital-based dental practices care for a disproportionate number of children with ECC, the majority of whom are covered by public insurance, which may impact the generalizability of our findings to other settings and populations.

Discussion

As health care costs in the United States continue to rise, economic evaluations of new interventions are increasingly used to inform health policy and treatment decisions. Payers are often reluctant to reimburse new clinically effective models of care unless there is evidence of their economic impact and affordability. In this study, we examine the cost-effectiveness of a promising risk-based DM program to prevent and manage ECC, implemented at BCH in 2008. The DM program was associated with fewer hospital-based restorative or surgical treatment visits, and lower overall costs compared with a baseline group of patients. Overall, the DM program was cost-effective from the health care system, Medicaid and societal perspectives.

Our findings are consistent with previous economic evaluations, many of which have reported that various dental caries prevention programs can be cost-saving (25-27). Others, however, have found that caries prevention increases overall costs (28). In these cases, whether the intervention is considered cost-effective depends on payers' willingness to pay to prevent caries and related treatment. A notable example is an evaluation of Medicaid-eligible children that reports that a caries prevention program was only 32 percent likely to be cost-saving and 95 percent likely to be cost-effective at a willingness to pay of $2,331 per avoided hospital episode (29). While the question of cost and cost-effectiveness of dental caries prevention and DM is still not fully answered, it seems plausible that comprehensive prevention programs including the one implemented at BCH have the potential to be cost-saving because they adopt a multipronged approach to target ECC, through fluoride treatment, parent education aimed at behavior change, and treatment optimization based on risk assessment.

Given the large proportion of children with ECC in the United States, improving access to dental care has become a national public health priority. Having adequate insurance is one of the strongest predictors of such access; yet, children are more than twice as likely to lack dental compared with medical insurance (15). State Medicaid programs play an important role in insuring low-income beneficiaries; still, less than one in five Medicaid-covered children receive at least one dental visit within a year (14). Our analyses show that a clinically effective disease prevention and management program implemented in hospital-based dental clinics can also be financially attractive to state Medicaid programs. Initial investments can be recuperated within a year through reduced utilization of expensive restorative or surgical treatment. However, because this is a small observational study, a larger multicenter trial is warranted to answer the question whether reimbursement of DM-driven dental care may improve access to preventive treatment and lower costs to Medicaid programs across states.

Importantly, we find that parents incurred relatively high out-of-pocket non-health costs. Many had to take time from work, resulting in lost wages, in addition to the caregiver and travel costs for each visit to BCH. These costs – typically exceeding daily state average wages – can be a significant deterrent to access to treatment and a disincentive to continuous participation in DM programs that require periodic visits. From a societal perspective, these costs were offset from reduced utilization of dental care; therefore, it might be prudent and cost-saving for payers to design incentives encouraging families to seek preventive dental treatment, for example, through various cost-sharing arrangements, similar to the ones that are beginning to be implemented in the rest of the health care system. At the same time, reimbursement of DM and greater widespread adoption of the DM approach could allow access closer to home and reduce the travel and time costs.

In conclusion, the DM program implemented at BCH appears cost-saving and cost-effective, pointing to its broad economic value to society. It is recommended that the program be implemented and evaluated on a wider scale.

References

1. Dye BA, Tan S, Smith V, Lewis BG, Barker LK, Thornton-Evans G, *et al*. Trends in oral health status: United States, 1988-1994 and 1999-2004. NationalCenter for Health Statistics. *Vital Health Stat*. 2007;**11**(248).
2. Rowley ST, Sheller B, Williams BJ, Mancl L. Utilization of a hospital for treatment of pediatric dental emergencies. *Pediatr Dent*. 2006 Jan–Feb;**28**(1):10-7.
3. Sheller B, Williams BJ, Lombardi SM. Diagnosis and treatment of dental caries-related emergencies in a children's hospital. *Pediatr Dent*. 1997 Nov-Dec;**19**(8):470-5.

4. Griffin SO, Gooch BF, Beltran E, Sutherland JN, Barsley R. Dental services, costs, and factors associated with hospitalization for Medicaid-eligible children, Louisiana 1996-97. *J Public Health Dent.* 2000;**60**(1):21-7. Winter.
5. Ramos-Gomez FJ, Huang GF, Masouredis CM, Braham RL. Prevalence and treatment costs of infant caries in Northern California. *ASDC J Dent Child*. 1996 Mar-Apr;**63**(2):108-12.
6. Kanellis MJ, Damiano PC, Momany ET. Medicaid costs associated with the hospitalization of young children for restorative dental treatment under general anesthesia. *J Public Health Dent*. 2000;**60**(1):28-32. Winter.
7. Almeida AG, Roseman MM, Sheff M, Huntington N, Hughes CV. Future caries susceptibility in children with early childhood caries following treatment under general anesthesia. *Pediatr Dent*. 2000 Jul-Aug;**22**(4):302-6.
8. Berkowitz RJ, Moss M, Billings RJ, Weinstein P. Clinical outcomes for nursing caries treated using general anesthesia. *ASDC J Dent Child*. 1997 May-Jun;**64**(3):210-1, 228.
9. Eidelman E, Faibis S, Peretz B. A comparison of restorations for children with early childhood caries treated under general anesthesia or conscious sedation. *Pediatr Dent*. 2000 Jan-Feb;**22**(1):33-7.
10. Graves CE, Berkowitz RJ, Proskin HM, Chase I, Weinstein P, Billings R. Clinical outcomes for early childhood caries: influence of aggressive dental surgery. *J Dent Child (Chic)*. 2004 May-Aug;**71**(2):114-7.
11. Barbosa TS, Gavião MB. Oral health-related quality of life in children: part II. Effects of clinical oral health status. A systematic review. *Int J Dent Hyg*. 2008 May;**6**(2):100-7. doi: 10.1111/j.1601-5037.2008.00293.x.
12. World Health Organization. *The global burden of disease: 2004 update*. Geneva: World Health Organization; 2006.
13. Filstrup SL, Briskie D, da Fonseca M, Lawrence L, Wandera A, Inglehart MR. Early childhood caries and quality of life: child and parent perspectives. *Pediatr Dent*. 2003;**25**(5): 431-40.
14. Adams PF, Marano MA. Current estimates from the National Health Interview Survey, 1994. National Center for Health Statistics. Vital Health Stat 10(193). 1995.
15. Casamassimo PS, Thikkurissy S, Edelstein BL, Maiorini E. Beyond the dmft. The human and economic cost of early childhood caries. *J Am Dent Assoc*. 2009;**140**:650-7.
16. U.S. Department of Health and Human Services. *Healthy People 2010. With Understanding and Improving Health and Objectives for Improving Health*, 2 vols. Washington, DC: U.S. Government Printing Office. 2000.
17. Featherstone JD. The science and practice of caries prevention. *J Am Dent Assoc*. 2000 Jul;**131**(7):887-99.
18. U.S. Department of Health and Human Services. *National call to action to promote oral health*. Rockville, MD: U.S. Department of Health and Human Services, Public Health Service, National Institutes of Health, National Institute of Dental and Craniofacial Research; 2003. NIH Publication No. 03-5303, Spring.
19. Ng MW, Torresyap G, White A, Melvin P, Graham D, Kane D, Scoville R, Ohiomoba H. Disease management of early childhood caries: results of a pilot quality improvement project. *J Health Care Poor Underserved.* 2012 Aug;**23**(3 Suppl):193–209. doi: 10.1353/hpu.2012.0122.
20. American Academy on Pediatric Dentistry Council on Clinical Affairs. Policy on use of a caries-risk assessment tool (CAT) for infants, children, and adolescents. *Pediatr Dent*. 2008-2009;**30**(7 Suppl.):29-33.
21. Ramos-Gomez FJ, Crall J, Gansky SA, Slayton RL, Featherstone JD. Caries risk assessment appropriate for the age 1 visit (infants and toddlers). *J Calif Dent Assoc*. 2007 Oct;**35**(10):687-702.
22. Gold MR, Siegel JE, Russel LB, Weinstein MC. *Cost-effectiveness in health and medicine*. New York: Oxford University Press; 1996.
23. Li Y, Wang W. Predicting caries in permanent teeth from caries in primary teeth: an eight-year cohort study. *J Dent Res*. 2002 Aug;**81**(8):561-6.
24. Griffin SO, Jones K, Tomar SL. An economic evaluation of community water fluoridation. *J Public Health Dent*. 2001 Spring;**61**(2):78–86.
25. Mariño R, Fajardo J, Morgan M. Cost-effectiveness models for dental caries prevention programmes among Chilean schoolchildren. *Community Dent Health*. 2012 Dec;**29**(4): 302–8.
26. Crowley SJ, Campain AC, Morgan MV. An economic evaluation of a publicly funded dental prevention programme in regional and rural Victoria: an extrapolated analysis. *Community Dent Health*. 2000 Sep;**17**(3):145–51.
27. Källestål C, Norlund A, Söder B, Nordenram G, Dahlgren H, Petersson LG, Lagerlöf F, Axelsson S, Lingström P, Mejàre I, Holm AK, Twetman S. Economic evaluation of dental caries prevention: a systematic review. *Acta Odontol Scand*. 2003 Dec;**61**(6):341–6.
28. Stearns SC, Rozier RG, Kranz AM, Pahel BT, Quiñonez RB. Cost-effectiveness of preventive oral health treatment in medical offices for young Medicaid enrollees. *Arch Pediatr Adolesc Med*. 2012 Oct; **166**(10):945–51.
29. Bureau of Labor Statistics. State occupational employment and wage estimates Massachusetts. 2012 [cited 2012 Dec]. Available from: http://www.bls.gov/.

Appendices

Appendix I

Total societal costs (2011 US$) and effects over 12 months: results from generalized linear models

	Costs			Number of restorative care visits/extractions		
	Estimate	Standard error	*P*-value	Estimate	Standard error	*P*-value
Health care perspective						
Intercept	6.304	0.329	<.0001	–0.1269	0.1885	0.5009
Baseline (versus DM program)	0.465	0.157	0.003	0.2882	0.0925	0.0018
Asian	0.510	0.263	0.053	0.1414	0.1644	0.3898
Black/African American	0.441	0.217	0.042	–0.0969	0.1388	0.4853
Hispanic	0.361	0.212	0.088	–0.1431	0.1383	0.301
White	0.694	0.195	0.000	0.0599	0.1227	0.6257
Female	0.022	0.137	0.875	0.0512	0.0896	0.5681
Private (versus Medicaid)	–0.414	0.160	0.010	–0.015	0.1005	0.8811
English	–0.082	0.169	0.627	–0.2455	0.1043	0.0186
Age (in months)	0.016	0.007	0.024	0.0153	0.0036	<.0001
Societal perspective						
Intercept	6.924	0.249	<.0001	–0.1269	0.1885	0.5009
Baseline (versus DM program)	0.317	0.121	0.009	0.2882	0.0925	0.0018
Asian	0.377	0.210	0.072	0.1414	0.1644	0.3898
Black/African American	0.333	0.169	0.049	–0.0969	0.1388	0.4853
Hispanic	0.249	0.167	0.136	–0.1431	0.1383	0.301
White	0.503	0.152	0.001	0.0599	0.1227	0.6257
Female	0.009	0.108	0.932	0.0512	0.0896	0.5681
Private (versus Medicaid)	–0.278	0.125	0.026	–0.015	0.1005	0.8811
English	–0.088	0.133	0.507	–0.2455	0.1043	0.0186
Age (in months)	0.011	0.005	0.037	0.0153	0.0036	<.0001
Medicaid perspective						
Intercept	5.812	0.2197	<.0001	–0.3495	0.2071	0.0915
Baseline (versus DM program)	0.2094	0.1144	0.0673	0.3209	0.1086	0.0031
Asian	0.2212	0.2117	0.2962	0.1593	0.2058	0.4388
Black/African American	0.1646	0.1578	0.2968	–0.0355	0.1598	0.8241
Hispanic	0.1446	0.147	0.3252	–0.0851	0.1543	0.5813
White	0.1029	0.1504	0.4937	–0.004	0.1515	0.979
Female	0.0106	0.1042	0.9187	–0.0002	0.1069	0.9985
English	–0.0623	0.1177	0.5968	–0.1296	0.1168	0.2671
Age (in months)	0.0186	0.0048	0.0001	0.0191	0.004	<.0001

DM, disease management.

Appendix II

Difference in societal costs and effectiveness associated with disease management (DM) program (1,000 samplings)