

# Impact of Varicella Vaccination on Health Care Utilization

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**V**ARICELLA VACCINE IS RECOMMENDED for routine immunization of children aged 12 to 18 months and for older susceptible children and adults in the United States.<sup>1-4</sup> Before its licensure in 1995, almost everyone developed chickenpox; thus, incidence approximated the birth cohort, with about 13 000 hospitalizations and 100 to 150 deaths annually.<sup>5-9</sup>

Varicella vaccine coverage has increased steadily, reaching 81% in 2002 among children aged 19 to 35 months nationally, while varicella disease incidence has declined in all age groups.<sup>10-12</sup> However, the impact of vaccination on varicella-related health care utilization has been documented in only 1 study. Davis et al,<sup>13</sup> using data from the Nationwide Inpatient Sample, reported significant declines in varicella hospitalization rates and associated charges. For the current study, we used MarketScan databases to describe not only patterns of varicella hospitalization but also patterns of ambulatory visits and their associated medical expenditures in the United States. In addition, we stratified the analyses by state-level varicella vaccination coverage and by type of health insurance plan. We evaluated these factors beginning in 1994 (before availability of varicella vac-

**Context** Since varicella vaccine was first recommended for routine immunization in the United States in 1995, the incidence of disease has dropped substantially. However, national surveillance data are incomplete, and comprehensive data regarding outpatient as well as hospital utilization have not been reported.

**Objective** To examine the impact of the varicella vaccination program on medical visits and associated expenditures.

**Design, Setting, and Patients** Retrospective population-based study examining the trends in varicella health care utilization, based on data from the MarketScan databases, which include enrollees (children and adults) of more than 100 health insurance plans of approximately 40 large US employers, from 1994 to 2002.

**Main Outcome Measures** Trends in rates of varicella-related hospitalizations and ambulatory visits and direct medical expenditures for hospitalizations and ambulatory visits, analyzed using 1994 and 1995 as the prevaccination baseline.

**Results** From the prevaccination period to 2002, hospitalizations due to varicella declined by 88% (from 2.3 to 0.3 per 100 000 population) and ambulatory visits declined by 59% (from 215 to 89 per 100 000 population). Hospitalizations and ambulatory visits declined in all age groups, with the greatest declines among infants younger than 1 year. Total estimated direct medical expenditures for varicella hospitalizations and ambulatory visits declined by 74%, from an average of \$84.9 million in 1994 and 1995 to \$22.1 million in 2002.

**Conclusion** Since the introduction of the varicella vaccination program, varicella hospitalizations, ambulatory visits, and their associated expenditures have declined dramatically among all age groups in the United States.

JAMA. 2005;294:797-802

www.jama.com

cine) through 2002 (7 years after vaccine licensure).

## METHODS

### Data Source

Data were obtained from the MarketScan databases,<sup>14</sup> which include information from approximately 40 self-insured employers, including state governments, with about 4 million covered lives per year, from 1994 to 2002. The databases include more than 500 million claim records representing employees, retirees, and dependents from more than 100 health insurance plans in all continental states and the District of Columbia. The databases contain patient demographics, physician characteristics, dates of services, length

of stay (LOS) in hospital, payments, *International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM)* diagnostic codes, *Current Procedural Terminology* 1998 codes, and other variables. Total payments reported in MarketScan databases represent actual amounts paid to providers (eg, physicians and hospitals).

The study sample consisted of all inpatient admissions and ambulatory visits between January 1994 and Decem-

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See also p 845 and Patient Page.

ber 2002 with varicella diagnoses (ICD-9-CM codes 052.xx). We examined outcomes using only the primary diagnosis code and using all diagnoses to provide conservative and liberal estimates, respectively. We excluded events with coexistent herpes zoster diagnoses (ICD-9-CM codes 53.xx) as well as varicella in persons aged 50 years or older because these also are likely to represent herpes zoster.<sup>7</sup>

### Study Population

The MarketScan enrollment databases contain complete individual-level enrollment records on enrollees. However, not all enrollees are included in the enrollment databases. We included all enrollees aged 0 to 49 years from the MarketScan enrollment databases in our analysis of hospitalizations and ambulatory visit rates per 100 000 person-years. In a secondary analysis, we analyzed varicella hospitalizations among all enrollees (regardless of whether they were in the enrollment databases) as a proportion of total hospitalizations from all enrollees. Otherwise, enrollees who were not in the enrollment databases were excluded from analysis.

Because this study constituted analysis of secondary data without identifiers, it did not require institutional review board approval or informed consent.

### Data Analysis

Analyses were performed with SAS, version 8.0, statistical software (SAS Institute Inc, Cary, NC). We used 1994 and 1995 combined data as the prevaccination baseline. We conducted Poisson regression analysis to assess changes in varicella rates over time.  $P \leq .05$  was considered statistically significant.

We created 3 age categories corresponding to the prevaccination incidence and severity of varicella and to expected vaccination uptake: children younger than 10 years (high incidence and low severity in prevaccination period; high coverage after vaccination); children and adolescents aged 10 to 19 years (intermediate incidence and se-

verity; some coverage); and adults aged 20 to 49 years (low incidence and high severity; low coverage). We also evaluated infants (younger than 1 year), who are not eligible for vaccination.

We conducted stratified analyses of ambulatory visits for children younger than 10 years by state-level vaccination coverage and by type of health insurance plan. There were too few hospitalizations and too few ambulatory visits in older age groups for such analyses.

We stratified varicella vaccination coverage by categorizing children as belonging to high- or low-coverage groups based on state of residence, as reported by the National Immunization Survey.<sup>15</sup> We defined high-coverage states as those that consistently had higher annual coverage than the national average and low-coverage states as those that consistently had lower annual coverage than the national average during 1997-2003.<sup>10,15-20</sup> Enrollees from states whose coverage status changed during 1997-2003 were excluded from this analysis.

We compared varicella rates between capitated and noncapitated (ie, fee-for-service) insurance plans. Seven types of insurance plans were categorized as capitated (health maintenance organization, capitated or partially capitated point of service) or noncapitated (basic/major medical, comprehensive, exclusive provider organization, noncapitated point of service, and preferred provider organization).

We examined rates of ambulatory visits by residence in metropolitan statistical areas (MSAs) vs non-metropolitan statistical areas (non-MSAs),<sup>21</sup> and also by season.

We used total payments to providers to estimate expenditures for hospitalizations and ambulatory visits. Expenditures were standardized to 2002 US dollars using the medical Consumer Price Index.<sup>22</sup> We calculated mean LOS and total payments per hospitalization and mean total payments and out-of-pocket payments (co-payments plus deductible) for ambulatory visits, comparing prevaccination (1994 and 1995) and

postvaccination (2001 and 2002) periods. We used 1994, 1995, and 2002 US Census data<sup>23,24</sup> and values from the MarketScan databases to estimate national medical expenditures (for hospitalizations and ambulatory visits only) for varicella in the prevaccination and postvaccination periods.

## RESULTS

Eligible enrollees in the MarketScan databases increased from about 1.2 million in 1994 to 3.5 million in 2002 (representing 0.6% and 1.8% of the US population aged 0-49 years, respectively) (TABLE 1). About 26% of enrollees met the inclusion criteria in 1994 compared with 70% in 2002. This change was due to increasing completeness of the enrollment databases over time. Throughout the study period, there were slightly more female than male enrollees, there were more enrollees in MSAs, and age distributions varied slightly. The proportion of enrollees covered by managed care plans increased gradually over time.

### Rates of Varicella-Related Hospitalizations

Hospitalization rates with varicella as the primary diagnostic code declined from 2.3 per 100 000 population in the prevaccination period to 0.3 in 2002 (88% decrease;  $P < .001$ ). Declines in hospitalizations with varicella as any diagnosis were similar, from 4.8 to 0.6 per 100 000 population (85% decrease). For our main analyses, we therefore present only data on events with primary varicella diagnostic codes because they are more specific. FIGURE 1 shows the significant decline per 100 000 population in varicella hospitalizations in all age groups between 1994 and 2002, from an average of 9.9 in the prevaccination period to 0.9 in 2002 (91%) for children younger than 10 years; from 1.5 to 0.1 (92%) for children and adolescents aged 10 to 19 years; and from 0.8 to 0.2 (78%) for adults aged 20 to 49 years. The greatest decrease per 100 000 population, from an average of 45.1 in the prevaccination period to 0 in 2002 (100%), occurred among in-

**Table 1.** Demographic Characteristics of Eligible Enrollees Aged 0-49 Years, 1994-2002\*

Characteristics	1994 (n = 1 199 772)	1995 (n = 1 407 339)	1996 (n = 1 555 278)	1997 (n = 2 124 353)	1998 (n = 2 220 498)	1999 (n = 2 233 532)	2000 (n = 2 377 048)	2001 (n = 2 752 104)	2002 (n = 3 532 381)
Sex									
Male	49.2	49.3	48.3	48.2	47.9	48.0	48.4	48.3	47.9
Female	50.8	50.7	51.7	51.8	52.1	52.0	51.6	51.7	52.1
Age group, y									
<10	15.2	14.7	14.3	15.4	15.5	15.7	15.9	15.9	15.6
10-19	22.8	23.3	23.6	21.8	21.5	22.0	21.9	21.6	22.3
20-49	62.0	62.0	62.1	62.8	63.0	62.3	62.2	62.5	62.1
Resident of metropolitan statistical area									
Yes	81.9	75.8	70.7	73.2	74.9	74.7	74.0	77.4	81.4
No	18.1	24.2	29.3	26.8	25.1	25.3	26.0	22.6	18.6
Insurance plan type									
Basic/major medical	4.8	1.7	1.9	0.6	0.5	0.5	0	0	0
Comprehensive	56.1	60.3	64.5	31.5	32.8	32.9	18.4	14.1	13.6
Exclusive provider organization	0.5	0.4	1.1	0.3	0	0.9	0	2.5	4.4
Health maintenance organization	0	0	0	8.0	8.1	8.1	7.7	7.9	18.3
Noncapitated point-of-service	8.1	11.2	9.1	4.0	6.1	9.6	20.2	19.5	13.9
Preferred provider organization	35.3	28.1	25.3	36.0	31.7	22.9	30.3	32.4	35.3
Capitated or partially capitated point-of-service	0	0	0	20.3	21.2	25.5	23.5	23.7	14.5

\*All data are expressed as percentage.

fants. There was no significant difference between rates of hospitalizations among enrollees insured by noncapitated plans and those insured by capitated plans.

While hospitalization rates declined among both adults and children, the proportion of hospitalizations among adults increased relative to that of children. In the prevaccination period, 11.7% of varicella-related hospitalizations occurred among infants while 21.4% occurred among adults; in 2002, no hospitalizations occurred among infants and adults accounted for 40% of hospitalizations.

To verify that reductions in varicella hospitalizations were not an artifact of changes in the enrollment database population or otherwise affected by changes in health care utilization during the study interval, we analyzed varicella hospitalization rates from all enrollees (regardless of study database inclusion) as a proportion of total hospitalizations from all enrollees. Varicella hospitalizations constituted an average of 0.025% of all annual hospitalizations from all enrollees in the

**Figure 1.** Varicella-Related Hospitalization Rates, 1994-2002



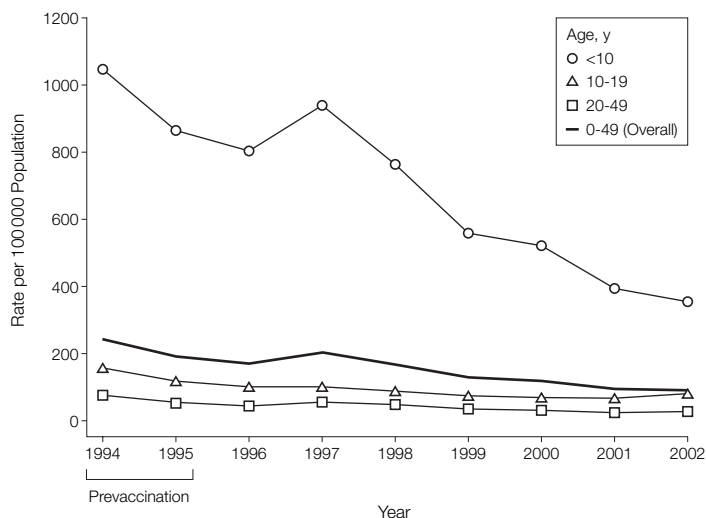
Varicella was the primary diagnosis code for data shown.

database in 1994 and 1995 compared with 0.003% in 2002, a decline of 87%.

**Rates of Varicella-Related Ambulatory Visits**

The rate of ambulatory visits with varicella as the primary diagnosis code de-

clined from an average of 215 per 100 000 population in the prevaccination period to 89 in 2002 (59% decrease;  $P < .001$ ). The decline was significant for all age groups (FIGURE 2). Similar declines were noted for ambulatory visits with any varicella code,

**Figure 2.** Varicella-Related Ambulatory Visit Rates, 1994-2002

Varicella was the primary diagnosis code for data shown.

from 238 to 89 per 100 000 population (62% decrease). Between 1994 and 2002, rates per 100 000 population for varicella as the primary diagnosis code declined from an average of 956 in the prevaccination period to 353 in 2002 (63%) for children younger than 10 years; from 136 to 78 (42%) for children aged 10 to 19 years; and from 65 to 26 (60%) for adults aged 20 to 49 years (Figure 2). The greatest decrease per 100 000 population, from an average of 1681 in the prevaccination period to 167 in 2002 (90% decline), occurred among infants.

We identified 11 states with consistently high varicella vaccination coverage and 19 states with consistently low coverage. Enrollees in both groups experienced significant declines in the rate of varicella ambulatory visits for children younger than 10 years. However, the decline in the high-coverage group was faster, indicated by significant interaction for coverage by year in the Poisson model ( $P=.006$ ). In 2002, the rate of varicella ambulatory visits for children younger than 10 years was 289 per 100 000 population for high-coverage states and 483 per 100 000 population for low-coverage states. The corresponding rates for the same groups of states in the prevaccination period

were 808 and 1035 per 100 000 population, representing reductions of 64% and 53%, respectively.

The rate of varicella ambulatory visits for children younger than 10 years was significantly higher among enrollees insured by noncapitated plans than those in capitated plans between 1997 and 2002. Decreases in both groups were significant but were more rapid in the noncapitated group ( $P=.009$ ).

In the prevaccination period, the ratio of hospitalizations to ambulatory visits was 0.010 among children younger than 10 years, 0.011 for children and adolescents aged 10 to 19 years, and 0.012 for adults aged 20 to 49 years. However, by 2001-2002, these ratios decreased, especially among persons younger than 20 years, with corresponding ratios of 0.002, 0.003, and 0.008 for persons younger than 10 years, 10 to 19 years, and 20 to 49 years, respectively.

As previously reported,<sup>5,11,25-28</sup> most varicella-related ambulatory visits occurred during winter and spring. In 1994, 65% of visits occurred in December through May. This seasonality declined somewhat by 2002, when 58% of visits occurred during those months. In the prevaccine period, ambulatory visits were more common among those residing in MSAs than in non-MSAs (206

vs 170 per 100 000 population, respectively;  $P<.001$ ); this difference was significant for all age groups. The MSA difference was no longer significant in 2002.

## Medical Expenditures

### Corresponding to Varicella Disease

For hospitalizations with varicella as the primary diagnosis, mean LOS and total hospitalization payments during the prevaccination period were 3.83 days (95% confidence interval [CI], 3.33-4.32 days) and \$7626 (95% CI, \$5586-\$9667), respectively. The corresponding values for the postvaccination period were 4.63 days (95% CI, 3.34-5.92 days) and \$7993 (95% CI, \$5055-\$10 930), respectively. Length of stay and payments did not change significantly between the 2 periods. Mean total payments and out-of-pocket payments for ambulatory visits during the prevaccination period were \$89.51 (95% CI, \$86.10-\$92.92) and \$28.50 (95% CI, \$27.39-\$29.61), respectively. The corresponding values for the postvaccination period were \$86.11 (95% CI, \$82.59-\$89.64) and \$23.73 (95% CI, \$22.74-\$24.72), respectively. The decline in out-of-pocket payments was significant ( $P<.001$ ). Mean LOS and total hospitalization payments were significantly higher among those in noncapitated vs capitated plans ( $P<.001$ ).

Based on our data with varicella as the primary diagnosis code, estimated annual national medical expenditures for hospitalizations and ambulatory visits declined in the United States from an average of \$84.9 million in 1994 and 1995 to \$22.1 million in 2002 (74%) (TABLE 2). For ambulatory visits and hospitalizations with any varicella diagnosis code, annual medical expenditures for varicella in the United States declined from an average of \$116.9 million in 1994 and 1995 to \$27.0 million in 2002 (77%).

## COMMENT

This is the first study, to our knowledge, to include both hospitalizations and ambulatory visits in the analysis of varicella health care utilization over a pe-

riod that spanned introduction and maturation of the varicella vaccination program in the United States. We found that rates of hospitalization and ambulatory visits for varicella decreased markedly over the study interval and that disease severity (as indicated by the changing ratio of hospitalization to ambulatory visits over time) declined as well. While it was beyond the scope of the study to conduct longitudinal analysis of individuals following vaccination to directly compare varicella outcomes by vaccination status, a causal role of the vaccination program in this decline is further supported by the inverse relationship between pediatric vaccine coverage in individual states and the rate of varicella. State-level coverage is associated with day care and school entry requirements,<sup>29</sup> suggesting that such laws have had the intended effect of reducing the burden of disease.

Health care utilization for varicella decreased across all age groups. Hospitalization rates declined by 88% between the prevaccination period and postvaccine year 2002, and rates for outpatient visits declined by 59%. These data are consistent with other observations.<sup>13,30</sup> The results are particularly notable for infants; since varicella vaccine is not indicated for infants, the declines reflect reduced force of varicella infection in the population (ie, herd immunity), as do declining rates among adults.<sup>2,9</sup> The declining rates of varicella hospitalization among adolescents and adults provide reassurance that to date, there is no evidence that the pediatric vaccination program is increasing disease rates in older children and adults, who are at greater risk of severe disease.<sup>31</sup>

The estimated national medical expenditures for varicella hospitalizations and ambulatory visits together declined by about \$63 million (74%) between prevaccination and postvaccination years. In the prevaccination period, about half of direct varicella health care expenditures were for outpatient visits. Since licensure, however, expenditures have shifted to the outpatient setting, with the proportion of varicella events that occur as hospitalization de-

**Table 2.** Estimated US National Expenditures for Prevaccination and Postvaccination Varicella Hospitalization and Ambulatory Visits

Expenditures	Prevaccination (1994/1995), Million \$ (% of Total)	Postvaccination (2002), Million \$ (% of Total)
Hospitalization	40.6 (47.9)	5.0 (22.0)
Ambulatory visits	44.2 (52.1)	17.1 (78.0)
<b>Total</b>	<b>84.9 (100)</b>	<b>22.1 (100)</b>

clining by more than 55%. This trend may be partially due to an increasing portion of varicella among vaccinated persons, who typically experience mild disease and who may be at lesser risk of complications such as invasive group A streptococcal infections.<sup>32-34</sup> As expected, mean LOS and unit hospitalization payments were higher for noncapitated plans than for capitated plans. Changes in patterns of insurance coverage may have contributed somewhat to reductions in varicella hospitalization expenditures over the study interval as well. However, changes in the mean unit cost between the prevaccination and postvaccination periods were not significant for either varicella hospitalization or varicella ambulatory visits.

This study was not designed to be a formal economic analysis or to evaluate other potential outcomes of the varicella vaccination program, such as adverse reactions to vaccination or changes in the incidence of herpes zoster. However, our data could be used as input for evaluating the cost-effectiveness of the varicella vaccination program. Based on 2002 Biological Surveillance (unpublished data, Centers for Disease Control and Prevention) and National Immunization Survey data,<sup>10-12</sup> the total costs of varicella vaccines for 4 million children, which approximates the annual birth cohort in the United States, were estimated to be about \$144 million.

The changes we found in hospitalization rates following vaccine licensure were qualitatively similar to those reported by Davis et al,<sup>13</sup> although our study methods were different. Davis et al used a sample of all US hospitalizations, whereas we ascertained rates and expenditures from the MarketScan population (ie, only private payment). Furthermore, to minimize mis-

classification, we excluded hospitalizations with secondary codes for varicella from our analysis. We also excluded persons aged 50 years or older, who are at very low risk of varicella, from analysis since varicella codes in this population often represent misclassification of herpes zoster.<sup>7,8</sup>

There are limitations to our analysis. MarketScan data are obtained from employer-based insurance, particularly from larger employers. The study population is therefore somewhat homogeneous and not fully representative. Nonetheless, with an average of 2.2 million enrollees who met the inclusion criteria during the 1994-2002 study interval, the population is large, draws from numerous medical settings, and represents a wide variety of geographic, social, and economic strata. Nationally, while most children and younger persons at risk of varicella are privately insured, utilization and medical expenditures per case for varicella may be greater for persons with Medicaid or without insurance,<sup>13</sup> making these estimates conservative. However, the proportion of the US population with private insurance has not changed during the study interval<sup>35</sup>; any bias in our analysis has been consistent over time and our estimates should provide a fairly accurate reflection of the degree of reduction in varicella utilization and expenditures.

One should be cautious in conducting surveillance using data that are collected for different (ie, administrative) purposes. There is no mechanism to validate MarketScan diagnostic codes through direct medical chart reviews. We did, however, review line listings for several hundred hospitalization and ambulatory records in the MarketScan databases with primary or secondary varicella diagnostic codes. We found no reason to question the validity of these

codes, with the exception of codes listing secondary varicella diagnoses for hospitalization events, which we excluded from analysis. The diagnostic codes that populate the MarketScan databases derive from abstraction of discharge diagnoses, similar to diagnostic information collected for any other administrative purposes; thus, data should be no less accurate than other ICD-9-CM-based data. The validity of these data is supported by comparable rates and age distributions for varicella hospitalizations published elsewhere.<sup>7,8</sup>

Our study may have missed some varicella events because of incomplete coding or multiple insurance plans for the same enrollee. In general, these instances are rare. Another limitation is that trends for varicella events could be affected by secular changes in the MarketScan source population, its enrollment databases, or in insurance or associated utilization patterns. We showed that varicella hospitalizations among all enrollees (whether in the study database or not) declined by 88% as a proportion of total hospitalizations. This analysis controls for both changes in the study databases and changes in criteria for hospitalization that might have occurred over time. Finally, declines in hospitalization occurred among both capitated and noncapitated insurance plans, also suggesting that the declines were not a simple artifact of secular changes in insurance coverage.

The data in our study demonstrate the substantial success that the varicella vaccine program has shown since it was implemented 10 years ago. However, nationally representative data are needed to more accurately monitor the impact of the varicella vaccination program. The Council of State and Territorial Epidemiologists has recommended that states now begin to conduct case-based surveillance.<sup>36</sup>

**Author Contributions:** Dr Zhou had full access to all of 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:** Zhou, Harpaz, Jumaan, Shefer.

**Acquisition of data:** Zhou.

**Analysis and interpretation of data:** Zhou, Harpaz, Jumaan, Winston.

**Drafting of the manuscript:** Zhou, Harpaz, Jumaan. **Critical revision of the manuscript for important intellectual content:** Zhou, Harpaz, Jumaan, Winston, Shefer.

**Statistical analysis:** Zhou, Winston.

**Administrative, technical, or material support:** Harpaz, Jumaan, Shefer.

**Study supervision:** Jumaan.

**Financial Disclosures:** None reported.

**Disclaimer:** The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention, US Department of Health and Human Services.

**Acknowledgment:** We thank the following individuals from the Centers for Disease Control and Prevention: Jane Seward, MBBS, MPH, and Darya Guris, MD, MPH, for their thoughtful reviews of an early version of the manuscript; and Mary McCauley, MTSC, for her editorial assistance.

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