

Childhood Vaccine Purchase Costs in the Public Sector: Past Trends, Future Expectations

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The use of vaccines has greatly reduced the morbidity and mortality attributable to several childhood diseases.¹ Childhood vaccinations remain some of the most favorable and cost-effective prevention strategies available.^{2,3}

Federal and state programs help ensure delivery of the vaccines recommended by the Advisory Committee on Immunization Practices (ACIP) of the Centers for Disease Control and Prevention (CDC) to American Indian and Alaska Native children, as well as to children who have public health insurance (Medicaid or state child health insurance extensions of Medicaid), no health insurance, or insurance with incomplete vaccine coverage.⁴ The federal Vaccines for Children (VFC) program purchases vaccines recommended by ACIP for administration to program-eligible children, currently approximately 35% of the national birth cohort,⁵ at a cost that exceeded \$500 million for fiscal year 2000.⁴ State programs purchase and deliver vaccines to children besides those entitled to VFC-purchased vaccines, and receive funding through grants from the federal Section 317 (childhood immunization) program as well as from state appropriations. Overall, more than half of all childhood vaccine doses in the United States are purchased in the public sector.⁴

The number of vaccines recommended for universal administration to children has climbed steadily in the past 15 years.^{6–18} As a result, federal and state governments bear a growing cost burden to vaccinate children. With the addition of pneumococcal conjugate vaccine (PCV) to the consensus vaccine schedule for childhood vaccinations in 2001,⁶ the cost of purchasing vaccines for a child at public-sector prices nearly doubled.¹⁹ Furthermore, recent Institute of Medicine (IOM) panels reported that several new vaccines may be recommended for children by 2020.^{4,20} The recent increases in vaccine purchase costs are a major concern for public-sector vaccination efforts, but the financial and programmatic

Objectives. We examined recent public-sector trends in childhood vaccine costs and estimated future costs.

Methods. We used public-sector price data to calculate vaccine purchase cost per child for children aged 0 to 6 years from 1975 to 2001. We fit a linear regression model to historical data and then used it to project costs per child from 2002 to 2020, adjusted to 2001 US dollars.

Results. Controlling for inflation, the cost of vaccine purchase per child climbed from \$10 in 1975 to \$385 in 2001. The cost of vaccine purchase in the year 2020 following recommendation of 7 additional vaccines is estimated to be \$1225 per child (95% confidence interval=\$891, \$1559).

Conclusions. The cost per child for recommended vaccines at public-sector prices may triple over the next 2 decades. These projections have implications for vaccine financing at federal and state levels. (*Am J Public Health.* 2002;92:1982–1987)

implications of these projections for vaccine purchase costs in the public sector have not been well characterized.

We conducted an analysis of trends in childhood vaccine costs in the public sector over the past 25 years, adjusting for inflation. We then used these historical data to estimate future costs for purchase of childhood vaccines in the public sector by 2020.

METHODS

Childhood Vaccination Schedules

Vaccine recommendations for the years 1975 to 2001^{6–18,21} were reviewed to identify typical patterns of provision of recommended vaccines for children up through age 6 years. Vaccines considered included oral poliovirus vaccine (OPV), inactivated poliovirus vaccine (IPV), measles–mumps–rubella vaccine (MMR), diphtheria and tetanus toxoids and whole-cell pertussis vaccine (DTP), diphtheria and tetanus toxoids and acellular pertussis vaccine (DTaP), *Haemophilus influenzae* type b vaccine (Hib), hepatitis B vaccine (HBV), varicella vaccine (Var), and PCV. We also considered new combination vaccines such as DTP/Hib, DTaP/Hib, and Hib/HBV, which combine antigens that previously were offered only separately during the period of study. MMR and DTP represent antigen combina-

tions that were available before the period of analysis.

During several years from 1975 to 2001, providers could choose among different patterns of provision for recommended vaccine series. For those years, we identified different combinations of vaccine series that represented feasible and common approaches to vaccinating children.

Two vaccines mentioned in ACIP recommendations were not included in these analyses. Rotavirus vaccine was added to ACIP recommendations in 1999⁷ but removed in 2000⁸ before the establishment of a federal contract price. Hepatitis A vaccine is recommended for administration to children only in areas of the United States where hepatitis A is endemic,²² rather than nationwide like the other vaccines in the current schedule.⁶

Public-Sector Vaccine Purchase Prices

The goal of this analysis was to characterize the minimum purchase costs for childhood vaccines at federal contract prices negotiated by the CDC. Therefore, in instances in which different prices per dose were available depending on the number of doses per vial purchased, or when different prices were available from different manufacturers, the lowest price per dose was used. Data regarding federal contract prices, obtained from the

CDC, reflected the price on or about January 1 of each year. All vaccine prices were indexed to 2001 US dollars using the Consumer Price Index.²³

Although DTP was recommended before 1975,²¹ a federal contract price was not set until 1985. Our perspective is that of vaccines purchased at public-sector prices, so for the purposes of describing time trends in costs we have treated DTP in 1985 as a change in childhood vaccine recommendations.

Cumulative Vaccine Purchase Costs

We calculated the cumulative vaccine purchase cost per child to be completely vaccinated (i.e., up to date) through age 6 years as the sum of the federal contract prices of all the doses of recommended vaccines in a given calendar year. In other words, in 1986 the cumulative cost per child reflects the sum of 1986 purchase costs for 5 doses of DTP, 4 doses of OPV, and 1 dose of MMR (adjusted to 2001 US dollars). For years in which alternative combinations of vaccines were possible, we calculated a cumulative cost for each combination and took the mean of the cumulative costs of the different combinations as the final cumulative cost per child for those years.

We calculated any change in the cumulative cost of vaccines attributable to a specific change in vaccine recommendations (“attributable change in cost”) as the difference between the total cumulative cost in the year of change and the cumulative cost of all vaccine series exclusive of the new vaccine.

Models of Cumulative Vaccine Purchase Costs

We conducted linear regression analyses of cumulative cost per child (in 2001 US dollars) as the outcome variable. Predictor variables included year indexed to 1975 (i.e., 1975 as year 0, 1976 as year 1, etc.), total number of vaccine series recommended, and whether a new recommendation represented a noncombination or combination vaccine. We also identified a single significant interaction term regarding year and the total number of vaccine series recommended, and included this term in our final model.

To estimate future cumulative vaccine costs, we relied principally on 2 IOM reports^{4,20} that project that as many as 7 addi-

tional vaccines (each with anticipated cost-effectiveness of no more than \$100 000 per quality-adjusted life-year gained) will be universally recommended for young children by the year 2020: *Helicobacter pylori*, hepatitis C, influenza, parainfluenza, respiratory syncytial virus, rotavirus, and group A streptococcus. According to the *Jordan Report 2000* of the National Institute of Allergy and Infectious Diseases,²⁴ as of the year 2000 these 7 noncombination vaccines were in various stages of development ranging from preclinical research to phase 3 trials. Two combination vaccines may be recommended as well: Var/MMR⁴ and a pentavalent vaccine directed against diphtheria, tetanus, pertussis, polio, and hepatitis B that is currently in phase 3 trials.²⁵

Given reasonable uncertainty about how many childhood vaccines will be recommended in the next 2 decades, we used the regression model based on historical cost data to estimate the cumulative vaccine purchase cost per child for the years 2002 to 2020 in 3 scenarios reflecting the recommendation of 3, 5, or 7 noncombination vaccines.

The recommendation of 7 new vaccines over 2 decades is most similar to the rate of new recommendations in the years 1991 to

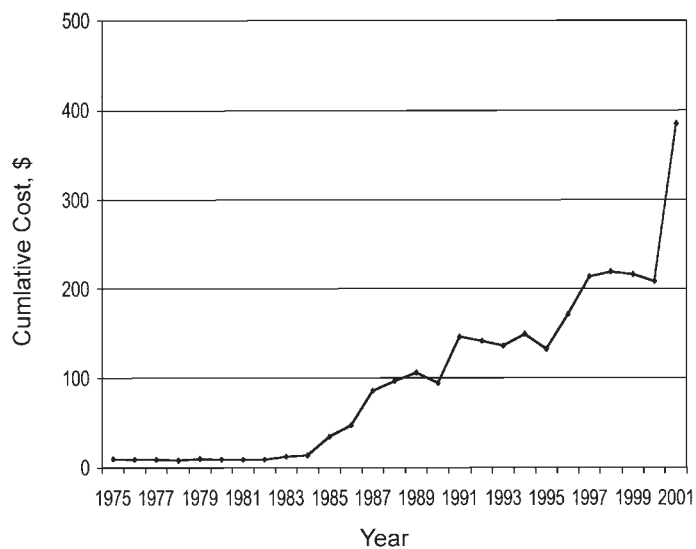
2001. Therefore, to examine the variation in costs associated with the recommendation of new vaccines at different rates over time, we estimated the annual cumulative vaccine purchase cost per child for the years 2002 to 2020 in 3 scenarios of the introduction of 7 vaccines: (1) an “even” scenario recommending 1 new noncombination vaccine every 2 to 3 years from 2002 to 2020; (2) an “early” scenario recommending 5 new noncombination vaccines by 2011, and then 2 additional vaccines by 2020; and (3) a “late” scenario recommending 2 noncombination vaccines by 2011, followed by a new vaccine every other year until 2020.

For all 3 scenarios, we also estimated cumulative costs with and without the introduction of 2 new combination vaccines, 1 in 2008 and 1 in 2016. All analyses were conducted with Stata 6.0 (Stata Corp, College Station, Tex).

RESULTS

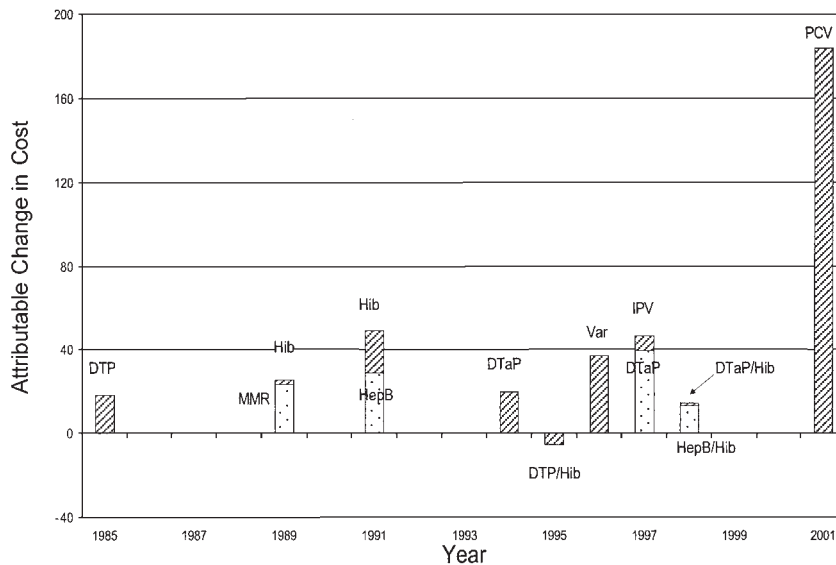
Historical Trends in Childhood Vaccine Purchase Costs

All findings are reported adjusting for inflation from 1975 to 2001. As shown in Figure 1, the cumulative cost of purchasing



Note. Vaccine series considered for children through age 6 years. All costs are in 2001 US dollars.

FIGURE 1—Cumulative cost of recommended vaccine series per child at public-sector prices, 1975–2001.



Note. DTaP = diphtheria and tetanus toxoids and acellular pertussis vaccine; DTP = diphtheria and tetanus toxoids and whole-cell pertussis vaccine; HBV = hepatitis B vaccine; Hib = *Haemophilus influenzae* type b vaccine; IPV = inactivated poliovirus vaccine; MMR = measles-mumps-rubella vaccine; Var = varicella vaccine. Each bar represents attributable change in cost for the vaccines indicated. Bars of different shades distinguish costs for different vaccines in years in which more than 1 change in recommendations occurred. New combination vaccines are indicated with "/" in the vaccine name. All costs are in 2001 US dollars.

FIGURE 2—Changes in cumulative costs per child of vaccine series attributable to changes in recommendations.

all recommended doses of vaccine for a child up through age 6 years at public-sector prices doubled from about \$100 in 1988 to about \$200 in 1997, and then nearly doubled again to \$385 in 2001 with the addition of PCV (all 2001 US dollars).

The increases in purchase costs attributable to changes in vaccine recommendations are presented in Figure 2. Two trends are evident. First, the stepwise introduction of a new recommendation over a sequence of years rather than in just one year (e.g., Hib in 1989 and 1991, DTaP in 1994 and 1997) disperses the increase in cumulative costs over those years. Second, combination vaccines do not increase the cost as much as noncombination vaccines, although combination vaccine prices per dose are comparable to those of noncombination vaccines (data not shown). This effect is attributable to direct substitution of the new combination vaccine for some of the doses of noncombination vaccines.

The overall mean rate of increase in cumulative vaccine purchase cost per child from 1975 to 2001 was 19% per year. For only

the years in which a change in vaccine recommendations occurred, the mean rate of increase in cumulative cost per child was 35% per year.

Models of Cumulative Purchase Costs

A linear regression model of historical cumulative vaccine costs per child up through age 6 years fit observed data well, with $R^2 = 0.95$. According to the model, the mean attributable change in cost associated with the introduction of a noncombination vaccine was \$38 per child, and increased with time from \$35 in 1991 to \$58 in 2001. Of note, the observed cumulative vaccine purchase cost per child in 2001 (\$385) with the addition of PCV is greater than the cost estimated by the model (\$322), and lies beyond the upper bound of the 95% confidence interval (CI), which is \$357.

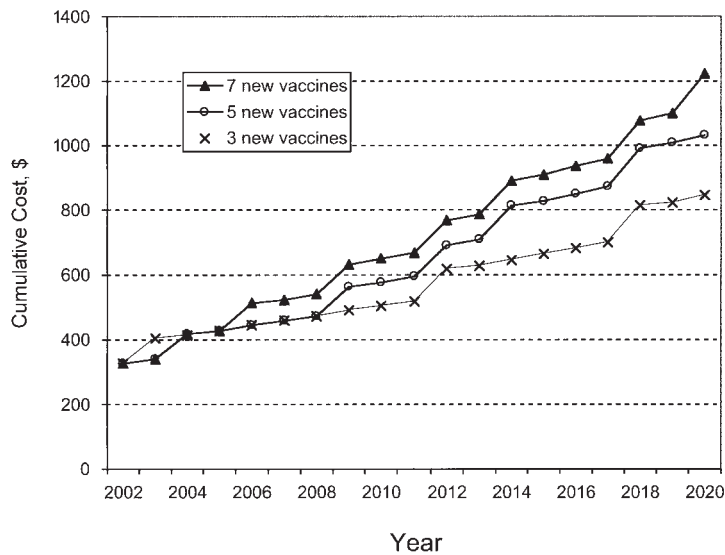
Estimates of future cumulative costs for purchase of childhood vaccines at public-sector prices, derived from the regression model, illustrate the effects of the potential introduction of 3, 5, or 7 new noncombination

vaccines by 2020 (Figure 3). Models of these 3 scenarios project that the cumulative vaccine purchase cost per child in 2020 will be \$845 (95% CI=\$619, \$1071) if 3 new noncombination vaccines are introduced, \$1032 (95% CI=\$756, \$1308) for 5 new vaccines, and \$1225 (95% CI=\$892, \$1559) after the introduction of 7 additional vaccines. In the 7-vaccine introduction model—which most closely resembles the pace of introduction of noncombination vaccines from 1991 to 2001—the estimated attributable change in cost per child for a noncombination vaccine is \$76 in 2009 and \$100 in 2020 (in 2001 US dollars). The potential introduction of 2 new combination vaccines by 2020 does not alter the estimated cumulative cost substantially in any vaccine introduction scenario (data not shown).

The pace at which new vaccines are potentially introduced in the next 2 decades affects the short-term purchase costs that federal and state vaccine policymakers may face, as illustrated in the 7-vaccine introduction model (Figure 4). If 5 new vaccines are recommended within the next decade and 2 more are added by 2020 (early scenario), the estimated cumulative cost in 2011 is \$821 per child—23% higher than the even scenario—and exceeds \$1000 per child by 2015. In contrast, in the late scenario the cumulative cost is less than \$600 per child in 2011 and does not exceed \$1000 per child until 2018.

DISCUSSION

Our analysis of public-sector vaccine price data reveals that the costs of childhood vaccine purchases over the last 25 years have grown at a mean rate of 19% per year, adjusted for inflation. Much of this growth is due to the addition of new and higher-priced vaccines to the recommended schedule; changes in vaccine recommendations increased purchase costs by 35% per year on average in each of the years they occurred. Moreover, our estimates of future vaccine costs suggest that vaccine purchase expenditures for each child at public-sector prices may triple by 2020 beyond the effects of inflation as the number of recommended vaccines doubles.



Note. All cost estimates are derived from the regression model of historical public-sector vaccine cost trends. Point estimates are shown for models of the introduction of 3 new noncombination vaccines in 2003, 2012, and 2018; 5 new noncombination vaccines in 2004, 2009, 2012, 2014, and 2018; and 7 new noncombination vaccines in 2004, 2006, 2009, 2012, 2014, 2018, and 2020. Potential introduction of combination vaccines is not shown. All costs are in 2001 US dollars.

FIGURE 3—Three scenarios of estimated cumulative costs per child of recommended vaccine series, 2002–2020.

We emphasize that our projections of future expenditures are conservative estimates that reflect the lowest possible purchase costs for childhood vaccines at public-sector contract prices. Whereas federal contract prices for childhood vaccines that have been used longer (HBV, Hib) are discounted >60% over private-sector levels, public-sector prices for more recently recommended vaccines (PCV, Var) have been set at approximately 20% below private-sector prices.¹⁹ If this trend continues, vaccine purchase costs per child may exceed our projections.

The total cost borne by federal and state government immunization programs also includes expenditures associated with excise taxes, vaccine distribution, clinic visit costs, nursing time, vaccine preparation, vaccine administration, and storage of vaccine.^{4,26} However, other investigators' models of overall costs associated with vaccination have been most sensitive to changes in vaccine purchase costs,²⁶ which suggests that future modifications to cumulative purchase costs will be the major determinants of changes in overall childhood vaccine program expenditures.

Therefore, our models of vaccine purchase expenditures have immediate relevance and applicability to current policy decisions, and have implications for the future financing of vaccination programs. Although concerns about increasing vaccination costs are certainly not limited to the public sector, we have chosen to focus on public-sector expenditures because of the prominent role of government vaccination programs in purchasing vaccines for more than half of all children in the United States.⁴

Applicability of Models to Policymaking

In a recent report,⁴ the IOM recommended that federal and state vaccine purchase budgets should be adjusted annually to reflect the estimated cost impact of new vaccines scheduled for consideration as additions to the recommended immunization schedule. However, this strategy does not facilitate long-range planning for federal programs such as VFC, and state legislatures that budget in 2-year cycles may find it difficult to adjust in a timely fashion to vaccine cost estimates issued

shortly after the end of their biannual legislative sessions.²⁷

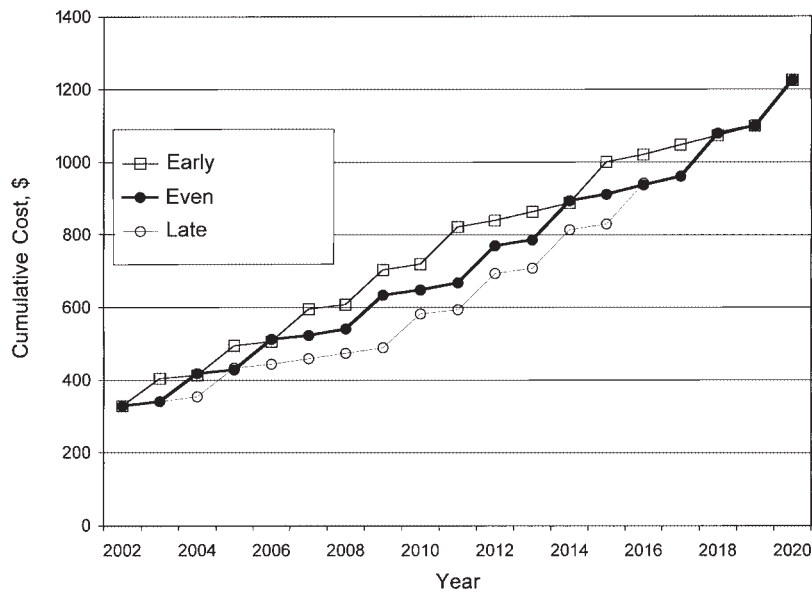
Our models allow policymakers to estimate the likely annual effects of changes in vaccine recommendations and to anticipate changes over the next 5, 10, and 20 years. Legislators, vaccine program officials, and advocacy groups may also use the models to examine the range of possible vaccine purchase costs per child, given different scenarios of introduction of new recommendations.

Future Vaccine Financing

The effects of vaccine purchase cost increases on financing for immunization programs may be different at federal and state levels. The estimated rate of growth in vaccine purchase costs implies that VFC funds for vaccine purchases, amounting to \$500 million before the addition of PCV in fiscal year 2000,⁴ will need to be \$1.5 billion or more (in 2001 US dollars) by 2020, a sum that will go principally to children receiving Medicaid because they make up the majority of VFC-eligible children. Although this is a substantial increase in vaccine purchase expenditures, this figure is dwarfed by the multiple billions of dollars in Medicaid expenditures annually. Of note, VFC vaccine purchase expenditures will change as the numbers of Medicaid-eligible, uninsured, or underinsured children vary from current levels.

At the state level, steadily increasing vaccine purchase costs may have quite different effects. When PCV was introduced, several state immunization officials expressed concern about whether state legislatures would be willing or able to increase funding for vaccine purchasing to the level necessary to serve children not eligible for VFC-purchased vaccines.²⁷ Although our model suggests that PCV is unusually expensive from an historical perspective, our estimates indicate that state lawmakers will be facing increases of \$60 to \$100 per child (in 2001 US dollars) for each newly recommended vaccine series in the next 2 decades.

States' ability to cope with such increases for childhood vaccine purchasing may depend upon securing federal Section 317 program grants, which are typically used for a combination of vaccine purchasing and program infrastructure. The IOM has recom-



Note. Early scenario = 5 new vaccines by 2011 and 2 more vaccines by 2020; even scenario = a new vaccine every 2 to 3 years; late scenario = 2 new vaccines by 2011 and 1 more new vaccine every other year between 2011 and 2020. All scenarios reflect the introduction of 7 new noncombination vaccines by 2020, with costs derived from the regression model of historical public-sector vaccine cost trends. Combination vaccines are not shown. All costs are in 2001 US dollars.

FIGURE 4—Comparison of cumulative vaccine purchase costs per child in 3 potential vaccine introduction scenarios, 2002–2020.

mended that the Section 317 program be modified so that it uses a formula grant mechanism that reflects states' needs.⁴ Our findings suggest that the Section 317 formula may also need to take into account the necessary balance of infrastructure and vaccine purchasing at the state level so that increasing vaccine purchase costs will not consume funds designated for the infrastructure necessary for delivery of vaccines to children.

Public Versus Private Burden of Vaccine Costs

Compared with public purchasers, private purchasers (e.g., physicians, third-party payers) face higher vaccine prices,¹⁹ and our estimates of future vaccine purchase costs raise concerns about the balance of costs borne by the public and private sectors. Rising vaccine costs may discourage physicians from purchasing adequate doses to meet the demand in their practices,²⁸ and may discourage third-party payers from including coverage for newly recommended vaccines in their poli-

cies. As part of the VFC program, families for whom recommended childhood vaccines are unavailable at their physicians' offices or whose insurance does not cover the vaccines can receive ACIP-recommended vaccines at no cost at federally qualified health centers or rural health centers. This shift of vaccine cost burden from the private to the public sector may worsen with rising vaccine prices, and may increase future public vaccine expenditures disproportionately to increases in vaccine prices alone.

More generally, mounting vaccine costs may lead to increasing scrutiny among public and private purchasers about the cost-effectiveness of vaccines, which to this point have remained some of the most cost-effective interventions available in health care and public health.^{2,3} Cost-effectiveness analyses of 2 recently recommended vaccines reveal societal savings for Var²⁹ and societal costs of \$80 000 per life-year gained for PCV³⁰ when both direct medical costs and indirect costs (e.g., parents' time lost from work as a result

of children's illness) are considered. Although cost-saving vaccines may generally engender support in state legislatures when vaccination program appropriations are considered, state funding for the purchase of vaccines with less favorable cost-effectiveness ratios may be less consistent.²⁷

Study Limitations

We wish to emphasize 2 important caveats in this work. First, although the period since 1975 represents a very active era in vaccine development and new recommendations, our estimates of future cumulative costs per child—particularly with the introduction of combination vaccines—are still based upon relatively few data points. Second, cumulative costs from our model fit observed costs very well, but 2001 cost data including PCV were outliers in the model. Whether the price of PCV is unusually high or our model is a relatively conservative predictor of future costs is not known. Future vaccine price data will permit recalculation of the effects of the variables in the model, as necessary, to determine whether PCV will remain an outlier or serve as a harbinger of future cost trends.

CONCLUSIONS

Costs of purchasing vaccines for children in the public sector will continue to increase over the next 2 decades. Our estimates of future costs, based upon historical data, suggest that federal and state programs may face 3 or more times the cost of vaccinating each child in 2020 than they do now, beyond the effects of inflation. This dramatic increase in costs has serious implications for the structure and function of state vaccination programs and the vaccination status of the children served by those programs. We hope that a better understanding of the future of vaccine purchasing will help today's scientists and policymakers plan for continued success in vaccinating children tomorrow. ■

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Contributors

M.M. Davis planned the study, collected and analyzed the data, and wrote the article. J.L. Zimmerman assisted with study planning, data analysis, and data presentation, and contributed to the writing of the article. J.R.C. Wheeler supervised data analysis and contributed to the writing of the article. G.L. Freed supervised study planning and contributed to the writing of the article.

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Human Participant Protection

No protocol approval was needed for this study.

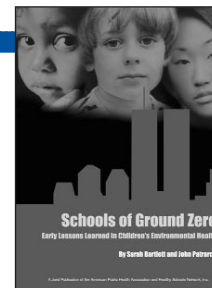
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The Schools of Ground Zero

Zero:

Early Lessons Learned in Children's Environmental Health

The Schools of Ground Zero is the story of how public school districts in Lower Manhattan dealt with the events of Sept. 11, 2001, and their aftermath. Written by the parents of two children who attend public school in lower Manhattan, this book focuses on the effect that the Sept. 11 attacks had on the physical and mental health of New York City schoolchildren and their parents.

The Schools of Ground Zero uses the example of the World Trade Center attacks to illustrate how school officials may be unprepared to cope with emergencies, and uncertain how to proceed after the event. Drawing on interviews with parents, teachers, New York Board of Education officials and environmental consultants, the authors make practical recommendations for safeguarding the health and safety of schoolchildren in times of crisis.

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