Progress in Timely Vaccination Coverage Among Children Living in Low-Income Households

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Objective: To evaluate progress in timely vaccination coverage associated with low-income households.


Participants: Children aged 19 to 35 months living in low-income households who were sampled between 1995 and 2007 (N=232,318). Low-income households had an annual income that was 133% or less of the federal poverty level, and high-income households had an annual income of 400% or more of the federal poverty level.

Main Outcome Measures: Administration of 4 or more doses of diphtheria, tetanus, pertussis (DTaP-DTP) vaccine; 3 or more doses of polio; 1 or more doses of measles, mumps, rubella (MMR); 3 or more doses of Haemophilus influenzae type b (Hib); 3 or more doses of hepatitis B; and 1 or more doses of varicella vaccines by age 19 months as reported by the children’s vaccination providers. Progress in timely coverage was evaluated by tracking changes between consecutive annual birth cohorts born between 1994 and 2004.

Results: Among low-income children, timely vaccination coverage increased significantly between consecutive birth cohorts by an estimated 0.5% for DTaP-DTP, 0.3% for polio, 0.6% for MMR, 1.2% for hepatitis B, and 5.3% for varicella vaccines but did not change significantly for the Hib vaccine. Disparities in timely coverage for low- vs high-income children declined significantly between consecutive birth cohorts by an estimated −0.3% for MMR, −0.3% for hepatitis B, and −0.5% for varicella vaccines, did not change significantly for the polio vaccine, and increased significantly by 0.4% for the DTaP-DTP vaccine.

Conclusions: Disparities in vaccination coverage associated with low household income persist. Further progress in timely vaccination may be achieved by improving health care providers’ reminder/recall systems, implementing educational interventions that address barriers to vaccination, and increasing parents’ awareness of the Vaccines for Children Program.


In the United States, there was a resurgence in the incidence of measles between 1989 and 1991.1 Research conducted by the Centers for Disease Control and Prevention (CDC) revealed that cases observed during the measles resurgence were disproportionately inner-city, preschool-aged, American Indian, Hispanic, or black children younger than 5 years who had not been vaccinated2,3 and who were living in low-income households.4 In response to the outbreaks, in 1993 the Childhood Immunization Initiative5 was proposed to addres significant disparities in vaccination coverage among young children in America. Among the strategies for achieving this goal was to increase access to vaccines by eliminating cost as a barrier. In October 1994, the Vaccines for Children (VFC) Program6,7 was established to achieve this goal by providing publicly purchased vaccines at no cost to VFC-enrolled vaccination providers to be administered to children who were eligible for the program.

An important conclusion of CDC research conducted during the US measles resurgence was that vaccines need to be administered on time because delays indicate inadequate protection against vaccine-preventable disease.

The purpose of this study is to describe progress in timely coverage for the diphtheria, tetanus, pertussis (DTaP-DTP); polio; measles, mumps, rubella (MMR); hepatitis B; Haemophilus influenzae type b (Hib); and varicella vaccines among 19- to 35-month-old children living in low-income households. Progress in timely pneumococcal conjugate vaccination coverage among low-income children has been described previously.11,12 Specifically, in this study, we describe the estimated percentage of children living in low-income households; evaluate progress in timely vaccination coverage for consecutive annual birth cohorts born between 1994 and 2004 among children living in low-income households; and evaluate whether disparities in timely vaccination coverage between children liv-

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ing in low- and high-income households have increased or decreased between these consecutive birth cohorts.

METHODS

NATIONAL IMMUNIZATION STUDY

We analyzed data from 232,318 children sampled by the 12 annual surveys of the National Immunization Study (NIS) conducted between 1995 and 2007 who had provider-reported vaccination histories. In the first phase of NIS data collection, a list-assisted random digit dialing survey is conducted to identify households that include a 19- to 35-month-old child. Among households with age-eligible children, sociodemographic information about the children, their mothers, and the household is collected. If consent is obtained from the NIS respondent, age-eligible children’s vaccination providers are mailed a questionnaire to obtain the vaccination history. Age-eligible children’s provider-reported vaccination histories were used to evaluate the vaccination status of children sampled in the NIS. Between 1995 and 2007, the NIS CASRO (Council of American Survey Research Organizations) response rates (response rate number 3; American Association for Public Opinion Research, Lenexa, Kansas) for the random digit dialing portion of the NIS ranged from 65% to 76%, and the percentages of sampled children that had a sufficiently detailed vaccination history returned from vaccination providers to accept as a complete report ranged from 62% to 70%. More detailed descriptions of the sampling design and methods used by the NIS are available.14-17 In all our analyses, we used the survey library18 in the R statistical software package,19 which took into account the NIS sampling weights and design, independence of sampling from year-to-year, and clustering of age-eligible children within households. The use of human subjects in the NIS was last approved by the National Center for Health Statistics on October 14, 2008.

Children belonging to an annual birth cohort are between 19 and 35 months of age in the 3 consecutive years that follow their birth year and were eligible to be sampled by the NIS in those consecutive years. We restricted our analyses to cohorts born between 1994 and 2004 because complete information was obtained from each of them from 3 consecutive annual survey years of the NIS. Because the varicella vaccine had wide geographic distribution after 1996, we tracked progress for that vaccine using cohorts born between 1996 and 2004. In our study, estimated percentages and differences of percentages are reported with their 95% confidence intervals (CIs).

TIMELY VACCINATION COVERAGE

The current vaccination schedule20 recommends the administration of 4 doses of DTap-DTP, 3 doses of polio, 1 dose of MMR, 3 doses of hepatitis B, 3 doses of Hib, and 1 dose of the varicella vaccine by age 19 months. Therefore, we defined timely vaccination coverage as receipt of at least the recommended number of doses of each vaccine by age 19 months.

INCOME DEFINITIONS

States receiving federal funds to support Medicaid programs are mandated to serve families that meet a variety of criteria, including annual income 133% or less of the federal poverty level (FPL).21 For this study, we defined a low-income household as one with an annual income of 133% or less of the FPL. Children living in a household with an annual income between 134% and 399% of the FPL and 400% or more of the FPL are referred to as middle-income and high-income, respectively. In our analyses, FPL was determined by comparing sampled households’ reported annual income to the current poverty thresholds published by the US Census Bureau.22

RESULTS

PERCENTAGE OF LOW-INCOME CHILDREN

Among the 6,025,000 children who were aged 19 to 35 months in 2007, 2,519,000 (41.8%; 95% CI, 40.3%-43.3%) lived in a low-income household. The estimated percentage of low-income children aged 19 to 35 months varied widely among states, from 16.3% (95% CI, 9.0%-23.6%) to 56.6% (95% CI, 48.7%-64.5%). Approximately
The disparity in timely vaccination coverage between consecutive birth cohorts was statistically significant at the \( P < .05 \) level. 1,075,000 children living in low-income households were Hispanic (42.7%), 826,000 (32.8%) were non-Hispanic white, 457,000 (18.1%) were non-Hispanic black, 66,000 (2.6%) were Asian, and 95,000 (3.8%) belonged to other racial/ethnic groups, including American Indian/Alaskan Native. Compared with non-Hispanic white children (mean, 25.0%; 95% CI, 23.5%-26.5%), the estimated percentage of low-income children was significantly higher among the Hispanic (68.1%; 95% CI, 65.1%-71.1%), non-Hispanic black (64.0%; 95% CI, 60.3%-67.7%), and other racial/ethnic groups (51.2%; 95% CI, 41.9%-61.5%) (\( P < .05 \)) but was not significantly different for Asian children (26.6%; 95% CI, 18.2%-35.0%; \( P = .71 \)).

**TIMELY VACCINATION COVERAGE**

Among low-income children, timely vaccination coverage increased significantly between consecutive birth cohorts from 1994 through 2004 for the DTaP-DTP, polio, MMR, hepatitis B, and varicella vaccines (Table and Figure 1 and Figure 2). However, the mean increase in timely vaccination coverage between consecutive birth cohorts was not statistically significant for the Hib vaccine.

### Low- vs High-Income Children

For every annual birth cohort born between 1994 and 2004, estimated timely vaccination rates for the DTaP-DTP, MMR, Hib, and varicella vaccines were significantly lower among low- vs high-income children (Figures 1 and 2). Also, estimated timely vaccination rates for the polio and hepatitis B vaccines were significantly lower among low- vs high-income children for every birth cohort born between 1994 and 2003. However, timely vaccination rates for high- vs low-income children were not significantly different for the 2004 birth cohort for the polio and hepatitis B vaccines.

### Consecutive Birth Cohorts

The disparity in timely vaccination coverage for low- vs high-income children increased significantly between consecutive birth cohorts by approximately 0.4% for the DTaP-DTP vaccine (Figure 3) and decreased significantly between consecutive birth cohorts by approxi-

### Table. Estimated Average Increase (in Percentage) in Timely Vaccination Coverage Between Consecutive Birth Cohorts Born Between 1994 and 2004 by Vaccine

<table>
<thead>
<tr>
<th>Vaccine</th>
<th>Estimated Increase (95% CI), %</th>
</tr>
</thead>
<tbody>
<tr>
<td>DTaP-DTP</td>
<td>0.5 (0.3 to 0.7) (^a)</td>
</tr>
<tr>
<td>Polio</td>
<td>0.3 (0.1 to 0.4) (^a)</td>
</tr>
<tr>
<td>MMR</td>
<td>0.6 (0.4 to 0.8) (^a)</td>
</tr>
<tr>
<td>Hib</td>
<td>0.1 (−0.1 to 0.3)</td>
</tr>
<tr>
<td>Hepatitis B</td>
<td>1.2 (1.0 to 1.4) (^a)</td>
</tr>
<tr>
<td>Varicella</td>
<td>5.3 (3.0 to 5.5) (^a)</td>
</tr>
</tbody>
</table>

Abbreviations: CI, confidence interval; DTaP-DTP, diphtheria, tetanus, pertussis; Hib, *Haemophilus influenzae* type b; MMR, measles, mumps, rubella.

\(^a\) The estimated mean change in timely vaccination coverage between consecutive birth cohorts was statistically significant at the \( P < .05 \) level.

Among the problems that contributed to the measles resurgence in the late 1980s and early 1990s was the low level of timely vaccination coverage throughout the population, particularly among low-income children. In our analyses, we found that among low-income children, timely vaccination coverage rates for all vaccines except Hib have increased significantly between consecutive cohorts born after the measles resurgence. However, estimates of timely vaccination coverage for Hib have also been high among low-income children and have exceeded 85% for every birth cohort born between 1994 and 2004.

Also, significant disparities in timely vaccination coverage were found between low- and high-income children for all childhood vaccines and nearly every birth cohort born between 1994 and 2004. However, those disparities have been declining significantly for the MMR, hepatitis B, and varicella vaccines. For the 2004 birth cohort, the disparity in estimated timely vaccination coverage for hepatitis B is not statistically significant, offering hope that progress in closing gaps in timely coverage between low- and high-income children can be achieved. Although the mean disparity in timely coverage did not change significantly for the polio vaccine from 1994 through 2004, the estimated timely coverage rate for low-income children is not significantly different from that of high-income children for the 2004 birth cohort, which provides hope that further progress in disparity reduction may be forthcoming.

Of potential concern is the widening disparity between low- vs high-income children in timely coverage for the DTaP-DTP vaccine. However, our results show that timely coverage for the DTaP-DTP vaccine has increased significantly across consecutive birth cohorts for low-income children. Therefore, the disparity between low- and high-income children for DTaP-DTP is attributable to a more rapid increase in timely coverage for DTaP-DTP among high-income children. Because the fourth dose of DTaP-DTP is recommended to be administered no sooner than age 6 months after the administration of the third dose, further progress in timely coverage of DTaP-DTP by age 19 months may be achieved by ensuring that the third dose is administered no later than age 12 months, and, preferably, soon after it is recommended at age 6 months. The recommended vaccination schedule permits the fourth dose of DTaP-DTP to be administered as early as age 12 months. Arranging...
the administration of vaccines so that completion of the entire childhood vaccination schedule can be completed by age 12 months may be more convenient and less costly for low-income families. These adjustments might lead to further progress in timely vaccination coverage for low-income children.

STRENGTHS AND WEAKNESSES

Our work has several strengths. First, data from our study were drawn from a large, nationally representative sample of 19- to 35-month-olds that has been conducted annually for the past 14 years using the same methods. Also,
estimates of vaccination coverage are based on health care provider–reported vaccination histories that are known to be more accurate than parental reports from memory. These features allow us to obtain reliable estimates of trends in vaccination coverage over time.

However, the findings in this report are subject to potential limitations. Because the NIS is a telephone survey, results are weighted to be representative of all children aged 19 to 35 months in the United States. Separate statistical adjustments have been made to the survey weights to account for noncoverage of households with no telephones, nonresponse to the NIS telephone interview, nonresponse to the NIS survey mailed to vaccination providers, underascertainment of vaccination histories among children with more than 1 vaccination provider, and other effects that could bias estimates from the NIS. When data used in this study were collected, the percentage of children who lived in

Figure 3. Trends in disparities in timely vaccination coverage for low- vs high-income children for diphtheria, tetanus, pertussis (DTap-DTP) (A), polio (B), and measles, mumps, rubella (MMR) (C) vaccines. Vertical blue lines are 95% confidence intervals (CIs).

Figure 4. Trends in disparities in timely vaccination coverage for low- and high-income children for Haemophilus influenzae type b (Hib) (A), hepatitis B (B), and varicella (C) vaccines. Vertical blue lines are 95% confidence intervals (CIs).
a household with no telephone service was approximately 1.5%. However, in recent years, the percentage of households with children that have cellular phone service only has grown from 2.3% in 2004 to 11.6% in 2007. Bias in complex sample surveys such as the NIS is equal to the product of the percentage of the target population not covered by the survey multiplied by the difference in vaccination coverage between the portion of the target population that is covered by the survey and the portion that is not covered by the survey. Because the percentage of children in nontelephone and cellular-only households is moderate (13.1%) and the difference in vaccination coverage between covered and noncovered portions of the target population is expected to be no more than moderate (<10%), the maximum bias in national estimates that can be attributable to noncoverage of nontelephone and cellular-only households is expected to be small (<2%). Recent work suggests that adjustments made to NIS survey weights to reduce bias are effective and that the bias in national-level estimates from the NIS that can be attributed to noncoverage of portions of the population and nonresponse to the survey mailed to health care providers is small.

CONCLUSIONS

An important conclusion reached from the CDC research conducted during the measles resurgence in the United States was that vaccines need to be administered on time because delay of timely vaccine administration represents inadequate protection against vaccine-preventable disease. Subsequent research found that many children in the United States experienced substantial delays in receiving recommended vaccinations and that these delays were especially prevalent among socioeconomically disadvantaged subpopulations. Other literature has evaluated the association between poverty and low vaccination coverage and found that poverty continues to be a persistent barrier to receiving the recommended number of vaccinations. The results of our study are concordant with those previous findings. However, our study shows that there has been progress in timely vaccination coverage among low-income children for selected vaccines and suggests that further progress is possible.

How could further progress be realized? First, higher levels of timely vaccination coverage and reduction of disparities may be achieved by increasing awareness of the VFC program. For eligible children, VFC eliminates cost as a barrier to being vaccinated. Next, educational interventions that address health concerns and barriers to vaccinations have been strongly associated with increased coverage and could be implemented to achieve higher timely coverage levels. Also, reminder/recall systems have been strongly associated with higher vaccination coverage. Therefore, higher levels of timely vaccination coverage and reduction of disparities attributable to family income may be achieved by ensuring the effective implementation of these strategies. Furthermore, clinic-based assessment of timely vaccination and other systems such as state registries may offer information needed by vaccination providers to administer vaccines in a timely manner. Finally, inadequate provider reimbursement has been identified as a potential barrier to being vaccinated for low-income children eligible for Medicaid and VFC. To overcome this barrier, the Vaccine Financing Working Group of the National Vaccine Program Office has recommended that VFC should be expanded to cover vaccine reimbursement for all VFC-entitled children and adolescents; that the maximum allowable Medicaid reimbursement amounts be updated for each state to include all appropriate non–vaccine-related costs; and that the federal match for vaccine administration reimbursement in Medicaid be increased to levels in line with other services of public health importance.

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Author Contributions: Dr Smith had full access to all the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Smith. Acquisition of data: Smith. Analysis and interpretation of data: Smith, Jain, Stevenson, Mannikko, and Molinaro. Drafting of the manuscript: Smith and Jain. Critical revision of the manuscript for important intellectual content: Smith, Stevenson, Mannikko, and Molinaro. Statistical analysis: Smith, Stevenson, and Molinaro. Obtained funding: Smith. Administrative, technical, and material support: Smith and Mannikko. Study supervision: Smith.

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