

The Denver School-Based Adolescent Hepatitis B Vaccination Program: A Cost Analysis With Risk Simulation

ABSTRACT

Objectives. This study sought to compare the cost-effectiveness of a school-based hepatitis B vaccine delivery program with that of a vaccine delivery program associated with a network health maintenance organization (HMO).

Methods. The vaccination program enrolled 3359 sixth-grade students from 18 middle schools in Denver, Colo. Immunization status and direct and indirect program costs were compiled. The sensitivity of the outcomes was assessed by simulation methods.

Results. The per-dose cost-effectiveness ratio for the school-based delivery system was \$31. This cost-effectiveness ratio remained stable when the model was simulated with costs that were underestimated or overestimated by 20%. In the network HMO, the direct cost per dose was \$68 and the societal cost was \$118 when the child's father worked full-time and the mother worked part-time. There is less than a 5% chance that the network HMO-based vaccination program could be more cost-effective than the school-based program.

Conclusions. The cost per dose of the school-based program was significantly less than that of the network HMO-based program, because in the school program government-purchased vaccine was available at a lower cost and parents did not incur work-loss costs. (*Am J Public Health*. 1999;89:1722-1727)

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On April 17, 1996, the Colorado State Board of Health mandated that as of July 1, 1997, all students would be required to complete a 3-dose hepatitis B vaccination series before entering the seventh grade. The strategy was recommended by the Advisory Committee on Immunization Practices, the American Medical Association, the American Academy of Pediatrics, and the American Academy of Family Physicians after attempts to decrease rates of infection by targeting high-risk adolescent groups failed.¹⁻⁸

An estimated 17% of the 100 000 to 140 000 annual hepatitis B virus infections in the United States occur among adolescents aged 10 to 19 years (Centers for Disease Control and Prevention, unpublished data, 1994). Although adolescents do acquire hepatitis B infection through sexual or household contacts or through injection drug use, in approximately one third of the cases the source of infection is unknown.⁹ This means that some adolescents will be missed because of unrecognized high-risk behaviors.

Vaccinations can be given to school-aged children by either a personal care provider or a school-based delivery system. In Colorado, private providers administer most vaccines. Recent studies have shown school-based vaccination delivery systems to be acceptable and efficient.¹⁰⁻¹² In Denver, a free, voluntary school-based hepatitis B vaccination program was offered to students in the sixth grade during the 1996-1997 school year. We report on a study done to evaluate the cost-effectiveness of this school-based hepatitis B vaccine delivery system and compare these costs with those of a vaccine delivery system associated with a network health maintenance organization (HMO). The methodology used here has potential application in evaluating other vaccine delivery systems.

Methods

Setting

The project was implemented in 18 middle schools of the Denver Public Schools (DPS) system that had on-site health clinics with full-time nurses. The program was made possible through a collaboration between the Denver Health and Hospital Authority (hereafter called Denver Health) and its Public Health Department and Community Health Services; DPS; the Colorado Department of Public Health and Environment; the Centers for Disease Control and Prevention; and the health plans Kaiser Permanente of Colorado, PacificCare Health Systems, Inc, and Colorado Access.

Denver County, which includes the city of Denver, has an ethnically diverse population of nearly 500 000, which is served by a single large public school district. Denver Health is the largest primary health care provider for this population and delivers vaccines through its family health centers, school-based clinics, and public health department.

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PacifiCare, a network individual practice association HMO, is one of the 3 largest managed care organizations in Colorado. It serves 10650 of the 56928 sixth-graders in Colorado, 1518 of whom live in the Denver metropolitan area. PacifiCare was the sole network HMO evaluated in this study.

Design

This is a cost-effectiveness analysis of a school-based vaccination program conducted during 1 year, and therefore no discounting of costs and effects is applied. Cost-effectiveness ratios (CERs) were calculated in 2 ways: cost per dose and cost per completed series (i.e., cost per fully immunized student). The costs in the numerator are limited to immediately observable program and outreach costs for the school setting. The denominator of the CER is a measure of intermediate health outcomes resulting from the intervention, 2 of which are calculated here: the number of students receiving the complete 3-dose series of hepatitis B vaccine given at the proper intervals and the total number of doses administered. This model does not make allowance for the costs of hepatitis B cases averted, the costs of mortality, the costs of productivity losses averted, or the costs of side effects.

The CERs obtained for the school-based system were compared with the cost per dose for a network HMO delivery system, which was calculated on the basis of data obtained from PacifiCare. These data did not include a count of doses administered; rather, they were estimates provided by PacifiCare of the costs for a network provider to administer a dose of vaccine. This is not an incremental cost-effectiveness analysis; that is, CERs for the school-based program were not compared with a previous or ongoing immunization program in the schools, and actual patient data were not reported to investigators by the HMO. (Methods of estimating costs in the HMO are described in "Determination of Costs.")

We adopted a comprehensive societal perspective for this study. The societal perspective includes all health care costs, social service costs, spillover costs to other social services (e.g., education), and costs borne by the patient's family.

The target population consisted of 4665 sixth-grade students enrolled in the 18 DPS middle schools at the beginning of the 1996–1997 school year. Educational presentations on the hepatitis B vaccine were given to the parents, guardians, and students. A packet of information with a single consent form for the 3-dose series of hepatitis B vaccine was sent home for parents or guardians. If the consent form was not returned, at least one additional packet was sent.

Vaccinations were administered according to the schedule 0, 2, and 4 months in November 1996, January 1997, and March 1997; a make-up clinic was held in May 1997.¹³

Determination of Costs

We identified direct costs for administering the hepatitis B vaccine through the schools and PacifiCare. Data were collected from the Denver School-Based Hepatitis B Immunization Project for education and outreach, vaccine delivery, and program management. We distinguished between start-up costs and ongoing costs. PacifiCare provided cost-per-patient data. Indirect costs were not measured in the school-based clinics because we assumed that students would be brought to school to attend classes even in the absence of the vaccination program.

Costs for the school-based program. Education and outreach costs used in this analysis included the salaries and benefits of personnel, the personnel time devoted to the project (self-reported), and the cost of educational materials. Educational materials for parents and students were developed by Denver Health and the Colorado Department of Health and Environment and were distributed to school nurses and science teachers. The cost of supplies, consent forms, postage, and copying was based on use and on charges internally allocated to the program. Costs incurred in calling parents about consent forms were based on the amount contracted with the individual schools for that purpose.

DPS vaccine delivery costs were collected at each of the school clinics. Staffing data for each clinic were used to determine the actual personnel costs associated with administering the vaccine and the estimated "cost" of volunteers who might at some point need to be replaced with paid workers. Medical supply costs were based on the costs of start-up supplies used.

The estimated cost for the volunteers who administered vaccinations was \$19.75 per hour, based on the amount Denver Health paid to Hospital Shared Services for licensed practical nurses who gave injections. The estimated cost for the volunteers who organized the clinics was \$8.35 per hour, based on the pay of clerks with similar duties. A median value based on DPS pay scales was used for DPS staff other than school nurses.

Program management costs included all labor costs associated with the design of school-based clinics for effective student flow, hiring and supervision of qualified staff, development and implementation of clinical immunization protocols on site, collection and analysis of data pertaining to each clinic, oversight of

data entry into the vaccine registry, and evaluation of clinic effectiveness at each site.

Costs for the PacifiCare program. PacifiCare reimburses network physicians for the average wholesale price of the vaccine, a 10% markup, and \$7.50 in administration costs, which covers the costs of giving the injection, supplies other than the vaccine (alcohol, swab, cotton, syringe and needle, and bandage), and documentation. The societal cost is defined as the cost to the network HMO plus the cost to the patient, which includes the copayment and the cost of work lost by the parents. PacifiCare estimated the time for administration of the complete hepatitis B series as 9 hours (3 clinic visits of 3 hours each). For working parents, this time had to be taken as sick leave, vacation time, or leave without pay and therefore carried an opportunity cost. In a recent patient survey, PacifiCare found that children were taken to the pediatrician by a woman (usually the mother) 85% of the time.

No information was available about the employment status or income of parents in the PacifiCare HMO. Instead, estimates of work loss costs were based on 1996 US Bureau of the Census data for incomes of married-couple families with 1 or more children aged 6 to 17 years.¹⁴ Estimates were calculated for all combinations of employment status for husband and wife (full-time work, work, or no work). For the estimated relative income of husband and wife, it was assumed that on average women earned 74% as much as men in 1996.

In calculating the cost per completed series, we excluded from the denominator all students who did not complete the series. However, the doses delivered to those students who did not complete the series were included in the denominator of the cost per dose administered. Because there was some concern that costs incurred at the onset of the vaccination program (start-up costs) might inflate the CERs, we distinguished start-up costs from ongoing costs and we report CERs with and without start-up costs.

Statistical Analysis

Risk simulation model: DPS. Because CERs obtained from simple point estimates may not represent the full range of costs and effects over time and in different settings, we performed a stochastic risk analysis and constructed a set of scenarios to explore the policy implications of various potential actions. The risk analysis consisted of the following steps:

1. Using Microsoft Excel for Windows 95 (version 7.0), we developed a

model in spreadsheet format in which all costs and effects are summarized. The model sums costs from education and outreach, vaccine delivery, and program management, and enters them as fixed (nonrandom) values.

2. We identified uncertain cost variables as well as their possible probability distributions. To study the effects of different cost structures, we randomly varied these costs according to a probability distribution chosen on the basis of available information about the data set. We then represented most of these costs as random variables arising from the triangular distribution, a probability distribution often used in the absence of a large data set.

3. We put the probability distributions into the spreadsheet and substituted the appropriate triangular random variables for the analogous point estimates, using the software package @RISK, an Excel add-in.¹⁵

4. We simulated sets of values for the probability distribution functions contained in the cells and formulas of the spreadsheet, using Monte Carlo sampling and @RISK to sample realizations of the above random variables to simulate the cost structure.

5. We recalculated the spreadsheet, using the new sampled values to determine the range and probabilities of all possible outcomes. We performed 1000 independent trials of the simulation and stored the resulting cost sample statistics and empirical distributions for subsequent analysis.

6. We performed a sensitivity analysis to determine which cost categories were the most significant with regard to the total cost of the school-based inoculation program.

Simulation model: PacifiCare. For each combination of parental employment status (e.g., husband working full-time and wife working part-time), 800 independent trials of the simulation were run to estimate work loss costs. Data used in the simulations included probabilistic estimates around the mean of family income. Other data included estimates of the hours per doctor visit, the probability of the wife's vs the husband's taking the child to the doctor, the female-to-male wage differential, and the number of hours worked per year (mean 2082 for full time).

Results

Costs and CERs for the school-based program are shown in Tables 1 and 2, respectively. Estimated work-loss costs for parents bringing their children to the PacifiCare network HMO are shown in Table 3.

TABLE 1—Costs (\$) of Providing 8886 Doses of Hepatitis B Vaccine to 3359 Sixth-Grade Students in School-Based Immunization Clinics: Denver, Colo, September 1996–May 1997

	Education and Outreach	Vaccine Delivery	Program Management	Total
Start-up costs				
Development	4 196	...	...
Supplies	245	340	...	
Personnel	...	...	20 497	
Total	4 441	340	20 497	25 278
Ongoing costs				
Training	27 266	...	...
Supplies	17 520	2 441	...	
Vaccine	...	77 308	...	
Personnel	...	46 808	75 252	
Gift certificates	...	...	425	
Total	44 786	126 557	75 677	247 020
Total costs	49 227	126 897	96 174	272 298

TABLE 2—Cost-Effectiveness Ratios (\$) of the School-Based Hepatitis B Vaccination Program: Denver, Colo, September 1996–May 1997

Cost-Effectiveness Ratio	Mean (SD)	(95% Confidence Interval)
Including all costs		
Per dose	30.64 (0.94)	(28.80, 32.48)
Per completed series	95.29 (2.94)	(89.53, 101.05)
Excluding start-up costs		
Per dose	27.79 (0.93)	(25.97, 29.61)
Per completed series	86.45 (2.90)	(80.77, 92.13)

Intermediate Health Outcomes

During the 1996–1997 school year, 3903 (84%) of the 4665 sixth-grade students given consent forms returned the completed form. Of these 3903 students, 3359 (86%) accepted and 544 (14%) declined vaccination. Of those who accepted vaccination, 2855 (85%) completed the vaccine series; 2490 (87%) received all 3 doses of vaccine at DPS, and 365 (13%) received 1 or more doses elsewhere. In total, 8886 doses of hepatitis B vaccine were given to students by DPS; 8156 (92%) of these doses were given to students who completed the series.

Of the 504 students with signed consent forms who did not complete the series, 317 (63%) left the school system during the vaccination program and 185 (37%) were chronically absent or had other reasons not to be vaccinated. Of these 504 students, 277 (55%) received 2 doses, 176 (35%) received 1 dose, and 49 (10%) did not receive any vaccine.

Costs

Denver Public Schools. Table 1 shows the costs of the DPS-based vaccination program by cost center. Eighteen percent of the total program costs were attributable to edu-

cation and outreach, 47% to vaccine delivery, and 35% to program management. Start-up costs represent 9% of total costs. Analysis of the costs by contributor (not shown) shows that Denver Health and DPS together accounted for 85% of the costs of education and outreach as well as 99% of program management costs. Vaccine delivery costs were borne mostly by the Colorado Department of Public Health and Environment (61%) and Denver Health (25%).

The cost per dose and per completed hepatitis B vaccination series for the DPS clinics were \$30.64 and \$95.29, respectively. When start-up costs were excluded, the CERs were \$27.79 and \$86.45, respectively (Table 2).

Figure 1 shows the estimated cost per dose obtained by running 1000 iterations of the @RISK model. The corresponding mean for this cost per dose is \$30.64 (95% confidence interval [CI] = \$28.80, \$32.48). The slight asymmetry of the confidence interval about the point estimate of \$30.64 results from not assuming normality of the costs, although normality is probably reasonable, judging from Figure 1.

PacifiCare. For patients older than 11 years who received the hepatitis B vaccine, PacifiCare reimbursed network physi-

TABLE 3—Estimated Work-Loss Cost per Visit to Parents of Sixth-Grade Students Brought to a Network-Based Health Maintenance Organization for Hepatitis B Vaccination

Parents' Work Status	Cost, Mean (SD), \$
Both worked full-time	42.31 (2.63)
Wife worked full-time, husband worked	41.14 (2.59)
Wife worked full-time, husband did not work	46.69 (4.07)
Wife worked, husband worked full-time	40.36 (2.53)
Both worked	39.10 (2.44)
Wife worked, husband did not work	34.52 (3.48)
Wife did not work, husband worked full-time	10.17 (1.58)
Wife did not work, husband worked	9.25 (1.43)
Neither worked	9.06 (0.94)

Note. The estimates shown are based on 800 iterations of a Monte Carlo simulation, using the 1996 median income of married-couple families with one or more children aged 6 to 17 years (data from US Bureau of the Census¹⁴). The following assumptions are made: (1) 85% of the time, it is the mother who takes the child to the pediatrician; (2) an average vaccination visit takes 3 hours, including travel time; (3) the female-to-male wage differential is 0.74 (US Bureau of the Census¹⁴); (4) a full-time worker works 2080 hours per year (80 hours per pay period x 26 pay periods); and (5) incomes are normally distributed for each work status category.

cians \$68.06 per dose. Parents' copayment was \$10.00 per dose. The opportunity cost of a vaccination visit varied from \$9.25 (when the wife did not work and the husband did) to \$46.69 (when the wife worked full-time and the husband did not work). Table 3 and Figure 2 show the results of simulations using different assumptions about parents' work status. Whatever work-status assumption is used, the cost per dose delivered in the

DPS system (\$30.64) is far below the cost of delivering the vaccine through the HMO.

At \$30.64, the total cost per dose of the school-based vaccination program is significantly less ($P < .001$) than the HMO administrative cost of \$68.08 per dose; moreover, estimated work loss costs, ranging to more than \$40 per dose, apply to the HMO setting only and increase the differential in costs between the school-based program and HMO

administration. This conclusion holds even if the DPS costs are overestimated or underestimated by 20%. A sensitivity analysis (not explicitly described here) showed that the cost per dose for the school-based program could increase by \$28.77, to \$59.41 (95% CI = \$57.88, \$61.01), before there would be a 5% chance that the network HMO-based vaccination program would be more cost-effective than the school-based program.

Table 3 shows the combinations of parental work status and the corresponding estimates of work loss costs, reported as the mean of 800 simulations for each. The highest work loss estimate (\$46.69) occurs for families in which the wife worked full time and the husband did not work. For families in which the husband worked full time and the wife had some work, the estimate is \$40.36. Figure 2 depicts total costs for administration of the vaccine in the HMO, including the work loss estimates as increments above the fixed copayment cost of \$10 and vaccine and administration costs of \$68.06. For families in which the husband worked full time and the wife had some work, the total estimated cost is therefore \$118.42.

Discussion

This was the first program in Denver to offer universal hepatitis B vaccination beyond

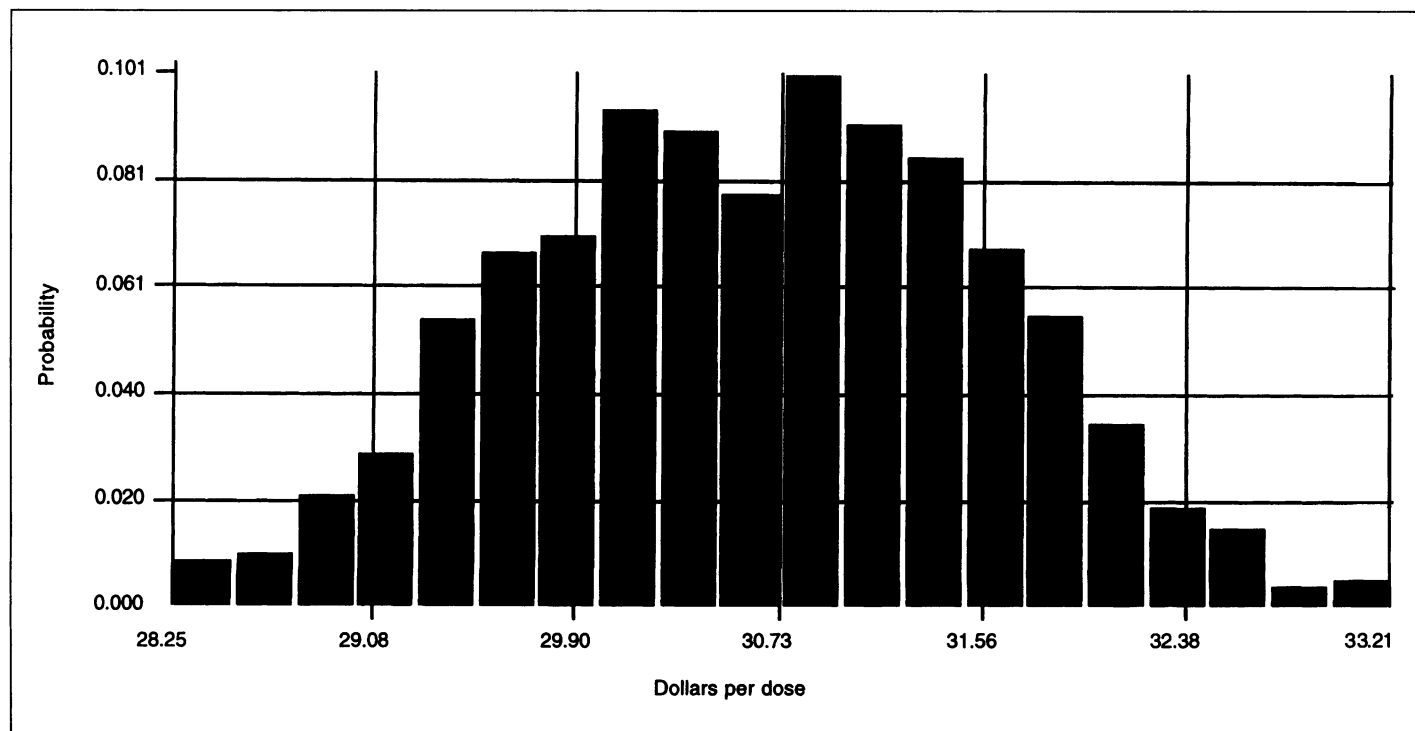


FIGURE 1—Distribution of costs per dose of hepatitis B vaccine delivered in the Denver Public Schools system, September 1996–May 1997: simulation results assuming costs are underestimated or overestimated by 20%.

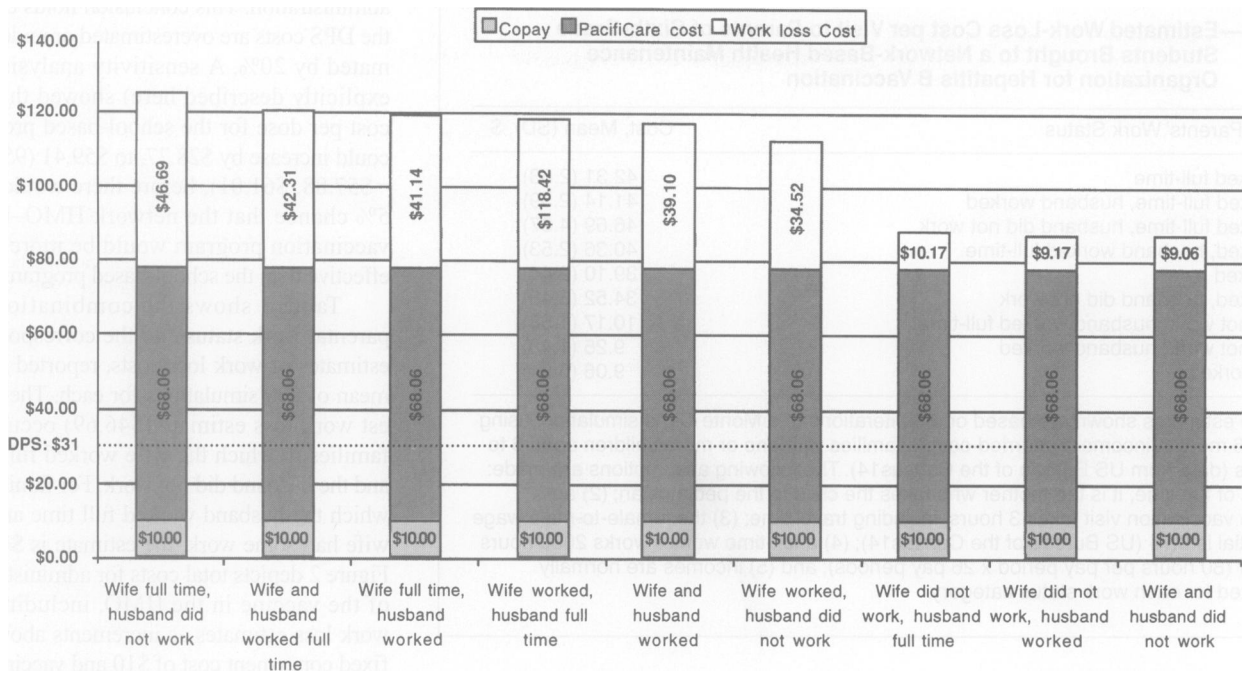


FIGURE 2—Societal cost (copayment, HMO cost, and parents' work-loss cost) per dose of hepatitis B vaccine delivered in an HMO (PacifiCare), compared with a cost of \$30.64 per dose delivered in the Denver Public Schools (DPS) system, September 1996–May 1997.

infancy. This voluntary program was successful in completing the vaccination series for 85% of the students who consented to be vaccinated. Coverage and dropout rates were consistent with those of other school-based demonstration projects in the United States that vaccinate adolescents against hepatitis B.^{10,11}

To measure the cost-effectiveness of the school-based program, we used a deterministic cost-accounting model and a probabilistic simulation model. Both models are fully documented and relatively easy to use and can aid policymakers involved in vaccine delivery decisions. The models strongly suggest that the Denver school-based system was cost-effective, with a significantly lower cost per dose than the network HMO we used for comparison. Because only one type of managed care organization was included in this study, these findings do not suggest that school-based systems are always more cost-effective than managed care organizations in delivering hepatitis B vaccine.

As expected, vaccine, personnel, and training costs contributed most to the costs of the school-based system. The \$2.84 per dose start-up cost did not materially inflate the CERs. Start-up costs accounted for only 9% of the total costs of the school-based program.

Some of the sixth-grade students in our study were eligible to receive vaccines through the Vaccines for Children program. We did

not adjust our model for this variable because the network HMO's reimbursement to the provider was independent of the child's eligibility for the program. Compared with a model that adjusts the vaccine costs for children who are eligible for the Vaccines for Children program, the school-based CERs in our model may overestimate the real costs.

The models we used do not take compliance into account. We have no data at present on compliance rates outside the school-based system, and it is unclear at what rate adolescents receiving the hepatitis B vaccination through other providers complete the 3-dose series. To be comparable, costs per completed series should be weighted by some index of compliance.

We did not consider the long-term benefits, that is, the cost of illness avoided through immunization, as was done by Margolis et al.¹⁶ and Krahn et al.¹⁷ In our analysis, parents' costs were limited to the cost of lost work hours and the cost of the copayment; by not including the costs of transportation and making an appointment, we underestimated the real parental costs in the network HMO delivery system. If the child was vaccinated as part of a routine well-child visit, attributing the entire cost of this visit to vaccination would result in an overestimation of vaccination costs in the HMO system.

In conclusion, there were 2 major advantages to the school-based hepatitis B vaccina-

tion program that accounted for most of its cost-effectiveness: (1) the school-based clinics used government-purchased vaccine, at a cost of \$8.70 per dose, whereas the HMO reimbursed at \$68.06 per dose, and (2) parents of children vaccinated in school-based clinics did not incur work-loss costs, whereas parents of children vaccinated in the HMO did.

Contributors

R. R. Deuson and E. J. Hoekstra wrote the paper; each of the other authors reviewed all drafts of the manuscript. R. R. Deuson designed the cost-effectiveness study, and E. J. Hoekstra designed the epidemiology study. R. Sedjo worked closely with R. R. Deuson in the design of the cost-effectiveness study, collected cost data, and created the database. G. Bakker coordinated all aspects of the data collection process, provided access to secondary data sources, and supervised the overall research process in the field. P. Melinkovich and F. N. Judson provided access to the middle schools and organized the vaccination campaign. D. Daeke supervised the HMO branch of the study and provided access to PacifiCare cost data. A. L. Hammer monitored the vaccination campaign in the middle schools and collected cost data. D. Goldsman edited all 23 drafts of the manuscript and, with R. R. Deuson, designed the simulation model and assisted in the model's calibration and validation.

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