Economic Analysis of a Child Vaccination Project Among Asian Americans in Philadelphia, Pa

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Objective: To ascertain the cost-effectiveness and the benefit-cost ratios of a community-based hepatitis B vaccination catch-up project for Asian American children conducted in Philadelphia, Pa, from October 1, 1994, to February 11, 1996.

Design: Program evaluation.

Setting: South and southwest districts of Philadelphia.

Participants: A total of 4384 Asian American children.

Interventions: Staff in the community-based organizations (1) educated parents about the hepatitis B vaccination, (2) enrolled physicians in the Vaccines for Children program, and (3) visited homes of children due for a vaccine dose. Staff in the Philadelphia Department of Public Health developed a computerized database; sent reminder letters for children due for a vaccine dose; and offered vaccinations in public clinics, health fairs, and homes.

Main Outcome Measures: The numbers of children having received 1, 2, or 3 doses of vaccine before and after the interventions; costs incurred by the Philadelphia Department of Public Health and the community-based organizations for design, education, and outreach activities; the cost of the vaccination; cost-effectiveness ratios for intermediate outcomes (ie, per child, per dose, per immunoequivalent patient, and per completed series); discounted cost per discounted year of life saved; and the benefit-cost ratio of the project.

Results: For the completed series of 3 doses, coverage increased by 12 percentage points at a total cost of $268,660 for design, education, outreach, and vaccination. Costs per child, per dose, and per completed series were $64, $119, and $537, respectively. The discounted cost per discounted year of life saved was $11,525, and 106 years of life were saved through this intervention. The benefit-cost ratio was 4.44:1.

Conclusion: Although the increase in coverage was modest, the intervention proved cost-effective and cost-beneficial.

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SUBJECTS AND METHODS

THE PROJECT

The Asian/Pacific Islander Hepatitis B Immunization Demonstration Project 1994-1996, in Philadelphia, was conducted with a grant from the Centers for Disease Control and Prevention. This 2-year education and outreach project started in the fall of 1994 and was conducted by the Immunization Program of the Division of Disease Control, Philadelphia Department of Public Health (DDC), which subcontracted with 2 local community-based Asian American organizations: Intercultural Family Services, Inc, and the Southeast Asian American Mutual Assistance Associations Coalition. Before and during this project, no other promotional hepatitis B vaccination efforts for API children were conducted in Philadelphia. Data from this study have been used to assess the effectiveness of a range of interventions in increasing vaccination coverage among API children, aged 2 to 13 years, living in the United States and to assess the impact of the interventions on the knowledge and practices of parents and physicians.

STUDY POPULATION

A database of 4384 Asian American children aged 2 to 13 years residing in the south and southwest districts of Philadelphia was created by the DDC and used during this intervention to track the children's vaccination status. To locate all Asian American children in the community, names were gathered from the School District of Philadelphia, the Philadelphia Department of Public Health District Health Centers, the Children's Hospital of Philadelphia, Mercy Health Plan (a health maintenance organization), the 2 community-based organizations, and a Buddhist temple. Preintervention hepatitis B vaccination coverage was ascertained by reviewing the immunization records of these children. Also, before intervention activities began, community organization staff conducted a survey of 212 households. The survey showed that 90% of parents in the estimated 1600 households with children in the study group were born outside the United States; most were from Cambodia or Vietnam. This survey reinforced the need for education, as about 90% of the parents said that they knew nothing about HBV. Only 58% of those who reported knowledge of hepatitis B said they knew about hepatitis B vaccine. Based on the assessment of the public health department, most parents in this community used the District Health Centers for their children's primary care.

Surveys of 73 of the 107 primary care physicians in the communities (survey instruments are available from the authors) showed that slightly more than 50% were white, 29% were Asian American, and 11% were African American. Most of the Asian American physicians were Vietnamese, Asian Indian, or Chinese, with at least 5 other ethnicities represented. About 54% of patients seeing Asian American physicians were Asian Americans, compared with 8% of patients seeing non-Asian American physicians. About two thirds of the physicians appeared well versed concerning hepatitis B disease, prevalence, and risk to Asian Americans and about vaccine effectiveness and safety. However, only about 30% understood the risk of HBV transmission during an invasive medical procedure, and few (24%) demonstrated knowledge of the risk of developing chronic HBV infection after being infected at birth. About half of the physicians offered 2 or fewer of the following vaccination-promoting services: early morning, evening, and weekend office hours; walk-in vaccinations; use of reminder systems; and vaccination without requiring a physical examination. Vaccination reminders were offered routinely by only one quarter of these physicians.

INTERVENTIONS

Intervention activities were conducted from March 11, 1995, through February 11, 1996. During this time, the computerized database of children enrolled in the study was used to track immunizations administered and to generate reminder letters for each child due for a vaccine dose. Intervention activities were culturally and linguistically specific to the primary Asian ethnicities. Staff educated parents about hepatitis B vaccination at 4 community health fairs and during 100 educational sessions attended by more than 300 adults at retail locations, schools and day care centers, churches, and public parks and buildings, on street corners, and in outdoor markets. They also arranged about 230 in-home educational forums attended by 800 adults to distribute information and answer questions. In addition to reminder letters, communication materials included brochures, posters, and an educational videotape. In the south Philadelphia communities, staff also conducted door-to-door outreach, and nurses provided in-home vaccination to 95 children in families who did not respond to the reminder letters.

Weighted results from a postintervention survey of a stratified random sample of 217 parents indicated that 69% remembered receiving a reminder letter and 52% remembered receiving a brochure about HBV; 16% attended a health fair and 9% an in-home forum. In the south Philadelphia community, 43% recalled receiving a home visit. The estimated percentage of the study population that knew about hepatitis B and hepatitis B vaccine increased from 11% and 6%, respectively, in the 2 communities before the intervention to 32% and 29%, respectively, after the intervention. The low level of formal education in this population (20% had less than a first-grade level and 78% had less than a high school level) may have limited the effectiveness of the brochures and reminder letters.

The Vaccines for Children program in Philadelphia began midway through the intervention, and a campaign was conducted to enroll private physicians who served the target population. The Vaccines for Children program is a federal program that provides vaccines to physicians at no cost for eligible low-income families. At the start of the campaign, none of the 13 physicians who provided childhood immunizations and served 90% of the target population in the intervention area were enrolled; after the campaign, all 13 physicians had enrolled.

DOSES ADMINISTERED

During the intervention, 2363 doses of the hepatitis B vaccine were administered. Most doses were administered by public health clinics (1603 [68%]), at the 4 health fairs sponsored by the DDC (601 [25%]), or in the home by a public health nurse (95 [4%]). The remaining vaccine doses (64 [3%]) were administered in hospitals, private offices, or offices associated with health maintenance organizations. At the end of the intervention, the number of children in the community who had received only the first dose in the series increased by 385 (Table 1), the number who had received the first 2 doses in the series increased by 206, and the number who had completed the series increased by 322. The number of children who had received at least 1 dose of vaccine increased by 1113.
MEASUREMENT OF INTERVENTION COSTS

To implement the interventions, the DDC and the community-based organizations incurred costs for design, education, outreach, and vaccination. Costs for design included salary and benefits for DDC and community organization personnel. The development of the computerized tracking system by the DDC is included in design. Costs for education included salary and benefits for community organization personnel to develop educational materials, conduct education sessions for parents, and conduct the Vaccines for Children physician enrollment campaign. Education costs also included salary and benefits for DDC staff to update the tracking system and to generate reminder letters. Printing and postage, health fair advertising, and transportation were included in education expenses. Outreach costs included salary and benefits for DDC and community organization personnel, transportation, and the salaries of nurses who provided in-home vaccinations. Vaccination costs included vaccine (purchased at the federal contract price by the DDC), the supplies for vaccine administration at health fairs and in homes, and the salaries of the nurses who administered vaccine at the health fairs. All costs are reported in 1995 dollars.

COST-EFFECTIVENESS ANALYSIS OF INTERMEDIATE OUTCOMES

Cost-effectiveness ratios for intermediate outcomes are useful for evaluating the present costs of a project. For example, the cost of immunizing one child in this project might be compared with the equivalent for another city's intervention. To examine the cost-effectiveness of intermediate outcomes, 6 cost-effectiveness ratios were calculated: cost per child receiving any dose; cost per dose delivered; cost per completed series; and 3 ratios for cost per additional child rendered seroprotected (antibodies to the hepatitis B surface antigen of at least 10 mIU/mL), which vary according to the assumption used for the seroprotection rate after receiving a single dose of vaccine. To estimate the number of 1-dose recipients rendered immune, the number of additional children in the population who received only the first dose was multiplied by 0.20, 0.35, and 0.50.12-16 Added to each of these 3 estimates were 85% of the additional number of children covered with the first 2 doses and 95% of the additional number of children covered with all 3 doses; these are accepted estimates of second- and third-dose seroprotection rates.12-16 A range of values was available for some cost estimates. To account for this, we performed a stochastic risk analysis using the best data available for input distributions. Because the output showed little variability (the 2.5th and 97.5th percentiles were within about 10% of one another), cost uncertainty was ignored and all calculations were done deterministically.

COST-EFFECTIVENESS AND BENEFIT-COST ANALYSES OF LIFETIME OUTCOMES

Measures of long-term outcomes are vital for understanding if money invested in an intervention will be repaid by benefits that accrue over years. We quantified long-term outcomes in 2 ways: discounted cost per discounted year of life saved; and benefit-cost over the life expectancy of the children in this population, when costs of hepatitis B infections or costs savings from averted infections will become apparent. We computed 4 base-case estimates of discounted cost per discounted year of life saved and 4 base-case estimates of lifetime benefit-cost, from combinations of 3% and 5% discount rates; and estimated 30% and 60% infection rates among susceptible persons. These discount rates are the standard used for economic analysis in the United States, and these infection rates are estimated to be within the conservative range of rates likely to prevail among first-generation immigrant Asian American children in unvaccinated populations. The use of a discount rate to calculate net present value of the project reflects project or program administrators' and planners' time preference for outcomes and costs.

The net present value of benefits was quantified through the following assumptions: vaccination produces protective levels of antibody in 20% to 50%, 85%, and 95% of vaccinees after 1, 2, and 3 doses, respectively.12-16; 60% of infections are asymptomatic and 40% are symptomatic; 15% of those infected as adolescents are at risk of chronic liver disease; those with asymptomatic chronic infection incur no lifetime disease costs or adverse outcomes; those with chronic liver disease were equally distributed among the chronic liver disease categories (chronic persistent hepatitis, chronic active hepatitis, cirrhosis, and primary hepatocellular carcinoma); and the outcome for those with chronic persisting hepatitis did not include death.

The costs of infection included direct (medical) and indirect (work loss) costs. Direct medical costs included the inpatient, outpatient, scanner, and laboratory costs for acute and chronic HBV infection. Indirect costs included medical visits and loss of earnings due to HBV-related illness and due to premature mortality caused by chronic active hepatitis, cirrhosis, and primary hepatocellular carcinoma.

All cost data in the model come from the Bureau of Labor Statistics, the Bureau of the Census, the MEDSTAT Marketscan database, refereed publications, interviews of experts in the field, and Centers for Disease Control and Prevention data.16-21 We used a spreadsheet program (BENCOST) developed at the Centers for Disease Control and Prevention and based on the work of Margolis et al.1

To calculate discounted cost per discounted year of life saved, the net present value of costs incurred in the project was divided by the discounted years of life saved by the intervention. To calculate benefit-cost, the net present value of benefits was divided by the net present value of costs incurred in the project.

For this intervention, 100% of the vaccine supply was purchased at public sector prices. However, since the percentage of vaccines delivered by the private sector in Philadelphia is increasing (to 40% in 1999), adjustments must be made in the analysis to account for price differences between vaccines purchased in the private and public sectors. Two hypothetical scenarios are examined: 60% and 100% of the vaccines purchased in the private sector.

For the discounted cost per discounted year of life saved and the benefit-cost ratio (for the actual project and the 2 hypothetical scenarios), we performed sensitivity analyses to explore the effect of the assumptions for discount rate and infection rate on the estimates of discounted cost per discounted year of life saved and the benefit-cost ratio. We computed ratios for all combinations of 3% and 5% discount rates and 15% to 75% infection rate, at increments of 15%. We used a broad range of infection rates to account for the potential variability resulting from differences in baseline vaccination levels and risk levels within countries of origin and the United States and from different ages at immigration.
The number of additional children protected by vaccination was estimated from the known numbers receiving 1, 2, and 3 doses in Table 1 and from estimates of vaccine seroprotection rates. At 20% first-dose seroprotection, the estimated number of additional immune vaccine recipients is 748 (17.1%). At 35% and 50% first-dose seroprotection, the estimates are 806 (18.4%) and 864 (19.7%), respectively.

INTERVENTION COSTS
At the time of the intervention, the federal contract price for the vaccine was $7.09 per dose for children younger than 11 years and $7.75 per dose for children 11 years and older. The private sector price was $16.17 per dose for children younger than 11 years and $18 per dose for children 11 years and older.

Intervention costs totaled $268,660 and are summarized by task in Table 2. The percentage distribution across major groupings of cost centers was as follows: salary, benefits, overhead, and transportation, 87%; vaccines and supplies, 8%; and printing, postage, and advertising, 5%. The percentage distribution of costs by task is shown in the Figure.

COST-EFFECTIVENESS OF INTERMEDIATE OUTCOMES
The cost per child and per dose was $64 and $119, respectively. Under the assumptions of 20%, 35%, and 50% first-dose seroprotection rates, the costs per immunoequivalent patient were $375, $348, and $325, respectively. Finally, the cost per completed series was $537.

COST-EFFECTIVENESS AND BENEFIT-COST ANALYSES OF LIFETIME OUTCOMES
In the base-case analysis, years of life saved by this intervention ranged from 106 (30% infection rate) to 213 (60% infection rate); the discounted cost per discounted year of life saved ranged from $5,763 (60% infection rate and 3% discount rate) to $27,691 (30% infection rate and 5% discount rate). Benefit-cost ratios ranged from 2.08:1 (30% infection rate and 5% discount rate) to 8.88:1 (60% infection rate and 3% discount rate) (Table 3).

In the sensitivity analyses of the actual intervention (100% of vaccines purchased at the federal contract price), years of life saved ranged from 53 to 266, as the assumed infection rate increased from 15% to 75%. The discounted cost per discounted year of life saved ranged from $4,610 (75% infection rate and 3% discount rate) to $55,381 (15% infection rate and 5% discount rate) (Table 3). The

community-based education and outreach project designed to increase hepatitis B vaccination coverage among Asian American children in Philadelphia, Pa; the program targeted children aged 2 to 13 years. Because the percentage of vaccines administered by the private sector is increasing, we also explore the impact on the cost-effectiveness and the benefit-cost of conducting such a project at private sector prices. The cost-effectiveness and benefit-cost ratios of this project are compared with those of routine vaccination efforts being conducted nationwide.

RESULTS

COVERAGE
The number of additional children protected by vaccination was estimated from the known numbers receiving 1, 2, and 3 doses in Table 1 and from estimates of
benefit-cost ratios ranged from 1.04:1 (15% infection rate and 5% discount rate) to 11.10:1 (75% infection rate and 3% discount rate). All of these benefit-cost ratios are more than the threshold point (1.0) at which benefits cover costs exactly. The results of the sensitivity analyses are similar for the 2 hypothetical scenarios. Assuming that 60% of the vaccines are purchased at the higher private sector price, the discounted cost per discounted year of life saved ranged from $4836 to $58135; for 100% purchased in the private sector, the discounted cost per discounted year of life saved ranged from $4988 to $59964. Benefit-cost ratios for the 60% private purchase scenario ranged across the infection rates from 0.99:1 to 10.38:1; and for the 100% private purchase scenario, from 0.96:1 to 10.25:1. For both hypothetical scenarios, only at the lowest infection rate did the ratios decline slightly below the threshold point, indicating a small net cost rather than a net benefit.

### Table 3. Years of Life Saved, Cost-effectiveness Ratios, and Benefit-Cost Ratios for Lifetime Outcomes, 15% to 75% Infection Rates, and 3% and 5% Discount Rates*

<table>
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<tr>
<th>Item</th>
<th>Infection Rate, %</th>
<th>15†</th>
<th>30‡</th>
<th>45§</th>
<th>60‡</th>
<th>75†</th>
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<td>Years of life saved</td>
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<td>160</td>
<td>213</td>
<td>266</td>
</tr>
<tr>
<td>Cost per year of life saved, $</td>
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<td>11525</td>
<td>7683</td>
<td>5763</td>
<td>4610</td>
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<tr>
<td>Benefit-cost ratio</td>
<td></td>
<td>2.22</td>
<td>4.44</td>
<td>6.66</td>
<td>8.88</td>
<td>11.10</td>
</tr>
</tbody>
</table>

*The intervention was the Asian/Pacific Islander Hepatitis B Immunization Project 1994-1996. The project was conducted in Philadelphia, Pa.
†Sensitivity analysis.
‡Base case.
§Values are the discounted percentages.

The intervention was labor intensive, with relatively high intervention costs and a relatively low marginal change in vaccination status; however, it proved cost-effective and cost-beneficial for all ratios reported in Table 3. Moreover, if education, outreach, and planning costs are held constant, examining each of the ratios suggests that if more children completed the 3-dose series, cost per completed series would decline appreciably, since 91% of the costs of the intervention are not related to the vaccination itself and would be spread among more children. Assuming higher coverage (60% receiving at least 1 dose, 50% at least 2 doses, and 40% all 3 doses) in the base-case scenario, model simulations (not shown herein) suggest that 242 years of life would be saved by the intervention, that the cost per discounted year of life saved would be $5530, and that the benefit-cost ratio would likely be 9.25:1 for the targeted population.

The increase in hepatitis B vaccination rates among the target population in this study has been attributed to the effects of the intervention for 2 reasons: (1) the increases observed in other cities before implementation of special catch-up efforts have only been about 1%§ and (2) no other catch-up efforts were conducted in Philadelphia before or during this project.

These economic models may be used to evaluate intermediate- and long-range outcomes of past or ongoing projects as shown in this study and may also be useful for planning and policy making. In addition, planners may conduct sensitivity analyses—as we did for our point estimate long-range model—to test how strongly the outcomes depend on assumptions. This is particularly useful in cases for which input values cannot be precisely defined. In the case of this study, because most of the ratios calculated in the sensitivity analyses (for the base case and for the 2 hypothetical vaccine purchase scenarios) show a net benefit, we may conclude that the results of the model are not qualitatively affected by differing assumptions about discount rates and infection rates or by the difference in public and private sector purchase prices. In this investigation, more detailed accounting of nonvaccine program costs would have allowed more in-depth analysis of the impact of administering some or all of the vaccines in the private sector. Because hepatitis B vaccine accounted for only 8.7% of the total cost of the program, and we only varied the cost of vaccine (but not other costs, ie, community education, outreach, and planning), the analyses of the impact of private vs public sector administration of vaccine are somewhat limited.

Economic analyses of projects such as this are feasible and practical, because recipients of most grants are required to provide detailed records of tasks, costs, and outcomes for the grant-financed program. Such data can be used as shown herein to help policy makers compare programs to assess their relative effectiveness and to maximize the return on investment by selecting the most effective programs.

While this analysis results from the accurate measurement of all program costs, and reflects the epidemiological conditions prevailing in Philadelphia, caution should be exercised in comparing the cost analyses of this study with others. For example, in this study, we calculated ratios using years of life saved, rather than qual-
ity-adjusted life years, a frequently used weighting procedure that quantifies the extent to which illness or disability lowers the quality of life.25 In addition, we did not consider the cost of adverse events due to the vaccination (because these are rare23) and we did not use estimates of wage and workforce participation rates specific to Philadelphia. Analyses of similar programs that use dissimilar methods or sources of data may have limited comparability.

In general, costs for this intervention compare favorably with other life-saving health interventions, despite a relatively low increase in hepatitis B vaccine coverage. Tengs et al24 reported the cost-effectiveness of 587 life-saving interventions in the United States. The median medical intervention cost per year of life saved was $19000. Hence, while the intervention appears modest by some measures (ie, 25.4% more children received 1 or more doses and 11.9% completed the hepatitis B vaccine series), the base-case intervention costs of $11525 per year of life saved falls well below the median (more cost-effective) reported by Tengs et al.

The cost-effectiveness of the catch-up hepatitis B vaccination efforts reported herein may be compared with the cost-effectiveness of infant vaccination efforts to control the ongoing transmission in the United States of the bacterium Bordetella pertussis. Some aspects of the diseases and the vaccine programs are similar enough to permit comparison. For example, despite widespread use of the vaccine, the incidence of pertussis has averaged about 3700 cases per year since 1980. As with hepatitis B, adolescents and adults are an important reservoir for B pertussis and are often the source of infection for infants and susceptible children. The diphtheria and tetanus toxoids with acellular pertussis vaccine is given in a primary series of 4 doses administered by the age of 18 months, followed by a booster. The benefit-cost ratios for the diphtheria and tetanus toxoids with acellular pertussis vaccine series from a societal and health care system perspective were 27:1 and 8:5:1, respectively.25

Recent articles published in the American Journal of Public Health26 and in the Archives27,28 indicate that the measurable impact of most public health interventions is usually relatively small, and often statistically nonsignificant. In this instance, even though the intervention only increased series-complete coverage by 12 percentage points by the end of the 12 months, the impact was cost-effective and cost-beneficial. Nationwide, further improvement in the efficiency of outreach methods within API communities by community-based organization/public health department partnerships could increase API child hepatitis B vaccination coverage while reducing program costs and increasing benefit-cost ratios.

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