The Burden of Rotavirus Hospitalizations Among Medicaid and Non-Medicaid Children Younger Than 5 Years Old

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Objectives. We sought to compare the burden of hospitalizations associated with rotavirus gastroenteritis (RGE) in children younger than 5 years in US Medicaid and non-Medicaid populations in 2000 and 2003.

Methods. We used the Kids' Inpatient Database (KID) to examine the burden of RGE-associated hospitalizations in terms of numbers and rates of hospitalizations, lengths of stay, and hospital charges. Two indirect methods were also used to estimate RGE-associated hospitalizations, because rotavirus testing is not routinely performed.

Results. Approximately 40% of children younger than 5 years were enrolled in Medicaid in 2003, but this population accounted for nearly 50% of all RGE-associated hospitalizations and 60% of total charges. Children enrolled in Medicaid had significantly greater hospitalization rates, average lengths of stay, and average charges per stay than did those not enrolled.

Conclusions. Although RGE affects all socioeconomic groups, the Medicaid population accounted for a disproportionate number of the hospitalizations. With the inclusion of rotavirus vaccines in the pediatric immunization schedule, it is important that US children, especially those enrolled in Medicaid programs, are vaccinated to reduce the burden of RGE. (*Am J Public Health.* 2009;99: S398–S404. doi:10.2105/AJPH.2008.148494)

Rotavirus is the leading cause of severe acute gastroenteritis among children. By the age of 5 years, nearly every child is infected with rotavirus at least once.[1–3] Although many cases of rotavirus gastroenteritis (RGE) are mild, some can be severe. Recent studies have estimated that in the United States, RGE causes 55 000 to 70 000 hospitalizations, 205 000 to 272 000 emergency department visits, and 410 000 physician visits each year,[3,4] with total RGE-related direct and indirect costs estimated at approximately $1 billion annually.[5,6] Rotavirus accounts for 4% to 5% of all hospitalizations and 30% of hospitalizations for watery diarrhea among children younger than 5 years,[7–9] and the annual direct costs of RGE-associated hospitalizations are estimated at $175 to $198 million.[5,6]

In the United States, yearly epidemics of rotavirus disease occur from late fall to early spring, with the peak of disease varying by region.[7,8,10,11] In the Southwest, the peak epidemic rotavirus season is from November to December; it then travels sequentially across the United States from west to east, concluding in April to May in the northeast.[10] Because naturally acquired rotavirus infections provide protection against future severe RGE, hospitalizations because of RGE are more likely to occur in children younger than 5 years.[10]

Because many physicians do not test for rotavirus routinely, the rotavirus-specific *International Classification of Diseases, 9th Revision, Clinical Modification* (*ICD-9-CM*),[12] code 008.61 is underused and the incidence of this disease is generally underreported.[8,13–15] Therefore, indirect methods, such as the winter residual or the proportional methods, are commonly used to estimate the burden of hospitalizations associated with RGE based on hospitalizations for acute gastroenteritis.[4,7,8]

Limited data suggest that children from disadvantaged socioeconomic backgrounds are at greater risk of hospitalization from gastroenteritis, including viral gastroenteritis, compared with the general population.[16–18] Medicaid, a health program jointly funded by the states and federal government and administered by each state, is designed to support individuals and families with low incomes and limited resources. One recent study found that children younger than 24 months who were enrolled in Medicaid or without insurance were at increased risk of hospitalization caused by rotavirus.[17] Although children enrolled in Medicaid account for a substantial proportion of the US population of children, the burden of RGE-associated hospitalization in this population is not known.

For our study, we consolidated data from various sources to estimate and compare the burden of RGE-associated hospitalizations among children younger than 5 years in the Medicaid and non-Medicaid populations in 2000 and 2003. Because of the recent availability of rotavirus vaccines to prevent RGE,[19,20] we also provide a baseline assessment of the potential impact of the rotavirus immunization program being implemented in the United States.[21,22]

METHODS

We used data from the Kids' Inpatient Database (KID) of the Healthcare Cost and Utilization Project (HCUP), the Medicaid Statistical Information System (MSIS), and the US Census Bureau.

The KID includes discharge information and hospital charges for patients 20 years or younger from 2500 to 3500 community nonrehabilitation hospitals nationwide. It is the only all-payer–based inpatient care database for children in the United States. Each discharge record includes codes for primary and secondary payers, including Medicaid. The KID provides a nationally representative sample of 10% of uncomplicated in-hospital births and 80% of other pediatric cases from each participating hospital, which is extrapolated to reflect the universe of US community, nonrehabilitation hospitals.

To obtain national estimates, discharge weights were developed for hospitals from participating states using the American Hospital Association universe as the standard.[23] The

weights were based on stratifying hospitals by 6 characteristics contained in the American Hospital Association hospital files: geographic region, hospital ownership or control, location (urban versus rural), teaching status, bed size (classified as small, medium, or large), and hospital type (children's or other hospital).

The KID has been produced only triennially since 1997, and the latest data are from 2000 and 2003.[23] The 2003 file contains data from 36 states, whereas the 2000 file contains data from 27 states.[23] States in the 2003 KID represent an estimated 86.5% of the entire US population of children, a significant increase from 76.2% in the 2000 database. Both years were used in this analysis because RGE-associated hospitalizations fluctuate from year to year.[8,24]

The overall US population of children younger than 5 years of age was obtained from the dataset State Single Year of Age and Sex Population Estimates from the US Census Bureau.[25]

The Medicaid population estimate was obtained from the MSIS, which contains enrollment data from all states since 1999.[26] Because the eligibility for Medicaid depends on many factors, such as age and income, members may not maintain eligibility throughout the whole year. MSIS provides unique enrollment data by both fiscal year and individual month within the fiscal year. Unique enrollment data per year is likely to overestimate the Medicaid population. We converted the monthly enrollment data into person-year enrollment to more accurately characterize the Medicaid population. Because each state sets its own guidelines regarding eligibility and services for Medicaid, we estimated person-year enrollment by state and then obtained the national estimate of the Medicaid person-year enrollment. The MSIS only provides enrollment data for specific age groups, including children from birth to younger than 1 year and children aged 1 to 5 years. The Medicaid population for children younger than 5 years was derived by combining the age group of children younger than 1 year and 80% (four fifths) of the age group of children aged 1 to 5 years.

Study End Points

The burden of RGE-associated hospitalizations was evaluated in terms of numbers and rates of hospitalizations, lengths of hospital stay, and hospital charges and costs. Hospitalizations associated with RGE were first identified by the direct method using the rotavirus-specific *ICD-9-CM* code, 008.61.[7,8,27] The 2 indirect methods included the winter residual method and the proportional method. The winter residual method estimates the burden of rotavirus by comparing the number of hospitalizations for acute gastroenteritis that occur throughout the year with the excess that occur during the seasons when RGE is most common.[27]

The proportional method applies the monthly proportions of rotavirus-positive stool samples from a large surveillance study to the number of hospitalizations for acute gastroenteritis.[28] The way in which the 2 indirect methods were applied to this analysis of the KID was consistent with the approach used by Malek et al.,[8] who provided a more detailed description on how these methods were applied. The total charges were based on 2000 and 2003 dollars and were not adjusted for any price index. Because cost-to-charge ratios were provided by the HCUP for 75% of hospitals in the 2003 KID, the financial burden was presented in terms of costs as well.

Statistical Analysis

SAS version 9.13 survey procedures (SAS Institute, Cary, NC), which accounted for the sampling design of the KID, were used to estimate the burden of RGE-associated hospitalizations across the United States. The rates of hospitalizations were presented as the number of hospitalizations per 10 000 children. Population estimates obtained from the MSIS and the US Census Bureau were used as denominators for the hospitalization rate calculations and were assumed to be free of sampling error. The difference in rates, average lengths of stay, and average hospital charges between children in the Medicaid and non-Medicaid populations were calculated using the %SMSUB macro from SAS, which provides *P* values and 95% confidence intervals (CIs) for the estimates of the difference while adjusting for the 2-stage sampling design of the KID.[29] The cumulative incidence rate by age 5 years was calculated by inverting the rate per 10 000 and then dividing by 5.

RESULTS

Based on the US Census Bureau,[25] the 2003 US population of children younger than 5 years was 19 782 609, of whom 7 998 799 (40%) were enrolled in Medicaid and 11 783 810 (60%) were not enrolled in Medicaid. The estimated 8 million person-years for the Medicaid population was roughly 86% of the Medicaid unique enrollment of 9.3 million, indicating that the average number of months that children in this age group were enrolled in Medicaid was 10.3 months.

In 2000, the Medicaid population was 6 320 375, which represented 33% of the US population, compared with 12 868 042 (67%) for the non-Medicaid population. The estimated 6.3 million person-years for the Medicaid population represented 82% of the Medicaid unique enrollment of 8.0 million and an average of 9.9 months of enrollment.

The eligibility criteria for Medicaid among children who are enrolled when they are younger than 1 year differs from the eligibility criteria for older children. For example, children born to Medicaid-enrolled mothers are automatically covered for their first year of life. For the year 2003, children younger than 1 year accounted for 20% of US children aged 0 to 4 years. However, children younger than 1 year accounted for 25% of the Medicaid children aged 0 to 4 years compared with only 18% of the non-Medicaid children aged 0 to 4 years.

Number and Rate of Rotavirus Gastroenteritis Hospitalizations

In 2003, using the direct method with *ICD-9-CM* code 008.61, there were 31189 hospitalizations for RGE identified in children younger than 5 years. Of these, 14 804 (47.5%) were among children enrolled in Medicaid compared with 16 385 (52.5%) for those who were not enrolled (Table 1). Hospitalizations for RGE estimated by the direct method represented 20% of all hospitalizations for acute gastroenteritis.

The rate of RGE-associated hospitalizations per 10 000 children was 18.5 among children enrolled in Medicaid compared with 13.9 for those not enrolled (rate difference between groups=4.6; 95% CI=3.3, 5.9; $P<.01$; Table 1). The estimated cumulative incidence rates by age 5 years were 1 rotavirus hospitalization per 108 children in the Medicaid population and 1 per 144 children in the non-Medicaid population.

TABLE 1—Number and Rate of Hospitalizations for Gastroenteritis of Various Causes Among Children Younger Than 5 Years: United States, 2000 and 2003

	Medicaid		Non-Medicaid		
	No. of Hospitalizations	Rate per 10 000 Children	No. of Hospitalizations	Rate per 10 000 Children	Difference in Rates[a] (95% CI)
2000					
Gastroenteritis of any cause	70 635	111.8	79 935	62.1	49.6 (43.2, 56.1)
Viral gastroenteritis	22 367	35.4	30 136	23.4	12.0 (9.8, 14.2)
RGE by the direct method	12 286	19.4	16 250	12.6	6.8 (5.1, 8.5)
RGE by the winter residual method	24 060	38.1	31 982	24.9	13.2 (10.1, 16.3)
RGE by the proportional method	21 631	34.2	25 220	19.6	14.6 (12.3, 16.9)
2003					
Gastroenteritis of any cause	80 930	101.2	75 774	64.3	36.9 (31.1, 42.6)
Viral gastroenteritis	26 445	33.1	28 966	24.6	8.5 (6.6, 10.4)
RGE by the direct method	14 804	18.5	16 385	13.9	4.6 (3.3, 5.9)
RGE by the winter residual method	30 271	37.8	35 524	30.1	7.7 (5.0, 10.4)
RGE by the proportional method	25 072	31.3	25 753	21.9	9.5 (7.5, 11.5)

Note. CI = confidence interval; RGE = rotavirus gastroenteritis.
[a]*P* was less than .01 for all.

Based on the winter residual method, there were 65 795 hospitalizations for RGE, of which 30 271 (46%) were among children enrolled in Medicaid compared with 35 524 (54%) for those not enrolled (Table 1). Hospitalizations for RGE represented 42% of all hospitalizations for acute gastroenteritis. The rate of RGE-associated hospitalizations per 10 000 children was 37.8 among children enrolled in Medicaid compared with 30.1 for those not enrolled (rate difference between groups=7.7; 95% CI=5.0, 10.4; $P<.01$). The estimated cumulative incidence rates by age 5 years were 1 rotavirus hospitalization per 53 children and 1 per 66 children for Medicaid and non-Medicaid populations, respectively.

Based on the proportional method, there were 50 825 hospitalizations for RGE, of which 25 072 (49.3%) were among children enrolled in Medicaid compared with 25 753 (50.7%) for those not enrolled (Table 1). Hospitalizations for RGE represented 32% of all hospitalizations for acute gastroenteritis. The rates of RGE-associated hospitalizations per 10 000 children were 31.3 among children enrolled in Medicaid compared with 21.9 for those not enrolled (rate difference between groups=9.5; 95% CI=7.5, 11.5; $P<.01$). The estimated cumulative incidence rates by age 5 years were 1 rotavirus hospitalization per 64 children and 1 per 92 children for Medicaid and non-Medicaid populations, respectively.

Results based on the 2000 data were similar to the 2003 results and are presented in Table 1. The rate of RGE-associated hospitalizations was greater among children enrolled in Medicaid compared with children who were not enrolled. The number of hospitalizations for RGE among children enrolled in Medicaid represented 43.1% of all acute gastroenteritis hospitalizations based on the direct method, 42.9% based on the winter residual method, and 46.2% based on the proportional method. Hospitalizations for RGE represented 19% of all hospitalizations for acute gastroenteritis based on the direct method, 37% based on the winter residual method, and 31% based on the proportional method.

Characteristics of children hospitalized for RGE or gastroenteritis of any cause are presented in Table 2. For 2003, using the direct method, 7101 (48%) RGE-associated hospitalizations occurred in Medicaid children younger than 1 year and 7703 (52%) occurred in children aged 1 through 4 years. In the non-Medicaid population, 4953 (30%) cases occurred in children younger than 1 year and 11 432 (70%) occurred in children aged 1 through 4 years (Table 2).

Average Length of Stay for Rotavirus Gastroenteritis Hospitalizations

In 2003, based on the hospitalization records identified using *ICD-9-CM* code 008.61, the average length of stay for children younger than 5 years enrolled in Medicaid was significantly longer compared with those not enrolled. The average length of stay was 3.28 days (95% CI=3.1, 3.5) among Medicaid enrollees compared with 2.56 days (95% CI=2.4, 2.7) for children not enrolled (difference between groups=0.72 days; 95% CI=0.5, 0.9; $P<.01$; Table 3). For children younger than 1 year, the average length of stay was 3.88 days (95% CI=3.6, 4.2) among Medicaid enrollees compared with 2.97 days (95% CI=2.7, 3.1) among children not enrolled in Medicaid (difference between groups=0.91 days; 95% CI=0.5, 1.3; $P<.01$). Results for 2000 were similar and are presented in Table 3.

Charges and Costs of Rotavirus Gastroenteritis Hospitalizations

In 2003, based on the hospitalization records identified using *ICD-9-CM* code 008.61, the average RGE-associated hospital charge per stay for children younger than 5 years enrolled in Medicaid was significantly greater than that for children not enrolled. The average charge

TABLE 2—Characteristics of Children Younger Than 5 Years of Age, by RGE-Associated Hospitalizations and Hospitalizations for Gastroenteritis of Any Cause: United States, 2000 and 2003

	Medicaid Population		Non-Medicaid Population	
	2000, No. (%)	2003, No. (%)	2000, No. (%)	2003, No. (%)
Hospitalizations for RGE				
Total	12 286 (100)	14 804 (100)	16 250 (100)	16 385 (100)
Age, y				
<1 y	7 098 (57.8)	7 101 (48.0)	5 837 (35.9)	4 953 (30.2)
1–4 y	5 188 (42.2)	7 703 (52.0)	10 413 (64.1)	11 431 (69.8)
Gender[a]				
Boys	6 878 (56.0)	8 224 (55.5)	9 330 (57.4)	9 089 (55.5)
Girls	5 393 (43.9)	6 554 (44.3)	6 920 (42.6)	7 242 (44.2)
Race/ethnicity[b]				
White	4 081 (33.2)	4 024 (27.2)	9 146 (56.3)	8 028 (49.0)
Black	1 669 (13.6)	1 749 (11.8)	1 142 (7.0)	919 (5.6)
Hispanic	4 137 (33.7)	4 380 (29.6)	2 386 (14.7)	1 819 (11.1)
Asian or Pacific Islander	253 (2.1)	304 (2.1)	330 (2.0)	325 (2.0)
American Indian	54 (0.4)	63 (0.4)	51 (0.3)	32 (0.2)
Other	460 (3.7)	802 (5.4)	709 (4.4)	761 (4.6)
Hospitalizations for gastroenteritis of any cause				
Total	70 635 (100)	80 929 (100)	79 934 (100)	75 774 (100)
Age, y				
<1 y	38 422 (54.4)	37 976 (46.9)	28 122 (35.2)	23 952 (31.6)
1–4 y	32 213 (45.6)	42 953 (53.1)	51 812 (64.8)	51 822 (68.4)
Gender[a]				
Boys	39 191 (55.5)	44 291 (54.7)	43 918 (54.9)	40 702 (53.7)
Girls	31 402 (44.5)	36 462 (45.1)	35 999 (45.0)	34 794 (45.9)
Race/ethnicity[b]				
White	21 551 (30.5)	21 142 (26.1)	42 831 (53.6)	35 553 (46.9)
Black	11 633 (16.5)	11 161 (13.8)	6 768 (8.5)	5 196 (6.9)
Hispanic	21 948 (31.1)	22 996 (28.4)	12 380 (15.5)	9 943 (13.1)
Asian or Pacific Islander	1 061 (1.5)	1 308 (1.6)	1 936 (2.4)	1 558 (2.1)
American Indian	351 (0.5)	405 (0.5)	295 (0.4)	241 (0.3)
Other	3 238 (4.6)	4 211 (5.2)	3 417 (4.3)	3 391 (4.5)

Note. RGE = rotavirus gastroenteritis. RGE was defined using the *International Classification of Diseases, 9th Revision, Clinical Modification*[12] code 008.61.

[a]Data on gender were missing in 0.05% and 0.2% of all Medicaid discharges in 2000 and 2003, respectively, and 0.1% and 0.4% of all non-Medicaid discharges in 2000 and 2003, respectively.

[b]Data on race were missing in 15.3% and 24.4% of all Medicaid discharges in 2000 and 2003, respectively, and 15.3% and 26.2% of all non-Medicaid discharges in 2000 and 2003, respectively.

per stay was $8480 (95% CI=$7577, $9383) among Medicaid enrollees compared with $5624 (95% CI=$5189, $6059) for those not enrolled (difference between groups=$2856; 95% CI=$1968, $3745; $P<.01$; Table 4).

Cost-to-charge ratios were available for 80% of hospitalization records with the *ICD-9-CM* code 008.61. The average cost per hospital stay was estimated to be $3644 among Medicaid children compared with $2288 for those not enrolled in Medicaid. The average cost per hospital stay was approximately 43% and 41% of the average charge for Medicaid and non-Medicaid children, respectively. Results based on hospital charges for 2000 were similar and are presented in Table 4. We also compared the average hospital charges on a daily basis for children enrolled in Medicaid versus those not enrolled. In 2003, the average hospital charge per day was $2585 for Medicaid children compared with $2243 for children not enrolled in Medicaid (difference between groups=$342; 95% CI=$173, $510; $P<.01$).

In 2003, using the number of RGE-associated hospitalizations based on the direct method, the total charges for children enrolled in Medicaid were $126 million (57.8%) compared with $92 million (42.2%) for children not enrolled in Medicaid. Using the winter residual method, the total charges among children enrolled in Medicaid were $257 million (56.2%) compared with $200 million (43.8%) for those not enrolled; by the proportional method, total charges were $213 million (59.5%) for children in Medicaid compared with $145 million (40.5%) for those not enrolled. The total medical costs for RGE-associated hospitalizations in all children younger than 5 years were $91 million based on the direct method, $192 million based on the winter residual method, and $150 million based on the proportional method. For 2000, estimated total charges for RGE-associated hospitalizations for all children were $174 million using the direct method and ranged from $289 to $342 million using the 2 indirect methods.

DISCUSSION

Although there are fluctuations in the annual incidences of RGE, the numbers of hospitalizations and average lengths of stay were similar for 2000 and 2003. The rates of hospitalizations for RGE or acute gastroenteritis of any cause were significantly greater for children younger than 5 years enrolled in Medicaid compared with those not enrolled in Medicaid. RGE-associated hospitalizations in the Medicaid population represented 43% to 50% of all RGE-associated hospitalizations for this age group, depending on the year and method of estimation applied, despite only 33% and 40% of the population being enrolled in Medicaid in 2000 and 2003, respectively. The Medicaid population accounted for nearly 60% of the total RGE-associated hospitalization charges in 2003.

TABLE 3—Average Hospital Length of Stay for Gastroenteritis of Various Causes Among Children Younger Than 5 Years: United States, 2000 and 2003

	Medicaid, Days (SE)	Non-Medicaid, Days (SE)	Difference,[a] Days (95% CI)
	2000		
Gastroenteritis of any cause	3.29 (0.08)	2.69 (0.05)	0.60 (0.46, 0.74)
Viral gastroenteritis	3.01 (0.08)	2.42 (0.04)	0.59 (0.44, 0.73)
RGE by the direct method	3.38 (0.12)	2.70 (0.06)	0.68 (0.46, 0.90)
	2003		
Gastroenteritis of any cause	3.28 (0.08)	2.65 (0.05)	0.63 (0.48, 0.78)
Viral gastroenteritis	2.95 (0.07)	2.38 (0.04)	0.57 (0.44, 0.71)
RGE by the direct method	3.28 (0.10)	2.56 (0.06)	0.72 (0.52, 0.92)

Note. CI = confidence interval; RGE = rotavirus gastroenteritis.
[a]For all, $P < .01$.

The disproportionate share of the hospital charges in the Medicaid population may be attributed to the higher proportion of children younger than 1 year, the longer average lengths of stay, and the greater average daily charges among Medicaid children. It is not clear why the rates of hospitalization, the average lengths of stay, and the daily charges were greater among children enrolled in Medicaid. A number of factors may have contributed to these differences.

We illustrated that the Medicaid population's age distribution is skewed toward children younger than 1 year, because of differences in eligibility requirements for children younger than 1 year compared with older children. In addition, earlier studies have indicated that Medicaid enrollees have higher rates of hospitalization and emergency department visits for many conditions, because of differences in their health status and their access to primary care compared with the general population. Ray et al[18] recently theorized that the Medicaid population could be at greater risk of malnutrition, which affects the development of antibodies and immunity.

Access to primary care is affected by the education of the parents, the family support system, access to transportation, reimbursement for primary care, and the availability of primary care providers in the local area.[30–32] For acute gastroenteritis, a physician's decision to admit or discharge a child is, in part, subjective, and physicians need to assess how well parents will be able to keep the child hydrated at home.

TABLE 4—Average Hospital Charges per Stay for Gastroenteritis of Various Causes Among Children Younger Than 5 Years: United States, 2000 and 2003

	Medicaid, $ (SE)	Non-Medicaid, $ (SE)	Difference,[a] $ (95% CI)
	2000		
Gastroenteritis of any cause	7394 (398)	6193 (332)	1201 (477, 1925)
Viral gastroenteritis	6173 (385)	4653 (253)	1520 (829, 2211)
RGE by the direct method	7283 (634)	5217 (349)	2066 (986, 3146)
	2003		
Gastroenteritis of any cause	9272 (376)	7598 (298)	1674 (993, 2355)
Viral gastroenteritis	7578 (335)	5561 (207)	2018 (1439, 2597)
RGE by the direct method	8480 (460)	5624 (222)	2856 (1968, 3745)

Note. CI = confidence interval; RGE = rotavirus gastroenteritis.
[a]For all, $P < .01$.

Overall, RGE-associated hospitalizations identified using the direct method represented 19% and 21% of all hospitalizations for acute gastroenteritis in 2000 and 2003, respectively. As demonstrated by an earlier study, the *ICD-9-CM* code for RGE is underused, particularly because many physicians do not routinely test for rotavirus.[13] When the indirect methods were applied, the estimated number of all RGE-associated hospitalizations increased substantially, ranging from 31% to 44%, depending on the year and indirect method applied. Results from recent studies suggest that indirect methods may also underestimate the burden of RGE. For example, in a multicenter, hospital-based, active surveillance study in 862 children, 56% of hospitalized children with symptoms of diarrhea, vomiting, and unexplained fever had rotavirus-positive stool specimens.[14] In another prospective, hospital-based surveillance study of rotavirus disease in 7391 children younger than 5 years in Hong Kong, the estimated rate of hospitalization for diarrhea was 4 times greater based on collection of rotavirus-positive stool samples compared with the rate previously determined by indirect methods using routine discharge information alone.[33] The results of 2 large-scale phase 3 clinical trials also reported that vaccines for RGE reduced the rate of hospitalizations for all gastroenteritis by nearly 60%.[34,35]

Both indirect methods used in our study assumed that all children with diarrhea, vomiting, or fever were given one of the discharge codes, which has not yet been validated. The winter residual method did not account for episodes of RGE requiring care that occurred outside the winter season, and it assumed that other causes of gastroenteritis remained constant throughout the year. Furthermore, there was some subjectivity in the way in which the winter season was defined and how the baseline against which the excess number of health care encounters during the winter season was measured. The proportional method also had limitations because the peak rotavirus season may have occurred at different times of the year in different geographic areas. Additionally, the proportional method was based on data published more than 2 decades ago, and the seasonal and monthly patterns of RGE applied may vary today.[28] There were also certain limitations associated with the KID,

because the data were based on *ICD-9-CM* codes rather than on active surveillance. Not all children with vomiting, diarrhea, or fever may have been given a code for acute gastroenteritis. In addition, because there were no patient-level identifiers in the database, we could not determine whether specific children had more than 1 RGE-associated hospitalization. Interestingly, the previous rotavirus vaccine, Rotashield (Wyeth Laboratories, Inc, Marietta, PA), which was introduced to the market briefly in 1998 and then withdrawn for safety reasons in 1999,[36,37] did not appear to have affected the number of RGE hospitalizations reported in 2000.

Despite its limitations, the KID is the only all-payer–based inpatient care database for children in the United States and provided a robust nationally representative sample. Further, the KID includes payer information, allowing the evaluation of differences in payer types. Approximately 3% of the records in our analysis were uninsured (i.e., no charge or self-pay). Thus, it is likely that the gap between Medicaid and non-Medicaid populations identified in our study would be further widened if the uninsured children were removed from the non-Medicaid populations. However, given that the percentage of uninsured patients in our analysis was small, the impact on our main results would be minimal.

Our estimates of the total charges for RGE-associated hospitalizations in 2003 ranged from $357 million based on the proportional method to $456 million based on the winter residual method, which were substantially greater than the 2000 estimates of $140 to $180 million based on the median charge by Malek et al.[8] Based on the cost-to-charge ratios, the direct medical cost for RGE-associated hospitalizations was estimated at $150 to $192 million in 2003 dollars, which was consistent with the Widdowson et al.[6] estimate of $198 million (2004 dollars) and the Tucker et al.[5] estimate of $175 million (1996 dollars).

Although RGE affects all socioeconomic groups, the Medicaid population accounted for a disproportionate burden of the hospitalizations among children younger than 5 years based on greater rates of hospitalization, longer average lengths of stay, and greater daily and total charges compared with children not enrolled in Medicaid. Overall, the RGE-associated hospitalization burden for the United States is substantial in terms of both the number and the cost.

Currently, there are 2 vaccines, RotaTeq (Merck & Co, Inc, Whitehouse Station, NJ) and Rotarix (GlaxoSmithKline, Research Triangle Park, NC), approved for the prevention of RGE in the United States.[19,20] Data from clinical trials have shown that both vaccines significantly reduced the risk of severe RGE, especially RGE hospitalizations.[34,35] The most recent surveillance data from the Centers for Disease Control and Prevention have shown a significant reduction of disease burden in the 2007–2008 rotavirus season following the introduction of RotaTeq, the first of these 2 vaccines implemented in the United States.[38] With the inclusion of rotavirus vaccines in the pediatric immunization schedule,[21,22] it is important that children in the United States, especially those enrolled in Medicaid programs, are vaccinated to reduce the burden of rotavirus disease. ■

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Contributors

All authors participated in the conceptual development of this research, interpretation of the results, and writing of the article. Larry Ma conducted the data analysis and led the writing of the article.

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Human Participant Protection

This was a database study, in which data were obtained from various agencies of the US government and therefore approval was not needed.

References

1. Bresee JS, Parashar UD, Widdowson MA, et al. Update on rotavirus vaccines. *Pediatr Infect Dis J.* 2005;24:947–952.

2. O'Ryan M, Matson DO. New rotavirus vaccines: renewed optimism. *J Pediatr.* 2006;149:448–451.

3. Parashar UD, Glass RI. Public health. Progress toward rotavirus vaccines. *Science.* 2006;312(5775):851–852.

4. Charles MD, Holman RC, Curns AT, et al. Hospitalizations associated with rotavirus gastroenteritis in the United States, 1993–2002. *Pediatr Infect Dis J.* 2006;25:489–493.

5. Tucker AW, Haddix AC, Bresee JS, et al. Cost-effectiveness analysis of a rotavirus immunization program in the United States. *JAMA.* 1998;279:1371–1376.

6. Widdowson MA, Meltzer MI, Zhang X, et al. Cost-effectiveness and potential impact of rotavirus vaccination in the United States. *Pediatrics.* 2007;119:684–697.

7. Fischer TK, Viboud C, Parashar U, et al. Hospitalizations and deaths from diarrhea and rotavirus among children <5 years of age in the United States, 1993–2003. *J Infect Dis.* 2007;195:1117–1125.

8. Malek MA, Curns AT, Holman RC, et al. Diarrhea- and rotavirus-associated hospitalizations among children less than 5 years of age: United States, 1997 and 2000. *Pediatrics.* 2006;117:1887–1892.

9. Lee BP, Azimi PH, Staat MA, et al. Nonmedical costs associated with rotavirus disease requiring hospitalization. *Pediatr Infect Dis J.* 2005;24:984–988.

10. Dennehy P. Rotavirus vaccines: an overview. *Clin Microbiol Rev.* 2008;21:198–208.

11. Centers for Disease Control and Prevention. NREVSS: rotavirus surveillance: trends in the US. Available at: http://www.cdc.gov/surveillance/nrevss/rotadata.htm. Accessed June 30, 2008.

12. *International Classification of Diseases, Ninth Revision, Clinical Modification.* Hyattsville, MD: National Center for Health Statistics; 1980.

13. Hsu VP, Staat MA, Roberts N, et al. Use of active surveillance to validate international classification of diseases code estimates of rotavirus hospitalizations in children. *Pediatrics.* 2005;115:78–82.

14. Staat MA, Azimi PH, Berke T, et al. Clinical presentations of rotavirus infection among hospitalized children. *Pediatr Infect Dis J.* 2002;21:221–227.

15. Matson DO, Azimi P, Staat M, et al. Burden of rotavirus hospitalizations in children as assessed by active case finding [abstract]. *J Investig Med.* 2006;54:S292.

16. Newman RD, Grupp-Phelan J, Shay DK, et al. Perinatal risk factors for infant hospitalization with viral gastroenteritis. *Pediatrics.* 1999;103:E3. doi: 10.1542/peds.103.1.e3.

17. Dennehy P, Margaret M. Cortese, et al. A case-control study to determine risk factors for hospitalization for rotavirus gastroenteritis in US children. *Pediatr Infect Dis J.* 2006;25:1123–1131.

18. Ray PG, Kelkar SD, Walimbe AM, et al. Rotavirus immunoglobulin levels among Indian mothers of two socio-economic groups and occurrence of rotavirus infections among their infants up to six months. *J Med Virol.* 2007;79:341–349.

19. RotaTeq [package insert]. Whitehouse Station, NJ: Merck & Co, Inc; 2008.

20. Rotarix [package insert]. Research Triangle Park, NC: GlaxoSmithKline; 2008.

21. Parashar UD, Alexander JP, Glass RI. Prevention of rotavirus gastroenteritis among infants and children. Recommendations of the Advisory Committee on

Immunization Practices (ACIP). *MMWR Recomm Rep.* 2006;55(RR-12):1–13.

22. Centers for Disease Control and Prevention. ACIP provisional recommendations for the prevention of rotavirus gastroenteritis among infants and children. Available at: http://www.cdc.gov/vaccines/recs/provisional/downloads/roto-7-1-08-508.pdf. Accessed July 2, 2008.

23. HCUP Kids' Inpatient Database (KID). Healthcare Cost and Utilization Project (HCUP). 2000 and 2003. Rockville, MD: Agency for Healthcare Research and Quality. Available at: http://www.hcup-us.ahrq.gov/kidoverview.jsp. Accessed June 30, 2008.

24. Parashar UD, Holman RC, Clarke MJ, et al. Hospitalizations associated with rotavirus diarrhea in the United States, 1993 through 1995: surveillance based on the new ICD-9-CM rotavirus-specific diagnostic code. *J Infect Dis.* 1998;177:13–17.

25. US Census Bureau. State Single Year of Age and Sex Population Estimates: April 1, 2000 to July 1, 2007—RESIDENT. Available at: http://www.census.gov/popest/datasets.html. Accessed June 30, 2008.

26. Medicare and Medicaid (CMS) Medicaid Statistical Information System. Medicaid Statistical Information System data. Available at: http://www.cms.hhs.gov/MedicaidDataSourcesGenInfo/02_MSISData.asp. Accessed March 7, 2008.

27. Ho MS, Glass RI, Pinsky PF, et al. Rotavirus as a cause of diarrheal morbidity and mortality in the United States. *J Infect Dis.* 1988;158:1112–1116.

28. Brandt CD, Kim HW, Rodriguez WJ, et al. Pediatric viral gastroenteritis during eight years of study. *J Clin Microbiol.* 1983;18:71–84.

29. Sample SAS. 25033: %SMSUB macro provides additional capabilities for PROC SURVEYMEANS. Available at: http://support.sas.com/ctx/samples/index.jsp?sid=541. Accessed March 7, 2008.

30. Hakim R, Bye B. Effectiveness of compliance with pediatric preventive care guidelines among Medicaid beneficiaries. *Pediatrics.* 2001;108:90–97.

31. McConnochie KM, Roghmann KJ, Liptak GS. Socioeconomic variation in discretionary and mandatory hospitalization of infants: an ecologic analysis. *Pediatrics.* 1997;99:774–784.

32. Gill JM, Mainous AG, Nsereko M. The effect of continuity of care on emergency department use. *Arch Fam Med.* 2000;9:333–338.

33. Nelson EAS, Tam JS, Bresee JS, et al. Estimates of rotavirus disease burden in Hong Kong: hospital-based surveillance. *J Infect Dis.* 2005;192(suppl 1):S71–S79.

34. Vesikari T, Matson DO, Dennehy P, et al. Safety and efficacy of a pentavalent human-bovine (WC3) reassortant rotavirus vaccine. *N Engl J Med.* 2006;354:23–33.

35. Ruiz-Palacios GM, Perez-Schael I, Velazquez FR, et al. Safety and efficacy of an attenuated vaccine against severe rotavirus gastroenteritis. *N Engl J Med.* 2006;354:11–22.

36. Centers for Disease Control and Prevention. Intussusception among recipients of rotavirus vaccine, United States, 1998–1999. *MMWR Morb Mortal Wkly Rep.* 1999;48:577–581.

37. Smith PJ, Schwartz B, Mokdad A, et al. The first oral rotavirus vaccine, 1998–1999; estimates of uptake from the National Immunization Survey. *Public Health Rep.* 2003;118:134–143.

38. Centers for Disease Control and Prevention. Delayed onset and diminished magnitude of rotavirus activity—United States, November 2007–May 2008. *MMWR Morb Mortal Wkly Rep.* 2008;57:697–700.