



❖ Summary

The *2014 Vaccine-Preventable Diseases in Colorado's Children Report* summarizes our annual analysis of rates of childhood vaccination and vaccine-preventable illnesses in 2013.

Colorado continues to rank below the majority of US states in multiple measures of childhood vaccination, with under-vaccination resulting in preventable childhood illness, hospitalization and death. Our data also highlight the safety of childhood vaccination in Colorado and put rates of very rare vaccine adverse reactions in stark contrast to the very real burden—both human suffering and massive health expenditures—of vaccine-preventable disease.

In this analysis, we explore in detail 2013 rates of whooping cough (pertussis) in school-age children in order to inform stakeholders responsible for implementation of the recently passed mandate for schools and day care to assess and publish vaccination rates. Our analysis confirm that low rates of pertussis vaccination in school-age children were associated with almost 900 cases of whooping cough in this population in 2013, with the highest number of cases in children aged 10-14. These data highlight the risk of a vaccine exemption policy that makes it easy for parents, often based on misleading information, to opt out of vaccines for their children.

Our results support the need for continued strengthening of vaccine delivery systems, improving access to primary pediatric care, and increasing efforts to provide accurate information regarding the safety and benefits of childhood vaccination to parents who wish to protect their children from vaccine-preventable diseases.

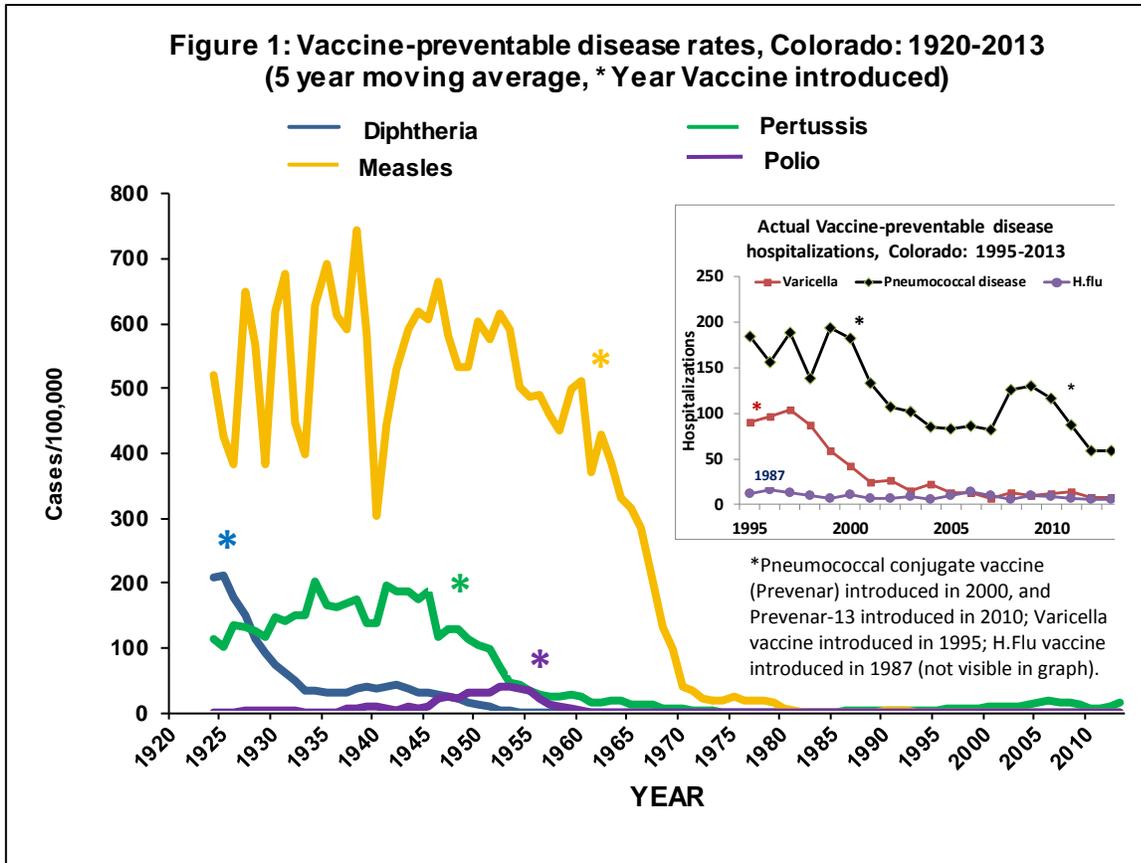
❖ Analysis

Data Sources (Epidemiological and statistical methods are described in Appendix A.)

1. National Immunization Survey (NIS), 2013.
2. Colorado Hospital Association Inpatient Database, 2013.
3. Colorado Department of Public Health and Environment, Reportable Disease Statistics 2013.

Vaccines are highly effective in Colorado

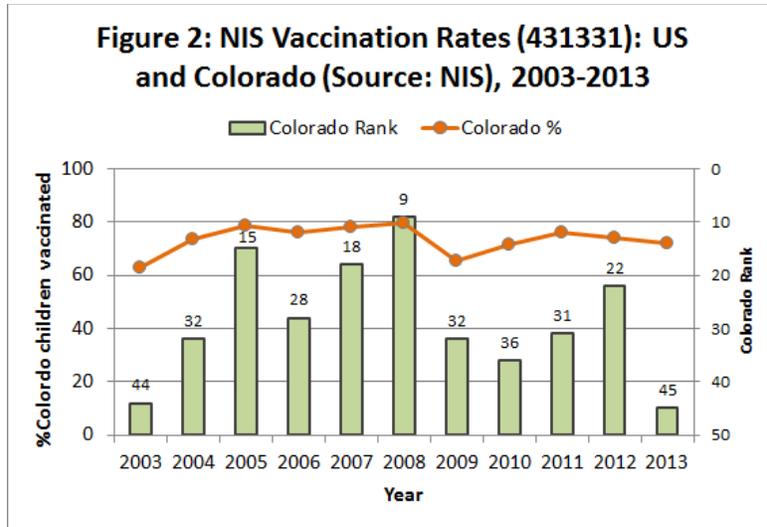
Vaccination of children represents perhaps the most effective public health intervention of the past century, and has protected countless children from serious illness around the world and in Colorado. Figure 1 shows the dramatic decrease in Colorado of reported cases and hospitalizations for four common vaccine-preventable diseases (diphtheria, measles, pertussis and polio) from 1920 to 2013. More recently (Figure 1, insert), newer vaccines for chickenpox, severe *Haemophilus influenzae* disease (meningitis) and pneumococcal disease have been introduced with a similar dramatic effect.



However, maintaining the gains that vaccination has achieved against these infectious diseases requires assuring that populations retain high levels of vaccine-induced immunity. Outbreaks of disease (including measles, mumps, polio, and pertussis (see below)) continue to occur when rates of vaccination are insufficient to prevent acquisition and transmission among vulnerable populations.

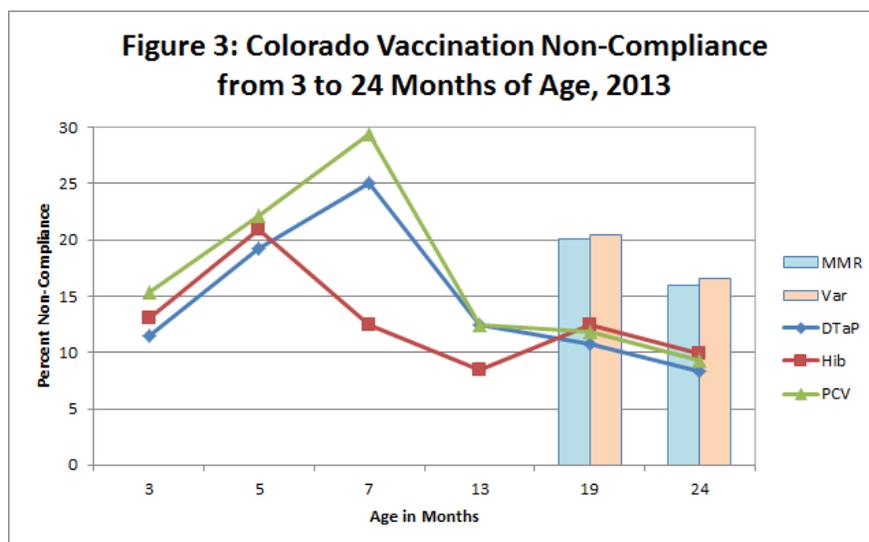
Colorado's Vaccination Gap and Its Impact on Our Youngest Children

In 2013, Colorado ranked 45th among US States in vaccination rates for children 19-35 months of age (Figure 2). More importantly, 27.9% of children surveyed in the NIS had received less than the recommended number of doses of Colorado Board of Health approved vaccines (431331: 4 doses of DTaP, 3 doses of polio (IPV), 1 dose of measles/mumps/rubella (MMR), 3 doses of hepatitis-B, 3 doses of *Haemophilus influenzae* type B (HiB) and 1 dose of varicella), leaving them vulnerable to these diseases.



Much of this gap stems from incomplete vaccination of young children (Figure 3). For instance, only 81.2% of Colorado's 19-36 month-old children had received the full DTaP series, and 82.8% had received the full HiB series. Coverage with any MMR vaccine was only 86%, well below the 92-95% levels, which are required to protect a population against outbreaks of measles¹. Furthermore, Colorado's overall vaccination rate according to this measure has not improved significantly in the last 10 years, and is, in fact lower in the last 5 years than in the 5 years prior.

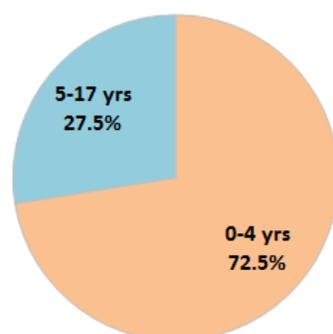
Our on-time vaccination completion rates are even lower in infants (Figure 3). This is especially concerning, since the highest burden of preventable illness overall occurs in this age group. For instance, more than a quarter of all 7 month infants in Colorado are behind in DTaP and PCV vaccinations, and pertussis and pneumococcal disease were the second and third most common reasons for hospitalization from vaccine-preventable diseases in young children in Colorado in 2013 (Table 1).



Age Differences in Impact of Vaccine-preventable Diseases

By far the greatest burden of disease requiring hospitalization falls on infants and young children (Figure 4), with younger children four times more likely than older children to be hospitalized with a serious vaccine-preventable disease. A more detailed breakdown of hospitalization from vaccine-preventable illnesses by age is presented in Table 1, using data from the Colorado Hospital Association. This data documents not only the numbers of cases of preventable disease, but also the hospital charges associated with these illnesses. The most common vaccine-preventable cause of hospitalization was influenza, which resulted in 297 cases in children under 5, and 127 cases in children age 5-19. Hospital charges for influenza cases alone exceeded \$20 million and total charges for childhood vaccine-preventable hospitalization were nearly \$30 million in 2013.

Figure 4: VPD Hospitalizations of Colorado Children in 2013, Including Influenza



| | 0 - 4 Years of Age | | | 5 - 19 Years of Age | | |
|-------------------------|----------------------|------------------|---------------------|----------------------|------------------|---------------------|
| | CHA Hospitalizations | | | CHA Hospitalizations | | |
| | Hospitalized Cases | Rate per 100,000 | Hospital Charges | Hospitalized Cases | Rate per 100,000 | Hospital Charges |
| Diphtheria | 0 | 0.0 | \$0 | 0 | 0.0 | \$0 |
| H. influenzae | 3 | 1.0 | \$354,488 | 3 | 0.3 | \$327,234 |
| Influenza, hospitalized | 297 | 94.9 | \$11,887,868 | 127 | 11.7 | \$8,788,456 |
| Measles | 1 | 0.3 | \$5,117 | 0 | 0.0 | \$0 |
| Mumps | 0 | 0.0 | \$0 | 0 | 0.0 | \$0 |
| Pertussis | 39 | 12.5 | \$1,285,359 | 1 | 0.1 | \$13,141 |
| Pneumococcal disease | 35 | 11.2 | \$3,156,573 | 24 | 2.2 | \$3,290,158 |
| Polio | 0 | 0.0 | \$0 | 0 | 0.0 | \$0 |
| Rubella | 0 | 0.0 | \$0 | 0 | 0.0 | \$0 |
| Tetanus | 0 | 0.0 | \$0 | 0 | 0.0 | \$0 |
| Varicella | 5 | 1.6 | \$46,375 | 3 | 0.3 | \$54,116 |
| Total | 380 | 121.4 | \$16,735,780 | 158 | 14.5 | \$12,473,105 |

Community Impact of Vaccine-preventable Disease: Pertussis Example

The non-hospital burden of pediatric vaccine-preventable disease is more difficult to quantify, since many cases of illness are not diagnosed or reported, but still have significant impact on:

- Productivity through lost time at work and school
- Expenditures for doctor visits and outpatient medications
- Patient morbidity

Analysis of whooping cough (pertussis) cases among Colorado's children in 2013 illustrates the significant impact of a vaccine-preventable illness on communities outside the hospital setting, and emphasizes the vulnerabilities of under-vaccinated school-age populations.

Whooping cough is a highly contagious bacterial infection that results in a severe and often prolonged coughing illness - for good reason it is called the "hundred day cough". Pertussis is often transmitted from older children or adults to infants who are at the greatest risk. In infants (who depend on older children and adults around them for protection from exposure to pertussis), it can cause apnea, difficulty feeding, hypoxia, brain injury and even death. Worldwide, pertussis is estimated to cause nearly 200,000 deaths in children every year.

In 2013 in Colorado, there were 1,432 cases of pertussis reported to the Colorado Department of Public Health and Environment, 81% of which were in children age 0-19. The highest number of cases (887 cases or 76%) occurred in children of school age. A map of the statewide distribution of pertussis cases in 2013 (Map) demonstrates that cases of pertussis were spread throughout the state, with more than half of all Colorado Counties reporting cases. Pertussis vaccination rates by county are not available from the NIS, so it is not possible to ascertain a direct relationship between vaccination rates of school-aged children and pertussis. However, Boulder County, which had by far the highest number of reported pertussis cases (170) in Colorado schoolchildren in 2013 (837 cases/100,000) has historically high rates of under-immunization and personal exemptions. For instance, in 2011 approximately 11% of Boulder Valley School District students had a signed vaccine exemption². Another study conducted by the Boulder County Public Health Department in 2012 noted that only 75% of entering kindergarten students were up to date on DTaP³.

| Disease | Index years ^a | Statewide pre-vaccination rate per 100,000 ^b | Statewide rate per 100,000 2013 ^b | Statewide reportable cases prevented: 2013 ^c | Actual hospitalized cases: 2013 ^d | Estimated hospitalized cases prevented: 2013 ^e | Estimated hospital charges prevented: 2013 ^f |
|----------------------|--------------------------|---|--|---|--|---|---|
| Diphtheria | 1920-1922 | 461 | 0.0 | 6,456 | 0 | 1,756 | \$95,343,111 |
| H. influenzae | 1984-1986 | 12.4 | 0.9 | 173 | 6 | 46 | \$5,173,260 |
| Measles | 1960-1962 | 784 | 0.0 | 10,981 | 1 | 2,987 | \$162,151,231 |
| Mumps | 1964-1966 | 408 | 0.0 | 5,723 | 0 | 1,557 | \$84,513,899 |
| Pertussis | 1945-1947 | 328 | 85.8 | 4,601 | 40 | 1,241 | \$40,277,626 |
| Pneumococcal disease | 1997-1999 | 14.8 | 4.2 | 207 | 59 | 148 | \$16,171,516 |
| Polio | 1952-1954 | 68 | 0.0 | 946 | 0 | 257 | \$13,969,882 |
| Rubella | 1966-1968 | 124 | 0.0 | 1,739 | 0 | 473 | \$25,680,365 |
| Tetanus | 1927-1929 | 1.1 | 0.0 | 15 | 0 | 4 | \$221,510 |
| Varicella | 1995-1997 | 8.7 | 0.6 | 122 | 8 | 114 | \$1,431,954 |
| Total | | 2,210 | 91.5 | 30,963 | 114 | 8,583 | \$443,502,400 |

^a Index years are the three years preceding first availability of vaccine.

^b Case counts from CDPHE, population estimates from US Census.

^c Calculated as the difference between pre-vaccination rate times 2013 population minus 2013 reported cases.

^d From CHA inpatient database.

^e Based on 27.2% of reported cases hospitalized among Colorado children ages 0-19 years: 2013, except for pneumococcal disease and varicella.

^f Calculated using average total hospitalization charges for VPD-related admissions of Colorado children ages 0-19 years from CHA inpatient database: 2013 where no hospitalized cases occurred; or average charges during 2013 for each VPD.

Vaccine Safety in Colorado in 2013

Vaccines in the United States undergo very rigorous safety testing and surveillance for unanticipated events. A recent systematic review article in the *Journal Pediatrics* evaluated the safety of current recommended childhood vaccines in the US and concluded that: "...[serious adverse] events are extremely rare and must be weighed against the protective benefits that vaccines provide"⁸. Data from Colorado in 2013 are consistent with this conclusion, as shown in Table 3. There were only 3 hospitalized cases associated with a vaccine adverse event, while there were 538 hospitalizations for potentially vaccine-preventable diseases, with a hospital charge difference of 1:1000. If all Colorado children were vaccinated on time (not including influenza), this analysis (tables 2 and 3) estimates that annually there would be four hospitalized vaccine adverse events compared to an estimated 9,000 prevented hospitalizations in Colorado children with an annual hospital charge savings of close to half a billion dollars.

Table 3: Annual case and charge estimates for vaccine preventable disease and vaccine-related adverse event hospitalizations among Colorado children 0-19 years of age in 2013

| | Number of Cases | Hospital Charge Estimate |
|--|-----------------|--------------------------|
| Colorado Hospitalized Vaccine Adverse Event (any diagnosis code) | 3* | \$29,938 |
| Colorado Hospitalized Vaccine Preventable Diseases (Table 1) | 538 | \$29,208,885 |

*Primary or secondary diagnosis codes: 978x, 979x, E948x, E949x (see Methods), actual hospital charges reported.

❖ Appendices:

Methods

Data Sources:

1. National Immunization Survey (NIS): The NIS is a list-assisted random-digit-dialing telephone survey conducted by the Centers for Disease Control and Prevention (CDC) followed by a mailed survey to children's immunization providers that began data collection in April 1994. (www.cdc.gov/nchs/nis.htm)
2. Colorado Hospital Association: The CHA is a consortium representing 100 hospitals and health systems throughout the state, and provides hospital utilization data from its online database program that collects monthly self-reported hospital utilization and financial data from health care facilities. (www.cha.com/Resources/Colorado-Hospital-Utilization-Data.aspx)
3. Colorado Department of Public Health and Environment: CDPHE collects data on statewide reportable infectious diseases, which include all infections preventable by routine Colorado childhood vaccinations. (https://www.colorado.gov/pacific/sites/default/files/ComDis_CD_Diagnosis-by-age-2013.pdf)

Case counts of hospitalization and corresponding hospital charges due to vaccine-preventable disease (VPD) and vaccine-related adverse events among Colorado children 0-19 years of age were calculated from the Colorado Hospital Association (CHA) Inpatient Database for 2013.

Additionally, the 2013 CDPHE reportable disease statistics were used to obtain VPD case counts for children 0-19 years of age and to calculate the case rate per 100,000. The 2013 CDPHE reportable disease statistics were used to obtain data on VPD cases that were not hospitalized, including pertussis and varicella. Population estimates to calculate incidence rates were obtained from the Current Population Survey, March Supplement from 2014 using DataFerrett⁹.

Archived infectious disease reports from the Colorado Department of Public Health and the Environment (CDPHE) provided reported infectious disease cases among the entire Colorado population from 1920 through 2013. Using population estimates from the US census¹⁰ for these children, pre-vaccination rates were calculated for selected VPDs in the three years before their

respective vaccines were approved for use in children. Additional morbidity reports for years 1955-1957 and 1984-1986 were used to determine the average percentage of polio and *H.influenzae* cases that were among children 0-19 years of age. This percentage was applied to estimate the number of hospitalizations in 2013 for selected VPDs that could have been prevented by vaccination among these children, similar to the methodology of van Panhuis, et al¹¹. The five-year moving average rates per 100,000 Colorado children were plotted for pertussis, polio, diphtheria, and measles from 1920-2013. Actual hospitalizations for pneumococcal disease, varicella, and *H.influenzae* were plotted from 1995-2013.

Hospitalized vaccine adverse events among Colorado children ages 0-19 years were determined by the presence of any of the following primary or secondary diagnosis codes: 978x (poisoning by bacterial vaccines), 979x (poisoning by other vaccines), E948x (bacterial vaccines causing adverse effects), or E949x (other vaccines causing adverse effects).

Limitations

There are several limitations to this report. Archived data were not available for reported cases of pneumococcal disease or varicella so their prevented hospitalizations and respective total charges could not be calculated. VPD case and pediatric population data were unlinked: they came from separate sources.

It was assumed that 85% of archived VPD case counts were in children 0-19 years of age, using only archived polio and *H. influenzae* case counts by age, as other archived VPD case counts were not broken down by age group. The actual percentage of each disease in children may vary. For example, an average of 97% of *H. influenzae* cases in 1984-1986 were among children 0-19 years of age, while an average of 71.4% of polio cases in 1955-1957 were in the same population. The proportion of hospitalized VPD cases to reported CDPHE cases for 2013, 27.2%, was applied to our calculation of prevented hospitalizations for all of the VPDs in this report, except pneumococcal disease and varicella. The actual value could vary for each VPD.

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