Impact of Rotavirus Infection at a Large Pediatric Hospital

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Information is limited about national patterns of rotavirus infection throughout the USA. Discharge records and laboratory rotavirus detection for 1979–1989 at the Texas Children's Hospital, Houston, were evaluated to determine the impact of rotavirus gastroenteritis at a large children's hospital. The availability since 1983 of diagnostic assays less expensive than electron microscopy was associated with increased rotavirus detection. Only 67% of rotavirus-positive samples came from children likely to have had community-acquired acute gastroenteritis. Combined laboratory results and ICD-9 discharge diagnosis codes (008.6, 008.8, and 558.9) measured rotavirus activity better than either alone. A case definition for hospitalization for rotavirus infection resulted in an estimate that an average of 473 children were hospitalized for rotavirus infection at Texas Children's Hospital each year over the 10-year period. These cases accounted for 3.0% of all hospital days and $1.5 million per year in bed costs at this hospital. Hospitalization rates and the impact of hospital costs for the USA were estimated by extrapolation.

Viral gastroenteritis is a major cause of illness and death worldwide. An estimate of diarrhea morbidity worldwide in 1977 was 3–5 billion cases per year with 5–10 million deaths [1, 2]. In the USA nonbacterial gastroenteritis is the second most common disease in families, and in a 10-year study completed in 1957 it was diagnosed in 16% of all illnesses in the home, or 1.52 cases per family member per year [3]. Rotaviruses are the most commonly recognized cause of acute gastroenteritis in children, but specific information about the incidence and cost of hospitalization for rotavirus infection in the USA is limited. The most frequently cited estimate for the hospitalization rate in children due to rotavirus infection (2.9/1000 children in the first 2 years of life) is based on a total of 23 hospitalizations over 3 years [4].

Investigators at the Centers for Disease Control (CDC) have estimated that 209,000 children <5 years old were hospitalized each year for diarrhea from 1979 to 1984, using a 0.5% sample of all hospital discharges in the USA plus a group of diagnosis codes as a surrogate measure of diarrhea activity [5].

Two-thirds of the cases in the CDC study occurred during the winter and likely were due to rotavirus. In part, specific information on rotavirus morbidity is lacking because assays for virus detection only became widely available in 1983. In addition, coding references used to assign discharge diagnoses to hospitalized children have no specific category for rotavirus infection. We used hospital laboratory records and medical record abstracts to assess the impact of nonspecific gastroenteritis and rotavirus-associated gastroenteritis at a large children's hospital. We also compared the ability of laboratory-based surveillance and surveillance based upon discharge diagnoses to detect rotavirus infection. We extrapolated the results from the hospital to estimate the incidence and cost of rotavirus infection as a cause of hospitalization within the USA.

Methods

Patient population. The study was conducted from July 1979 through June 1989 at Texas Children's Hospital, a 328-bed private not-for-profit pediatric hospital in Houston. The hospital, the largest pediatric hospital in the southwest USA, has 32% of the pediatric beds in Harris County, TX [6]. In 1980 Harris County had 2.41 million persons, 1.06% of the total US population [7]. About half the patients at Texas Children's Hospital are admitted by community-based physicians; 20% of those admitted reside in southwest Harris County, 40% elsewhere in the county, and 40% outside the county. In 1988, at this hospital, the average revenue per operating bed, which included room, isolation, intravenous fluid, and nursing charges, and other hospital-provided services was $603 per day.

Identification of rotavirus infections. Log sheets from the hospital serology and electron microscopy laboratories were used to identify children who had rotavirus infection. Stool samples received in the laboratory were ordered by the child's physician. Rotavirus was identified in the hospital laboratory by commercial ELISA or electron microscopy.

Patient hospitalization and demographic data. Additional data concerning the children hospitalized were obtained retrospectively from the medical records department. Chart abstracts for all discharged children were obtained for the period May 1987 through June 1989. Line listings for all children with selected diagnoses were obtained for the period July 1979 through April 1987. All diagnoses since 1979 were assigned according to the International Classification of Diseases (ICD), version 9, Clinical Modification [8].

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Statistical analyses. Results of laboratory testing were merged with medical record information. Each data base was analyzed for predictive value to monitor rotavirus infection. Analyses of adjusted and nonadjusted groups were performed using the EPI INFO statistical package [9].

We determined which discharge diagnosis codes were assigned to children who had a laboratory-identified rotavirus infection. For children discharged from July 1987 through June 1989, we performed χ^2 analyses for the 2 × 2 tables generated by the portion of children who were assigned an ICD-9 code and the portion with a laboratory-detected rotavirus infection. Diagnosis codes were analyzed without regard to the number of diagnoses assigned or to the priority of diagnoses when more than one was assigned.

Case definition for surveillance for rotavirus gastroenteritis. The comparative assessment of laboratory-based passive surveillance and of discharge diagnosis codes describing a rotavirus infection permitted the establishment of a case definition for surveillance for hospitalization for rotavirus infection. On the basis of the results of the analysis of the 2-year period noted, we identified all children with the diagnoses 008.6, 008.8, 009.0–009.3, and 558.9 discharged from Texas Children's Hospital from 1 July 1979 through 30 June 1989. These children were defined as cases of nonspecific gastroenteritis. We also determined which children with these diagnoses had rotavirus infection. Patients meeting the case definition at Texas Children's Hospital were identified. Estimates of the impact of rotavirus infection in Harris County and the USA as a whole were extrapolated from the data.

Results

Rotavirus activity assessed by passive laboratory-based surveillance. From July 1979 through June 1989, 4676 samples were submitted for laboratory detection of viral gastroenteritis pathogens. The distribution of these samples exhibited marked variability over the years studied (figure 1). The use of less expensive commercial assays for rotavirus detection in 1983 (figure 1, arrow), was associated with a marked increase both in the number of submitted samples and in the number of detected rotavirus infections. Physicians submitted more samples during the winter at the peak of rotavirus activity. During the winter peak (November–March, depending on the year), 40% of samples were rotavirus positive, whereas 7.9% were positive at other times. Rotavirus infections were detected primarily in children <23 months old (83.7%). Some 13.3% of children with positive samples were <3 months old. Variability of the magnitude of the seasonal peak was apparent. More positive samples were identified in the 1987/1988 season. In general, the pattern of rotavirus activity as measured by passive surveillance in the hospital laboratory was that of a predominantly winter illness with an increased incidence in infants and toddlers.

Many rotavirus-positive samples did not represent children with community-acquired acute gastroenteritis. A total of 4.5% of the rotavirus-positive samples were from children not hospitalized, and 14% were collected ≥7 days after hospitalization; the latter were from children with nosocomial infection or infected children from whom multiple samples were collected. Some 8.4% of the samples represented these additional positive samples. Also, 25% of the samples were from children who at discharge did not receive at least one of the 74 discharge diagnosis codes indexed under "enteritis" or "dysentery" in the ICD-9. Altogether, only 67% of the rotavirus-positive samples were from children with community-acquired acute gastroenteritis.

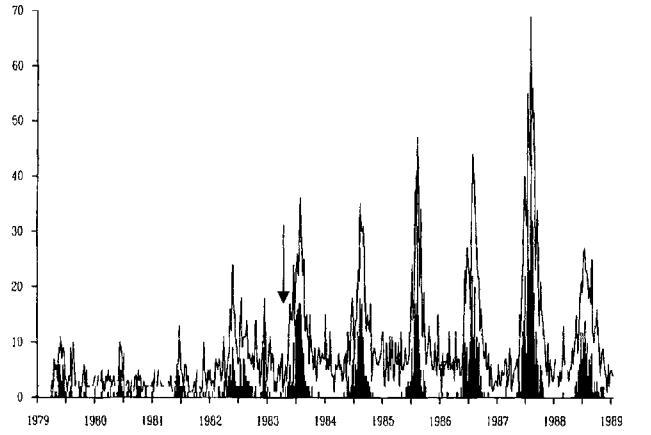

Figure 1. Weekly distribution of samples submitted for detection of viral gastroenteritis pathogens (open areas) and of samples positive for rotavirus (shaded areas), 1 July 1979 through 30 June 1989, at Texas Children's Hospital. At the beginning of the 1983/1984 season (arrow), the hospital laboratory began testing samples with commercial assays.

Discharge diagnoses associated with a laboratory-detected rotavirus infection. Together, three diagnosis codes (008.6, 008.8, and 558.9) describing nonspecific gastroenteritis were assigned to 85% of the children with a laboratory-detected rotavirus infection. These three codes were mutually exclusive; only three children in the 2-year period of analysis received more than one code for the same discharge. Eight other diagnostic conditions were associated with rotavirus infection (table 1). Some codes (276.2, 276.5, 782.1, 783.4, and 787.0) clearly were descriptive of severe gastroenteritis requiring hospitalization. The significance of the association with conjunctivitis and unspecified otitis media (372.30 and 382.1) is uncertain, although an association with otitis media has been noted [10, 11].

Specificity of "nonspecific gastroenteritis diagnosis codes" for gastroenteritis syndrome. The codes 008.6, 008.8, and 558.9 were the only 3 of the 74 diagnoses indexed under "enteritis" or "dysentery" in the ICD-9 that were significantly associated with a laboratory-detected rotavirus infection. Because the descriptive phrase for code 558.9 (other and unspecified noninfectious gastroenteritis and colitis) literally should exclude infectious gastroenteritis, we determined the other diagnoses that were significantly associated with 008.6, 008.8, and 558.9 (table 2). Of the 8 other conditions associated with a laboratory-detected rotavirus infection (table 1), 5 were

Table 1. Discharge diagnoses significantly associated with the laboratory detection of rotavirus among 24,401 consecutive hospital discharges, July 1987–June 1989.

Diagnosis code*	Condition	No. with rotavirus infection (%)	*P* for association†	Relative risk for association
Diseases				
008.6	Enteritis due to specified virus	115 (27)	<.001	15.7–35.1
008.8	(Intestinal infection) other organism not elsewhere classified	114 (27)	<.001	13.6–18.8
558.9	Other and unspecified noninfectious gastroenteritis and colitis	131 (31)	<.001	6.9–9.4
Other conditions				
079.8	Other specified viral infections	5 (1)	<.001	2.0–12.3
276.2	Acidosis	50 (12)	<.001	7.6–13.5
276.5	Volume depletion	231 (55)	<.001	10.8–13.3
372.30	Other and unspecified conjunctivitis	5 (1)	.038	1.2–7.1
382.9	Unspecified otitis media	64 (15)	<.001	1.8–2.8
782.1	Rash and other nonspecific skin eruption	7 (2)	.0012	1.7–7.8
783.4	Failure to thrive	24 (6)	.024	1.1–2.4
787.0	Nausea and vomiting	15 (4)	.002	1.4–3.8

* Codes [8] represent all assigned diagnoses, not just primary or sole diagnoses.
† Yates's corrected χ^2 or Fisher's exact test.

also significantly associated with one or more of the three nonspecific gastroenteritis codes. Seven additional diagnoses not associated statistically with a laboratory-detected rotavirus infection were associated with the group of nonspecific gastroenteritis diagnoses. These included diagnoses that described other conditions commonly associated with rotavirus gastroenteritis (hyperosmolality and/or hypernatremia, 276.0; two codes for malabsorption, 579.8 and 579.9; diaper rash, 691.0 and 692.9; and otitis media, 881.00). The age distribution of children assigned the three nonspecific gastroenteritis codes was similar to that of children with laboratory-detected rotavirus infection (table 3). The diagnosis code group associated with the nonspecific gastroenteritis diagnoses describes the same syndrome as the diagnosis code group associated with laboratory-detected rotavirus.

Many children hospitalized during the 1987/1988 and 1988/1989 rotavirus epidemic periods who received a nonspecific gastroenteritis code at discharge did not have a sample submitted for rotavirus detection (49%) or had a negative stool sample (17%). Children from whom samples were not collected tended to be older than the expected age for rotavirus infection (≥36 months, $P < .001$) or to have a shorter hospital stay (median 2 days without sample vs. 3 days with sample, $P < .001$, Kruskal-Wallis test). Children with nonspecific gastroenteritis in the rotavirus epidemic period with negative samples tended to be younger (≤3 months of age; $P < .001$) or to have the first sample submitted later in the hospitalization (detection rate 66% in the first 3 days vs. 38% in days 4–7, $P < .001$) than children with positive samples.

Patterns of nonspecific gastroenteritis admissions over a 10-year period. Others have determined that four codes used in the ICD-8 (009.0–009.3, used to code "ill-defined intestinal infections") and carried over into ICD-9 shared epidemiologic patterns with the codes 008.6, 008.8, and 558.9 [5]. The availability of 008.6 and 008.8 in the ICD-9 resulted in a disuse of 009.0–009.3 at Texas Children's Hospital. During the 2-year period July 1987 through June 1989, codes 009.0–009.3 were used eight times and only one of the eight children had a laboratory-detected rotavirus infection. However, in the 10-year period from July 1979 through June 1989, codes 009.0–009.3 were used 50 times, half in the first 3 years after the application of ICD-9 began. Because of the redundancy of codes available to describe nonspecific gastroenteritis, it seemed reasonable that some hospitals might use codes

Table 2. Association of diagnoses linked to rotavirus infection with other conditions among 24,401 consecutive hospital discharges, July 1987–June 1989.

Diagnosis code*	Disease	Total discharged with disease	No. admitted in rotavirus epidemic period	Epidemic cases with detected rotavirus infection	No. in epidemic period with associated diagnosis: Acidosis 276.2	Volume depletion 276.5	Unspecified otitis media 382.9	Rash† 782.1	Failure to thrive† 783.4
008.6	Enteritis due to specified virus	143	132	109	9‡	63‡	18§	3‖	9
008.8	(Intestinal infection) other organism not elsewhere classified	545	348	110	29‡	161‡	50‡	5‖	17
558.9	Other and unspecified noninfectious gastroenteritis and colitis	1060	607	124	54‡	322‡	118‡	5‡	37‡
Total		1748	1087	343	92	546	186	13	63
All patients with same condition (%)					332 (28)	1332 (41)	1684 (11)	116 (11)	872 (7)

* Codes [8] represent all assigned diagnoses, regardless of position or number assigned.
† Full wording for condition: 782.1, rash and other nonspecific skin eruption; 783.4, lack of expected normal physiologic development.
‡ $P < .001$, § $P < .01$, ‖ $P < .05$, probability for association by Yates's corrected χ^2 or Fisher's exact test.

Table 3. Age distribution for children assigned individual diagnosis codes linked to rotavirus infection, July 1987–June 1989.

Disease	Total discharged with diagnosis	No. discharged in rotavirus epidemic period	No. in age group, months 0–2	3–5	6–8	9–11	12–14	15–17	18–20	21–23	24–47	≥48
Total patients in age group*			4201	1490	1103	996	875	746	621	511	3107	10,746
Diagnosis code												
008.6 Enteritis due to specified virus	143	132	13	16	20	23	17	10	7	4	13	9
008.8 (Intestinal infection) other organism not elsewhere classified	545	348	43	35	29	41	39	26	13	15	54	53
558.9 Other and unspecified noninfectious gastroenteritis and colitis	1060	607	70	63	56	62	52	45	35	33	93	98
Total (% of total in age group)	1748	1087	126 (3.0)	114 (7.7)	105 (9.5)	126 (12.7)	108 (12.3)	81 (10.9)	55 (8.9)	52 (10.2)	160 (5.1)	160 (1.5)
Rotavirus-infected children discharged in the epidemic period			36	57	46	68	44	43	24	21	64	16

* 24,401 discharges were evaluated; age could not be determined for five children.

009.0–009.3 more frequently than others; also, because of a possible carry over from ICD-8, we included 009.0–009.3 during the 10-year analysis of nonspecific gastroenteritis activity.

An average of 883 cases of nonspecific gastroenteritis (range 690–1119) occurred each year; an average of 454 cases (range 338–718) occurred during the winter epidemic period. The pattern of admission for nonspecific gastroenteritis demonstrated a striking seasonality (figure 2). Unimodal peaks of nonspecific gastroenteritis activity occurred each winter. The winter peaks of nonspecific gastroenteritis were caused by winter peaks of rotavirus infection. The first three peaks of nonspecific gastroenteritis each occurred before the first of January in the winter rotavirus season. In the 1982/1983 season, there were two peaks of rotavirus activity. In the following seasons, the peaks of rotavirus activity occurred in January and February. However, in 1988/1989, the peak of the rotavirus season again was in December. These temporal shifts of rotavirus activity occurred in seasons following particularly intense rotavirus infection. The 1985/1986 season was notable for having the fewest cases admitted during the epidemic peak.

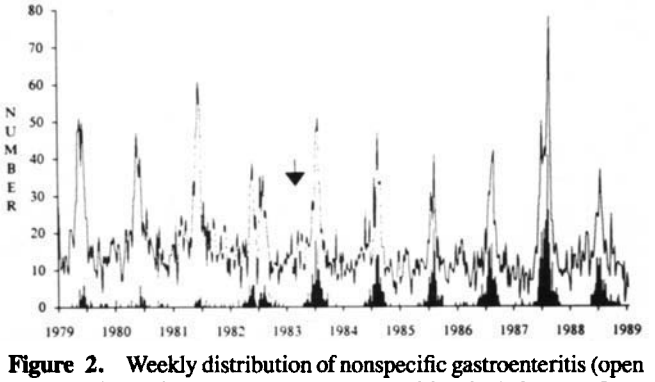

Figure 2. Weekly distribution of nonspecific gastroenteritis (open areas) and rotavirus-associated gastroenteritis (shaded areas) from 1 July 1979 through 30 June 1989 at Texas Children's Hospital. The number of cases for each epidemic peak varied greater than twofold during the study period. Arrow indicates beginning of 1983/1984 rotavirus season when samples were first tested with commercial assays.

Case definition for surveillance for rotavirus gastroenteritis. The proposed case definition for surveillance for hospitalization for rotavirus gastroenteritis includes both laboratory and medical records criteria (table 4). From July 1983 through June 1989, a uniform testing protocol was used in the hospital laboratory. Using the proposed definition, for the period of study at Texas Children's Hospital, 136 children with rotavirus infection who required hospitalization were classified as cases; if probable cases were included the number was 473, rising to 643 if probable and possible cases were included.

Table 4. Proposed case definition for a hospital case of rotavirus gastroenteritis.

Case definition	No./year at Texas Children's Hospital
Case: Rotavirus detected in stool *and* nonspecific gastroenteritis diagnosis code assigned	130
Probable case: Rotavirus detected in stool *or* Nonspecific gastroenteritis diagnosis code assigned during rotavirus epidemic period	19 324
Possible case: Diagnosis of volume depletion or acidosis during rotavirus epidemic period	170

Table 5. Annual incidence estimates and bed costs for hospitalization for rotavirus-associated gastroenteritis.

	Texas Children's Hospital	Harris County	USA
Cases and probable cases	473	1165	110,000
Hospitalization rate (per 1000 by age [y])			
<1		11.1	
1		5.8	
2		1.9	
3		0.82	
4		0.48	
5–18		0.19	
Hospital days for syndrome	2507	6175	583,000
Total hospital days	83,000	–	–
Bed costs (million)	$1.5	$3.7	$352

NOTE. Calculations based on mean cases and probable cases over 6 years = 473/year; mean hospital stay of 5.3 days; mean total hospital days at Texas Children's Hospital over 10-year study period of 83,000/year; 78.8% of hospitalized cases and probable cases were Harris County residents; average of 53,283 children were born in Harris County each year during 10-year period. Other factors are in Methods.

These numbers indicate that at this hospital most children likely to be hospitalized because of rotavirus infection lack a confirmatory assay for the virus.

Incidence and cost estimates for hospitalization for rotavirus gastroenteritis. The observed number of cases and probable cases of hospitalized rotavirus gastroenteritis permitted estimates of the incidence and hospitalization cost of rotavirus gastroenteritis (table 5). The 473 cases and probable cases each year were hospitalized about 2500 total days, which accounted for 3.0% of all hospital days (2.2%–4.6%/year over the 10-year period). The highest percentage of admissions ascribed to rotavirus gastroenteritis was 22% in January 1988. Over the course of the study, 17 children died with nonspecific gastroenteritis; 8 died in the winter and 3 had a proven rotavirus infection. Extrapolating the Texas Children's Hospital results to Harris County permitted an estimation of age-specific hospitalization rates. In the first year of life, for each 1000 children, 11.1 were hospitalized with definite or probable rotavirus gastroenteritis. This rate fell almost 50% in the second year of life to 5.8 per 1000 children. Of the hospitalizations, 3% represented a second or third admission for a child whose illness met the case definition as a case or probable case. Overall, in the first 18 years of life (the upper age limit for admission to Texas Children's Hospital) the risk for hospitalization was 1.21 per 1000 children per year, an overall risk of 1 in 46. Applying these rates to the USA by simple extrapolation results in an estimate of 110,000 children who are hospitalized annually as a case or as a probable case of rotavirus-associated gastroenteritis, for a total of 583,000 hospital days. The average cost for hospital care for these children would be ~$352 million per year.

Discussion

We evaluated hospital discharge information and hospital laboratory rotavirus detection data for a 10-year period to determine the impact of rotavirus gastroenteritis at a large children's hospital. The age-specific incidence of hospitalization for rotavirus infection and the seasonal pattern of gastroenteritis was like that observed elsewhere [2]. Rotavirus infection among hospitalized cases occurred outside the epidemic period and was detected in 7.9% of samples submitted then from children with nonspecific gastroenteritis. The youngest children, those expected to have the highest titers of transplacentally acquired antibody, were not spared rotavirus infection; 13.3% of children with positive samples were <3 months old.

Decisions about the overall impact of rotavirus gastroenteritis in the USA and the relative importance of rotavirus vaccines compared with vaccines against other agents have been based on extrapolations from small studies [12]. We sought to define an epidemiologic measure for surveillance for rotavirus infection. A combination of laboratory and medical records information provided a case definition for surveillance for hospitalization for rotavirus infection. The definition included variables that are readily retrievable in most hospital settings. Detection of rotavirus alone by the laboratory was an insufficient criterion to define a case. Children may be asymptomatic, have another illness while excreting rotavirus from a prior infection, may not be hospitalized, or, for reasons revealed only by a review of the individual medical records, not receive a viral diarrhea discharge code. The assignment of a nonspecific gastroenteritis discharge code alone also was insufficient to define a case because viral gastroenteritis occurred year-round, but rotavirus infection outside the winter peak was rarely detected. During the winter rotavirus season, children <3 months old with nonspecific gastroenteritis were less likely to have a laboratory-detected rotavirus infection than other children. Similarly, the laboratory detection rate for rotavirus infection among older children (≥4 years) with nonspecific gastroenteritis was also less. The case definition can be most easily applied at large hospitals that perform rotavirus assays in their laboratories. Even in such facilities it is likely that physicians order a sample for rotavirus detection for a minority of children hospitalized with rotavirus gastroenteritis. The inclusion of probable cases, defined by epidemiologic and discharge diagnosis code patterns, permits a broader, although certainly less definitive, measure of rotavirus activity.

The case definition is applicable for the study of rotavirus infection in certain groups of special interest. For example, in laboratories of small hospitals rotavirus assays usually are not performed. The percentage of submitted samples to be sent to a reference or commercial laboratory from hospitalized cases is likely to be less than in the large pediatric hospitals.

Because the epidemiology of individual rotavirus serotypes in rural areas may differ from that in urban areas [13], some measure of rotavirus activity in all settings is needed, and is provided by the case definition. The case definition can also be applied as an epidemiologic measure of nosocomial illness. The interval from the date of admission to the date of sample collection is an indirect measure of illness onset. A first sample submitted late in the hospital course for rotavirus detection likely comes from a child infected nosocomially. Greater certainty comes from the addition of coding information. Children admitted for nongastroenteritis reasons and who are discharged with a nonspecific gastroenteritis diagnosis are likely to have had nosocomial illness. The case definition can also be applied to the outpatient setting. Because reasons for an outpatient visit may be less defined than for a hospitalization, facilities that code outpatient visits and surveillance systems for outpatient illnesses could measure probable rotavirus activity using a combination of codes for nonspecific gastroenteritis and some laboratory measure indicating the duration of the rotavirus season in that community. Although only three ICD-9 codes for "enteritis" or "dysentery" were associated with rotavirus detection in this study, at other facilities other codes, especially 009.0–009.3, may be used. It is important to determine the use of individual codes to describe rotavirus gastroenteritis at other facilities. Given the impact of rotavirus illness worldwide, inclusion of a specific code for rotavirus infection in the ICD-10 is recommended.

Investigators from the CDC have evaluated the pattern of hospitalizations in the USA for diarrhea in children using a 0.5% sample of all hospital discharges [14]. An empiric selection of codes likely to represent viral or nonspecific gastroenteritis exhibited seasonal and age distributions and patterns of associated illnesses known to be characteristic of rotavirus infection. Those ICD-9 codes (008.6, 008.8, 009.0–009.3, and 558.9) were used as a surrogate measure of rotavirus infection. We used a different approach to determine which codes are used to describe rotavirus gastroenteritis. Beginning with children known to have been infected with rotavirus, we determined which of the many ICD-9 codes available actually were significantly linked to the laboratory detection of rotavirus infection and found only three "enteritis" codes. Our results confirm the accuracy of the CDC surveillance method. However, incorporation of laboratory results provides a better measure of rotavirus gastroenteritis than does the CDC measure alone. For general seasonal trends and incidence estimates, the addition of laboratory data provides a more accurate determination of the time of season onset and termination and of the affected population than surveillance using either diagnosis codes or laboratory-detected cases alone.

We acknowledge that extrapolation of the findings at Texas Children's Hospital to estimate a national disease burden for rotavirus gastroenteritis is tenuous. However, similar estimates have been made by more limited studies and have been used to guide national policy. We estimated the incidence for hospitalization for rotavirus gastroenteritis at 8.5 per 1000 children per year in the first 2 years of life. This estimate is 290% higher than the other population-based estimate in the USA of 2.9 per 1000 in the same age group [4]; the latter estimate was based on a total of 23 cases in a 3-year period in a population served by a health maintenance organization. In Denmark an estimate for hospitalization for rotavirus gastroenteritis in the first 2 years of life was 4.8 per 1000 children per year [15]. A committee of the Institute of Medicine estimated that ~24,000 cases of hospitalization for rotavirus infection and 95,000 hospital days result each year in the USA [12]. Our estimates are 460% and 610% higher, respectively. Within our study period the number of cases each winter period varied by 210%. No fewer than 338 cases occurred each winter at our facility. We estimate that 1 in every 46 children will be hospitalized for rotavirus gastroenteritis by age 18 years. Almost all of this risk is incurred in the first 5 years of life.

The much greater incidence estimate in Harris County than in the Washington, DC, area or in Denmark may reflect a more heterogeneous population, the continued circulation of four rotavirus serotypes, and the cyclic change of the predominant serotype every 1–2 years in the Houston region [13]. Changes in rotavirus serotype in Harris County have been associated with large changes in the number of hospitalized cases. The antigenic diversity of circulating rotaviruses in the Houston community may result in more cases of severe rotavirus infection than in other parts of the USA and may be more like that observed in less-developed countries (Peru, Argentina, India, Bangladesh). Whether similar diversity occurs in other large cities in the USA remains to be determined. But because of this antigenic diversity, it may be possible to study Third World rotavirus epidemiology in the Houston area.

Candidate rotavirus vaccines have been tested in the field with variable results [16]. Before initiation of national vaccine programs it is essential to know the impact of disease and how vaccine success (or failure) can be monitored. Our proposed case definition is suggested as one monitoring method. Further, the priority of individual vaccine programs is influenced by the impact of costs of the disease. Most direct costs for treating rotavirus-associated illness are attributable to hospitalization [17]. Unfortunately, data on the impact of rotavirus gastroenteritis in the USA have been lacking. In our facility, hospitalization for cases and probable cases of rotavirus gastroenteritis accounted for 3.0% of all pediatric hospital days over a 10-year period. By simple extrapolation this rate results in an estimate of the national annual cost of $352 million per year for the hospital care of these children. The committee of the Institute of Medicine recommended that "the National Institute of Allergy and Infectious Diseases and

other agencies should consider means of improving the epidemiologic data on which disease comparisons can be based. Lack of data in some areas and the variable quality of data in other areas are serious impediments to the development of a comprehensive priority selection scheme" [12]. Our results confirm that rotavirus-associated illness is a major cause of illness in children in the USA and should assist decisions concerning future intervention programs.

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