

Global Illness and Deaths Caused by Rotavirus Disease in Children

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To estimate the global illness and deaths caused by rotavirus disease, we reviewed studies published from 1986 to 2000 on deaths caused by diarrhea and on rotavirus infections in children. We assessed rotavirus-associated illness in three clinical settings (mild cases requiring home care alone, moderate cases requiring a clinic visit, and severe cases requiring hospitalization) and death rates in countries in different World Bank income groups. Each year, rotavirus causes approximately 111 million episodes of gastroenteritis requiring only home care, 25 million clinic visits, 2 million hospitalizations, and 352,000–592,000 deaths (median, 440,000 deaths) in children <5 years of age. By age 5, nearly every child will have an episode of rotavirus gastroenteritis, 1 in 5 will visit a clinic, 1 in 65 will be hospitalized, and approximately 1 in 293 will die. Children in the poorest countries account for 82% of rotavirus deaths. The tremendous incidence of rotavirus disease underscores the urgent need for interventions, such as vaccines, particularly to prevent childhood deaths in developing nations.

In 1985, de Zoysa and Feachem published their landmark review of the global prevalence of rotavirus disease (1). Their analyses indicated that rotavirus accounted for 6% of diarrhea episodes and 20% of deaths caused by diarrhea in children <5 years of age in developing countries. The incidence of rotavirus disease was observed to be similar in both industrialized and developing countries, suggesting that adequate control may not be achieved by improvements in water supply, hygiene, and sanitation. Consequently, the development, trial, and widespread use of rotavirus vaccines were recommended to prevent severe and fatal rotavirus disease.

Since then, rapid progress has been made in developing and testing several rotavirus vaccine candidates (2,3). In August 1998, a live, attenuated rotavirus vaccine (Rotashield, Wyeth Laboratories, Marietta, PA) was licensed in the United States and recommended for routine immunization of U.S. infants. However, 9 months later, the use of Rotashield was suspended because reports suggested a possible association with intussusception (4). After this association was confirmed, the recommendation for

use of Rotashield was withdrawn and the manufacturer stopped vaccine production.

Efforts are ongoing to develop other rotavirus vaccines, and several candidates are undergoing clinical testing (3). In addition to their safety and efficacy, the decision to implement these new rotavirus vaccines will be based on considerations of risk-benefit and cost-effectiveness. Updated estimates of rotavirus disease prevalence are a prerequisite to formulating such policy and carrying out economic analyses as well as advocacy for the next generation of rotavirus vaccines. Furthermore, each country that considers using a rotavirus vaccine may want to review the prevalence of rotavirus disease in their setting.

Since 1985, deaths from diarrheal diseases in children have declined substantially around the world, and a recent analysis suggested that deaths from rotavirus infections might also have been reduced during this period (5,6). Furthermore, scant information is available on the global extent of illness from rotavirus disease, particularly hospitalizations, which constitute a major component of total rotavirus health costs in industrialized nations. To provide updated estimates of the global illness and death from rotavirus disease in children, we reviewed studies of childhood deaths from diarrhea and of rotavirus infections published from 1986 to 2000. We also present preliminary estimates of country-specific mortality rates from rotavirus disease as targets for further study and refinement through local definition of problems. These findings should help policy makers assess the magnitude of the problem of rotavirus disease in their own countries and set priorities for interventions to prevent this disease.

Methods

Selection of Studies

The studies selected for this analysis were identified from a computer search of the scientific literature published in English between 1986 and 2000. To find studies of childhood deaths from diarrhea, we conducted a search using the keywords “childhood mortality,” “deaths,” and “diarrhea.” We added references by reviewing the citations in these articles and by consulting with experts in the field. Because most studies of diarrhea deaths were conducted in countries with a low-income population, we supplemented

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these studies with published reports of vital registration data to analyze child death patterns in selected countries with middle- and high-income populations.

To identify studies of rotavirus disease, we conducted a search using the keyword “rotavirus” and cross-linked the articles with a second set of articles obtained from a secondary search using these keywords: incidence, prevalence, public health, death rate, mortality, surveillance, burden, suffering, distribution, area, location, and country. We also searched for permutations of these root words: epidemiol, monitor, and geograph. We then reviewed the resulting linked set of articles and narrowed it down to articles with content that was relevant to the goals of this study. We identified additional citations from references in these articles. Studies of rotavirus were included if they continued for at least 1 year, contained data on children <5 years of age, and reported using an enzyme immunoassay (EIA) or similar reliable assay to detect rotavirus. A listing of the studies included in the analyses is available in Appendix A (online only; available from: URL: <http://www.cdc.gov/ncidod/EID/vol9no5/02-0562.appA.htm>).

Analysis of Data

Rotavirus-Associated Illness

To estimate the extent of illness from rotavirus in children in developing countries, we first multiplied the total population of infants (0–11 months) and children (12–59 months) in those countries by the estimated annual incidence of diarrhea in the respective age groups (5,7). On the basis of published estimates from a study in Chile (8), we then distributed these diarrhea episodes into three settings: mild cases only requiring care at home; moderate cases requiring care in an outpatient clinic; and severe cases requiring hospitalization. Next, on the basis of studies we reviewed, we calculated the median proportion of diarrhea episodes attributable to rotavirus in each of the three settings. Finally, we multiplied the total number of diarrhea episodes in each setting by the estimated proportion attributable to rotavirus to yield the number of rotavirus cases in each setting.

To estimate the number of hospitalizations for rotavirus among children in industrialized countries, we multiplied estimates of the total population of children <5 years of age with rotavirus-associated hospitalization rates derived from published studies. To calculate clinic visits and episodes of rotavirus disease, we evaluated studies documenting the frequency of these outcomes relative to hospitalizations and multiplied the calculated total number of rotavirus-associated hospitalizations by corresponding factors. The figures thus obtained were combined with estimates of rotavirus illness in children in developing countries to yield the global extent of illness from rotavirus disease.

Rotavirus-Associated Deaths

To estimate the total number of child deaths from diarrhea, we plotted (for each country with available data) the fraction of deaths of children <5 years of age attributable to diarrhea against per capita gross national product (GNP). Countries were classified on the basis of GNP per capita into World Bank Income Groups (low [$<U.S.\$756$], low-middle [$U.S.\$756\text{--}\$2,995$], high-middle [$U.S.\$2,996\text{--}\$9,265$], high [$>U.S.\$9,265$]) (9). For each income group, we calculated the median proportion of deaths of children <5 years of age attributable to diarrhea. We then multiplied the median proportion for each income group by the total number of deaths of children <5 years of age for each country in that income group to yield country-specific estimates of the mortality rate from diarrhea. These country-specific estimates were added to calculate the global mortality rate from diarrhea.

To estimate the fraction of diarrhea deaths attributable to rotavirus, we plotted the proportion of rotavirus infection detected in children hospitalized for diarrhea that was, by virtue of the need for hospitalization, presumed to be severe. These figures were again plotted against per capita GNP for each country to yield median rotavirus detection rates for countries in the four World Bank income groups. Previously estimated diarrhea mortality rates for each country in an income group was multiplied by the median rotavirus detection rate for that income group to yield the estimated number of rotavirus deaths by country. These figures were added to yield the number of global deaths from rotavirus diarrhea. For each income strata and overall, the risk of death from rotavirus diarrhea by 5 years of age was calculated by dividing the total number of live births by the total number of deaths from rotavirus.

Results

Rotavirus Disease in Children in Developing Countries

Total Number of Diarrhea Episodes

An estimated 125 million infants 0–11 months of age and 450 million children 1–4 years of age reside in developing countries. A recent review of 27 prospective studies from 20 countries published from 1990 to 2000 estimated the incidence of diarrhea as 3.8 episodes per child per year for children ≤ 11 months of age and 2.1 episodes per child per year for children 1–4 years of age (5). Multiplying these age-specific incidence data with the population of children in each age group yielded an overall estimate of approximately 1.4 billion diarrhea episodes per year in children <5 years of age (Table 1). Of these, 475 million episodes are estimated to occur in ≤ 11 -month-old infants and 945 million episodes in children 1–4 years of age.

Distribution of Diarrhea Episodes by Setting

A study from Chile demonstrated that in ≤ 11 -month-old infants, 88.2% of diarrhea episodes required only care at home, 10.3% required a clinic visit, and 1.5% required hospitalization (8). In 1- to 4-year-old children, 91.9% of diarrhea episodes required only care at home, 7.9% required a clinic visit, and only 0.2% required hospitalization. The proportion of all diarrhea episodes requiring hospitalization was similar in another study from Thailand (10). Therefore, we applied the estimates from the Chilean study to the previously calculated total number of diarrhea episodes in each age group and distributed them into episodes requiring only home care, clinic visit, or hospitalization (Table 1). Of the total of approximately 1.4 billion diarrhea episodes in children < 5 years of age, we estimated that 1.29 billion require home care only, 124 million require a clinic visit, and 9 million require hospitalization.

Number of Rotavirus Episodes in Each Setting

To estimate the number of diarrhea cases in each setting that are attributable to rotavirus, we applied proportions calculated from studies of rotavirus in children in developing countries. The review of 24 community-based studies, 13 clinic-based studies, and 72 hospital-based studies indicated that rotavirus accounted for a median of 8.1%, 18.8%, and 21.3% of diarrhea episodes in the three settings, respectively (Table 2). By multiplying these setting-specific proportions with the total number of diarrhea episodes in each setting, we calculated that rotavirus annually causes approximately 104 million episodes of diarrhea requiring home care, 23 million clinic visits, and 1.9 million hospitalizations.

Illness from Rotavirus Disease in Children in Industrialized Countries

Hospitalizations

Examination of rotavirus-specific annual hospitalization incidence from several industrialized countries demonstrated a median rate of 445 per 100,000 children (interquartile range, 283–715 per 100,000) (11–20) (Table

3). By multiplying these incidence estimates with the total population of 50,016,000 children < 5 years of age in industrialized nations, we estimated that a total of 223,000 (range 142,000–358,000) rotavirus-associated hospitalizations occur in children in industrialized nations.

Clinic Visits

No reliable estimates of rotavirus-associated clinic visit rates are available for children in industrialized countries. However, studies have shown that for each child hospitalized with rotavirus diarrhea, approximately 5–10 children require a visit to a healthcare facility or physician's office (17,21,22). Therefore, we multiplied the estimated 223,000 rotavirus hospitalizations by a factor of 8 (range 5–10) to obtain an estimated total of approximately 1,781,000 (range 708,000–3,576,000) clinic visits for rotavirus disease in children < 5 years of age.

Episodes Requiring Only Home Care

Studies have estimated that for each child requiring medical attention for rotavirus disease, an additional three to five children develop symptomatic disease requiring only home-care (21,22). Therefore, we multiplied the estimated 1,781,000 clinic visits by a factor of 4 (range 3–5) to estimate a total number of 7,122,000 (range 2,123,000–17,881,000) episodes of rotavirus gastroenteritis requiring only home care in children < 5 years of age.

Overall Illness from Rotavirus Gastroenteritis Worldwide

By adding the total prevalence of rotavirus illness in children in developing and industrialized nations, we estimated that each year rotavirus causes approximately 111 million episodes of gastroenteritis that require home care only, 25 million clinic visits, and 2 million hospitalizations in children < 5 years of age worldwide (Table 4).

Deaths from Rotavirus Disease in Children < 5 Years of Age Worldwide

The proportion of deaths in children ≤ 5 years of age attributable to diarrhea demonstrated a declining trend

Table 1. Estimates of the annual number of diarrhea episodes among children < 5 years of age in developing countries, by age group and setting^a

	Age group		Total (≤ 4 y)
	≤ 11 mo	1–4 y	
Total population (x1,000)	125,000	450,000	575,000
No. of diarrhea episodes per child per y ^b	3.8	2.1	NA
Total diarrhea episodes (x1,000)	475,000	945,000	1,420,000
No. of episodes at home (x1,000)	418,950 (88.2)	868,455 (91.9)	1,287,405
No. of episodes in outpatients (x1,000)	48,925 (10.3)	74,655 (7.9)	123,580
No. of case-patients hospitalized (x1,000)	7,125 (1.5)	1,890 (0.2)	9,015

^aFigures in parenthesis are percentages of total diarrhea episodes (7).

^bFrom reference (5).

Table 2. Estimates of the annual number of episodes of rotavirus diarrhea among children <5 years of age in developing countries, by setting

	Home	Outpatient	Inpatient
Annual no. of diarrhea episodes (x1,000)	1,287,405	123,580	9,015
Median % of episodes with rotavirus (IQR) ^a	8.1 (4.0–12.2)	18.8 (15.0–22.0)	21.3 (17.2–28.8)
Total rotavirus episodes (range) (x1,000)	104,280 (51,496–157,063)	23,233 (18,537–27,188)	1,920 (1,551–2,596)

^aIQR, interquartile range.

with increasing income level (Figure 1A); the median proportion for low-income countries was 21%; for low-middle income countries, 17%; for high-middle income countries, 9%; and for high-income countries, 1%. We multiplied these income stratum-specific median estimates with the combined ≤ 5 mortality estimates for countries in each of the four income strata to yield an overall estimate of 2.1 million (range 1.7 million–3.0 million) diarrhea deaths per year (Table 5). Of the median 2.1 million diarrhea deaths, 85% (N=1,805,000) occurred in children from low-income countries.

The proportion of diarrhea hospitalizations attributable to rotavirus demonstrated an increasing trend with increasing income level (Figure 1B); the median for low-income countries was 20%; for low-middle income countries, 25%; for high-middle income countries, 31%; and for high-income countries, 34%. We multiplied these stratum-specific proportions with the median estimate of total diarrhea deaths for countries in each of the four income strata to yield an estimated 352,000–592,000 (median 440,000 deaths) per year from rotavirus. Of the median 440,000 deaths, 82% (N=361,000) occurred in children from low-income countries.

To obtain country-specific estimates of deaths from diarrhea and rotavirus disease, we first multiplied United Nations Children's Fund estimates of total number of

deaths of children <5 years of age for each country in each income stratum with the median proportion for that stratum of deaths in children <5 years of age attributable to diarrhea. The obtained country-specific estimates of diarrhea deaths were further multiplied by the median proportion for that stratum of diarrhea hospitalizations attributable to rotavirus. The results of these calculations are presented in the Appendix B (online only; available from: URL: http://www.cdc.gov/ncidod/EID/vol9no5/02-0562_appB.htm) and shown in Figure 2.

Discussion

The findings of this study demonstrate the tremendous amount of global illness and deaths caused by rotavirus disease. Each year, rotavirus causes an estimated 111 million episodes of diarrhea requiring only home care, 25 million clinic visits, 2 million hospitalizations, and 352,000–592,000 deaths (median 440,000 deaths) in children <5 years of age. In other words, by 5 years of age, almost all children will have an episode of rotavirus gastroenteritis, 1 in 5 will require a clinic visit, 1 in 65 will require hospitalization, and approximately 1 in 293 will die (Figure 3). The incidence of rotavirus disease is similar in children in both developed and developing nations. However, children in developing nations die more frequently, possibly because of several factors, including

Table 3. Annual incidence of hospitalizations for rotavirus gastroenteritis in children <5 years of age in selected industrialized countries

Country (reference)	Y	Annual incidence/100,000 children	Cumulative incidence by 5 y of age
Spain (11)	1989–1995	250	1 in 80
Netherlands (12)	1998	270	1 in 74
United States (13)	1993–1995	274	1 in 73
Poland (14)	1996	310	1 in 65
Sweden (15)	1993–1996	370 ^a	1 in 54
United Kingdom (16)	1993–1994	520	1 in 38
Finland (17)	1985–1995	610	1 in 33
Australia (18)	1993–1996	750	1 in 27
Hungary (19)	1993–1996	840 ^a	1 in 24
Australia (20)	1991–1993	870	1 in 23

^aIncidence for children <4 years of age.

Table 4. Annual global illness incidence from rotavirus disease among children <5 years age, by setting

Setting	No. (range) of episodes of rotavirus disease (x1,000)		
	Developing countries	Industrialized countries	Total
Home	104,280 (51,496–157,063)	7,122 (2,123–17,881)	111,402 (53,619–174,946)
Outpatient	23,233 (18,537–27,188)	1,781 (708–3,576)	25,017 (19,245–30,764)
Inpatient	1,920 (1,551–2,596)	223 (142–358)	2,143 (1,693–2,954)

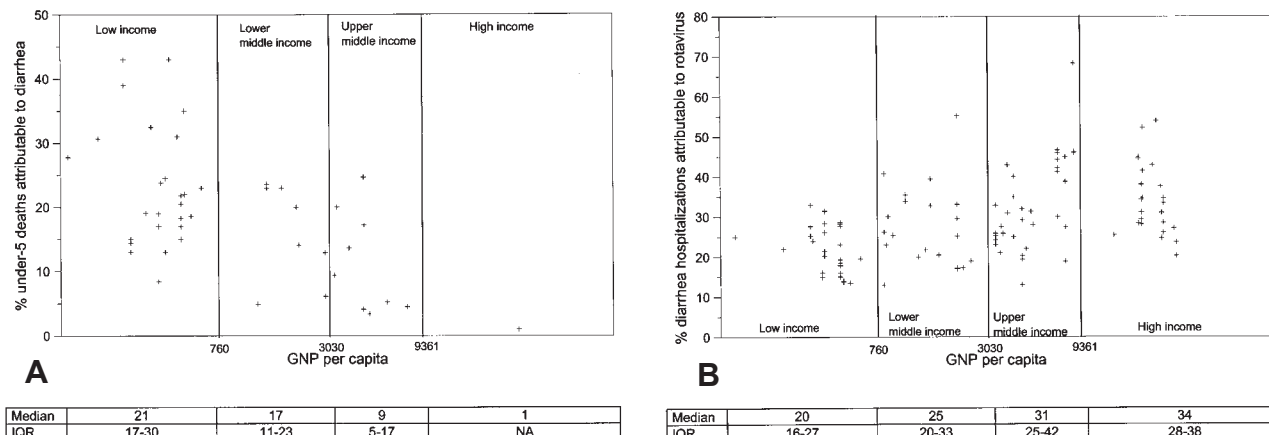


Figure 1. A. Percentage of deaths in children <5 years that are attributable to diarrhea for countries in different World Bank income groups, by gross national product (GNP) per capita of the country. B. Percentage of diarrhea hospitalization attributable to rotavirus for countries in different World Bank income groups, by GNP per capita of the country. IQR, interquartile range.

poorer access to hydration therapy and a greater prevalence of malnutrition. An estimated 1,205 children die from rotavirus disease each day, and 82% of these deaths occur in children in the poorest countries.

In 1986, the Institute of Medicine (IOM) estimated, on the basis of published studies and field experience, that annually rotavirus causes approximately 110 million episodes of mild diarrhea, 10 million episodes of moderate to severe diarrhea, and 9 million episodes of severe diarrhea in children <5 years of age worldwide (23). Our estimate of the incidence of rotavirus gastroenteritis is similar to the IOM estimate and is consistent with a recent analysis demonstrating that overall diarrhea illness in children worldwide has not declined appreciably in the past two decades (5). However, our estimate of total hospitalizations from rotavirus disease is substantially lower than the IOM estimate. The difference might be explained, in part, by the relatively low hospitalization rate for diarrhea in the study in Chile (1.5% of all diarrhea episodes) used in our calculations (8). However, a study in a low-income urban community in Thailand showed a similar hospitalization rate (1% of all diarrhea episodes) among children with diarrhea (10), giving us added confidence in our estimates.

Increased use of oral rehydration therapy and improvements in nutritional status are two factors that might explain a possible reduction in severe rotavirus cases without a concomitant decline in diarrhea incidence (24,25).

Our estimate of 352,000–592,000 deaths (median: 440,000 deaths) from rotavirus disease each year is similar to a recent estimate of 418,000–520,000 deaths proposed by Miller and McCann (6) but is substantially lower than the 1985 IOM estimate of 873,000 deaths. This decline in the rotavirus mortality rate parallels the decline in overall deaths from diarrhea in children in the past two decades, from an estimated 4.6 million deaths in 1982 (26) to our estimate of 2.1 million deaths in 2000. However, the patterns of diarrhea deaths reported in this study reflect the situation a decade ago, when most studies that we reviewed were conducted. Analyses of vital registration data from several countries have suggested that the proportion of deaths from diarrhea may have declined further in recent years (27). Other studies have noted marked discrepancies in the analysis of cause of death from vital registration data and prospective observational studies (28). Careful and detailed analyses are required to assess the current magnitude of the deaths from diarrhea in children,

Table 5. Global estimates of the annual number of diarrhea and rotavirus deaths among children <5 years of age, by income group

Income group	Total no. (x1,000)		Diarrhea deaths		Rotavirus deaths ^b		Risk of dying from rotavirus by age 5
	Births	Deaths	Median % (IQR ^a) of total deaths	Median no. (IQR) of deaths (x1,000)	Median % (IQR) of diarrhea hospitalizations	Median no. (IQR) of deaths (x1,000)	
Low	70,447	8,595	21 (17–30)	1,805 (1,461–2,579)	20 (16–27)	361 (289–487)	1 in 205
Low middle	37,402	1,609	17 (11–23)	274 (177–370)	25 (20–33)	69 (55–90)	1 in 542
Upper middle	11,520	366	9 (5–17)	33 (18–62)	31 (25–42)	10 (8–14)	1 in 1,152
High	9,931	60	1	<1	34 (28–38)	<1	1 in 48,680
Total	129,300	10,630	NA	2,112 (1,657–3,012)	NA	440 (352–592)	1 in 293

^aIQR, interquartile range; NA, not applicable.

^bThe estimated number and range of deaths from rotavirus are derived by multiplying the median and IQR of diarrhea hospitalizations attributable to rotavirus by the median number of deaths caused by diarrhea for each stratum

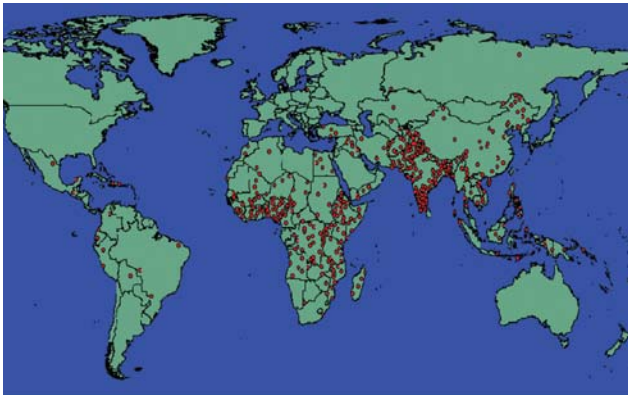


Figure 2. Estimated global distribution of 440,000 annual deaths in children caused by rotavirus diarrhea. One dot=1,000 deaths

and the results will directly affect our estimates of deaths from rotavirus disease. For example, if our estimated proportion of severe diarrhea cases attributable to rotavirus is applied to the recent estimate of 2.5 million annual diarrhea deaths developed by Kosek et al. (5), we estimate 416,000–700,000 annual deaths (median:520,000 deaths) from rotavirus disease.

Another important factor that could affect our estimate of rotavirus deaths is the possibility that as the overall mortality rate from diarrhea has declined over the past two decades, the proportion of diarrhea deaths attributable to rotavirus may have increased, given that this pathogen is often transmitted from person to person and is difficult to control through improvements in hygiene and sanitation. This hypothesis is supported by data from Mexico, demonstrating that whereas deaths from diarrhea declined substantially from 1989 to 1995, the decline was less evident for winter seasonal deaths in children <2 years of age whose illness met the epidemiologic features of rotavirus diarrhea (29). In addition, some recent studies of rotavirus based on hospital surveillance in developing countries have demonstrated detection rates in excess of 50% (30,31). If this trend is confirmed as additional data become available from ongoing surveillance studies in several regions of the world, the estimates of rotavirus deaths reported in this article will have to be revised to reflect current mortality patterns.

This review, based on a compilation of studies varying in design, time, and place, has several inherent limitations that we attempted to address. Because of the marked seasonality of rotavirus disease and the variation in the sensitivity and specificity of diagnostic tests for rotavirus, we restricted this review to studies that lasted at least 1 year and used reliable assays for the detection of rotavirus. To account for known temporal changes in the magnitude and patterns of diarrhea-associated childhood deaths, we reviewed only studies published within the last 15 years and used the most recent available estimates of total deaths

in children <5 years to calculate estimates of diarrhea deaths. Furthermore, because regional boundaries are primarily based on geographic and political considerations and do not necessarily reflect important determinants of health, we used indicators of socioeconomic status to stratify our analyses of mortality patterns.

Nevertheless, we could not adequately account for several factors that may have affected our findings. First, the studies we reviewed were conducted in selective populations that may not have been representative of the entire country. Second, most diarrhea mortality studies used verbal autopsies to determine the cause of death, which may affect our estimates because these methods have variable sensitivity and specificity and it is difficult, if not impossible, to assign a single cause of death for children who died with multiple conditions (32–34). Finally, because of a time lag between the conduct of studies and publication of their findings, our data likely do not reflect the most current trends of diarrhea and rotavirus disease patterns.

In 1998, the first rotavirus vaccine was licensed in the United States, offering an encouraging opportunity for the prevention of this disease. However, the vaccine was withdrawn within a year of licensure because it caused an estimated one case of intussusception for every 12,000 vaccinated infants. The lack of sufficient data on the efficacy of vaccine in developing countries as well as political and ethical considerations diminished prospects for its use in these settings. Our findings demonstrate that the next generation of rotavirus vaccines will have greatest impact in developing countries where the disease burden is greatest. Our estimates of rotavirus mortality rates for individual countries, although developed with relatively crude methods, compare favorably with those from more detailed analysis conducted in selected countries. For example, good concordance was noted between the previous figures and our estimates of rotavirus mortality for Bangladesh (14,850–27,000 vs. 13,104 deaths) (35), Peru (1,600 vs. 1,360 deaths) (36), and India (98,000 vs. 100,800 deaths) (37). The establishment of regional networks for rotavirus surveillance in sentinel hospitals will facilitate more time-

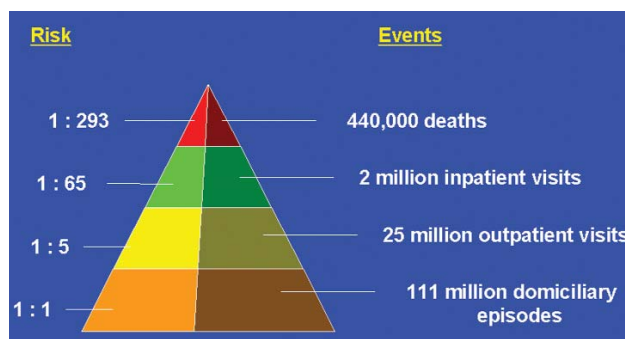


Figure 3. Estimated global prevalence of rotavirus disease.

ly and refined estimates of disease illness and death. These data, along with information on illness and costs of rotavirus infections, will assist policy makers in assessing the magnitude of the problem of rotavirus in their own setting and in setting priorities for interventions, such as the next generation of rotavirus vaccines, which may be available in the near future.

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References

- De Zoysa I, Feachem RG. Interventions for the control of diarrhoeal disease among young children: rotavirus and cholera immunization. *Bull World Health Organ* 1985;63:569–83.
- Parashar UD, Bresee JS, Gentsch JR, Glass RI. Rotavirus. *Emerg Infect Dis* 1998;4:562–70.
- Bresee J, Glass RI, Ivanoff B, Gentsch J. Current status and future priorities for rotavirus vaccine development, evaluation, and implementation in developing countries. *Vaccine* 1999;17:2207–22.
- Murphy TV, Gargiullo PM, Massoudi MS, Nelson DB, Jumaan AO, Okoro CA, et al. Intussusception among infants given an oral rotavirus vaccine. *N Engl J Med* 2001;344:564–72.
- Kosek M, Bern C, Guerrant RL. The magnitude of the global burden of diarrheal disease from studies published 1992–2000. *Bull World Health Organ* 2003, in press.
- Miller MA, McCann L. Policy analysis of the use of hepatitis B, *Haemophilus influenzae* type b-, *Streptococcus pneumoniae*-conjugate, and rotavirus vaccines, in National Immunization Schedules. *Health Economics* 2000;9:19–35.
- The sex and age distribution of the world's populations: The 1994 revision. New York: United Nations; 1994.
- Ferreccio C, Prado V, Ojeda A, Cayazo M, Abrego P, Guers L, et al. Epidemiologic patterns of acute diarrhea and endemic *Shigella* infections in children in a poor periurban setting in Santiago, Chile. *Am J Epidemiol* 1991;134:614–27.
- World Bank. Classification of economies by income, 2000 [cited 2003 Feb 25]. Available from: URL: <http://www.worldbank.org/poverty/wdrpoverty/report/ch12b.pdf>
- Punyaratabandhu P, Vathanophas K, Varavithya W, Sangchai R, Athipanyakom S, Echeverria P, et al. Childhood diarrhoea in a low-income urban community in Bangkok: incidence, clinical features, and child caretaker's behaviours. *Journal of Diarrhoeal Diseases Research* 1991;9:244–9.
- Visser LE, Cano Portero R, Gay NJ, Martinez Navarro JF. Impact of rotavirus disease in Spain: an estimate of hospital admissions due to rotavirus. *Acta Paediatr* 1999;88:S72–6.
- deWit MAS, Koopmans MPG, van der Blig JF, van Duynhoven YTHP. Hospital admissions for rotavirus infection in the Netherlands. *Clin Infect Dis* 2000;31:698–704.
- Parashar UD, Holman RC, Clarke MJ, Bresee JS, Glass RI. 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;177:13–7.
- Mrukowicz JZ, Krobicka B, Duplaga M, Kowalska-Duplaga K, Domanski J, Szajewska H, et al. Epidemiology and impact of rotavirus diarrhoea in Poland. *Acta Paediatr* 1999;88:53–60.
- Johansen K, Bennet R, Bondesson K, Eriksson M, Hedlund KO, De Verdier Klingenberg K, et al. Incidence and estimates of the disease burden of rotavirus in Sweden. *Acta Paediatr* 1999;426:S20–3.
- Ryan MJ, Ramsay M, Brown D, Gay NJ, Farrington CP, Wall PG. Hospital admissions attributable to rotavirus infection in England and Wales. *J Infect Dis* 1996;174(Suppl 1):S12–8.
- Vesikari T, Rautanen T, Bonsdorff CHV. Rotavirus gastroenteritis in Finland: burden of disease and epidemiological features. *Acta Paediatr* 1999;426:S24–30.
- Carlin JB, Chondros P, Masendycz P, Bugg H, Bishop RF, Barnes GL. Rotavirus infection and rates of hospitalisation for acute gastroenteritis in young children in Australia, 1993?1996. *Med J Aust* 1998;169:252–6.
- Szucs G, Uj M, Mihaly I, Deak J. Burden of human rotavirus-associated hospitalizations in three geographic regions of Hungary. *Acta Paediatr* 1999;426:S61–5.
- Ferson MJ. Hospitalizations for rotavirus gastroenteritis among children under five years of age in New South Wales. *Med J Aust* 1996;164:273–6.
- Ford-Jones EL, Wang E, Petric M, Corey P, Moineddin R, Fearon M. Rotavirus-associated diarrhea in outpatient settings and child care centers. *Arch Pediatr Adolesc Med* 2000;154:586–93.
- Rodriguez WJ, Kim HW, Brandt CD, Schwartz RH, Gardner MK, Jeffries B, et al. Longitudinal study of rotavirus infection and gastroenteritis in families served by a pediatric medical practice: clinical and epidemiologic observations. *Pediatr Infect Dis J* 1987;6:170–6.
- Institute of Medicine. The prospects of immunizing against rotavirus. In: *New vaccine development: diseases of importance in developing countries*. Washington: National Academy Press; 1986: D13-1–D13-12.
- Victoria CG, Bryce J, Fontaine O, Monasch R. Reducing deaths from diarrhoea through oral rehydration therapy. *Bull World Health Organ* 2000;78:1246–55.
- de Onis M, Frongillo EA, Blossner M. Is malnutrition declining? An analysis of changes in levels of child malnutrition since 1980. *Bull World Health Organ* 2000;78:1222–33.
- Snyder JD, Merson MH. The magnitude of the global problem of acute diarrhoeal disease: a review of active surveillance data. *Bull World Health Organ* 1982;60:605–13.
- Miller P, Hirschhorn N. The effect of a national control of diarrheal diseases program on mortality: the case of Egypt. *Soc Sci Med* 1995;40:S1–30.
- Langsten R, Hill K. Diarrhoeal disease, oral rehydration, and childhood mortality in rural Egypt. *J Trop Pediatr* 1994;40:272–8.
- Villa S, Guiscafre H, Martinez H, Munoz O, Guierrez G. Seasonal diarrhoeal mortality among Mexican Children. *Bull World Health Organ* 1999;77:375–80.
- Cama RI, Parashar UD, Taylor DN, Hickey T, Figueroa D, Ortega YR, et al. Enteropathogens and other factors associated with severe disease in children with acute watery diarrhea in Lima, Peru. *J Infect Dis* 1999;179:1139–44.
- Nguyen VM, Nguyen VT, Huynh PL, Dang DT, Nguyen TH, Phan VT, et al. The epidemiology and disease burden of rotavirus in Vietnam: sentinel surveillance at 6 hospitals. *J Infect Dis* 2001;183:1707–12.
- Mobley CC, Boerma JT, Titus S, Lohrke B, Shangula K, Black RE. Validation study of a verbal autopsy method for causes of childhood mortality in Namibia. *J Trop Pediatr* 1996;42:365–9.
- Kalter HD, Gray RH, Black RE, Gultiano SA. Validation of post-mortem interviews to ascertain selected causes of death in children. *Int J Epidemiol* 1990;19:380–6.
- Snow RW, Armstrong JR, Forster D, Winstanley MT, Marsh VM, Newton CR, et al. Childhood deaths in Africa: uses and limitations of verbal autopsies. *Lancet* 1992;340:351–5.

35. Unicomb LE, Kilgore PE, Faruque SG, Hamadani JD, Fuchs GJ, Albert MJ, et al. Anticipating rotavirus vaccines: hospital-based surveillance for rotavirus diarrhea and estimates of disease burden in Bangladesh. *Pediatr Infect Dis J* 1997;16:947-51.
36. Ehrenkranz P, Lanata CF, Penny ME, Salazar-Lindo E, Glass RI. Rotavirus diarrhea disease burden in Peru: the need for a rotavirus vaccine and its potential cost savings. *Rev Panam Salud Publica* 2001;10:240-8.
37. Jain V, Parashar UD, Glass RI, Bhan MK. Epidemiology of rotavirus in India. *Indian J Pediatr* 2001;68:855-62.

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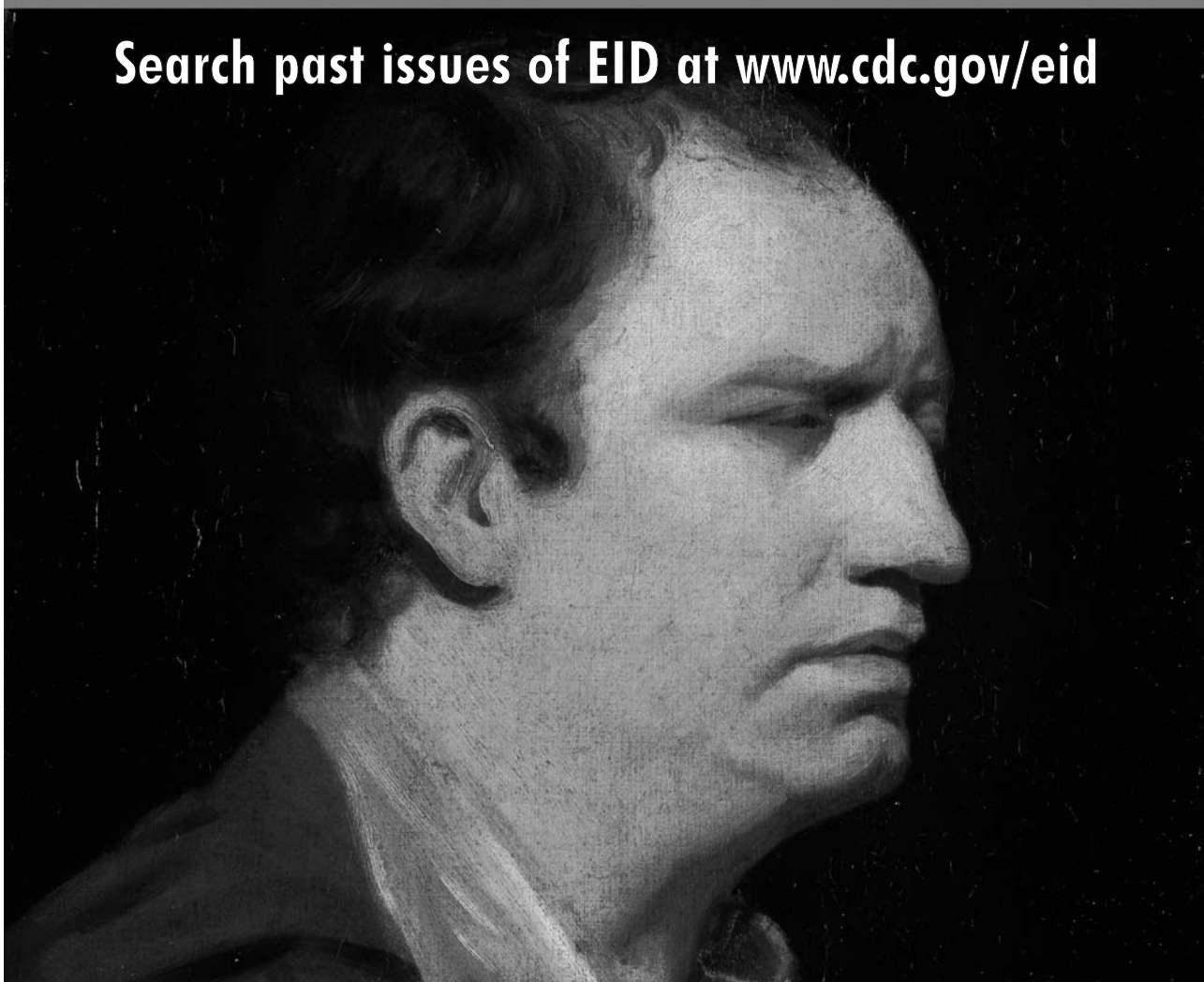
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Appendix A. [online only] Studies of Rotavirus Diarrhea Included in this Analysis

1. Bhan MK, Bhandari N, Sazawal S, Clemens J, Raj P, Levine MM, et al. Descriptive epidemiology of persistent diarrhoea among young children in rural northern India. *Bull World Health Organ* 1989;67:281–8.
2. Raj P, Bhan MK, Prasad AK, Kumar R, Bhandari N, Jayashree S. Electrophoretic study of the genome of human rotavirus in rural Indian community. *Indian J Med Res* 1989;89:65–8.
3. Nath G, Shukla BN, Reddy DCS, Sanyal SC. A community study on the aetiology of childhood diarrhoea with special reference to *Campylobacter jejuni* in a semiurban slum of Varanasi, India. *J Diarrhoeal Dis Res* 1993;11:165–8.
4. Nath G, Singh SP, Sanyal SC. Childhood diarrhoea due to rotavirus in a community. *Indian J Med Res* 1992;95:259–62.
5. Yachha SK, Singh V, Kanwar SS, Mehta S. Epidemiology, subgroups and serotypes of rotavirus diarrhea in north Indian communities. *Indian J Pediatr* 1994;31:27–33.
6. Schorling JB, Wanke CA, Schorling SK, McAuliffe JF, deSouza A, Guerrant RL. A prospective study of persistent diarrhea among children in an urban Brazilian slum. *Am J Epidemiol* 1990;132:144–56.
7. Black RE, de Romana GL, Brown KH, Bravbo N, Bazalar OG, Kanashiro HC. Incidence and etiology of infantile diarrhea and major routes of transmission in Huascar, Peru. *Am J Epidemiol* 1989;129:785–99.
8. Cravioto A, Reyes RE, Ortega R, Fernandez G, Hernandez R, Lopez D. Prospective study of diarrhoeal disease in a cohort of rural Mexican children: incidence and isolated pathogens during the first two years of life. *Epidemiol Infect* 1988;101:123–34.
9. Cruz JR, Caceres P, Cano F, Flores J, Bartlett A, Torun B. Adenovirus types 40 and 41 and rotaviruses associated with diarrhea in children from Guatemala. *J Clin Microbiol* 1990;28:1780–4.
10. Linhares AC, Gabbay YB, Freitas RB, da Rosa ES, Mascarenhas JDP, Loureiro ECB. Longitudinal study of rotavirus infections among children from Belem, Brazil. *Epidemiol Infect* 1989;102:129–45.
11. Perez-Schael I, Garcia D, Gonzalez M, Gonzalez R, Daoud N, Perez M, et al. Prospective study of diarrheal diseases in Venezuelan children to evaluate the efficacy of rhesus rotavirus vaccine. *J Med Virol* 1990;30:219–29.
12. Espinoza F, Paniagua M, Hallander H, Svensson L, Strannegard O. Rotavirus infections in young Nicaraguan children. *Pediatr Infect Dis J* 1997;16:564–71.
13. Perez-Schael I. The impact of rotavirus disease in Venezuela. *J Infect Dis* 1996 Sep;174(Suppl 1):S19–21.
14. Zaki AM, DuPont HL, el Alamy MA, Arafat RR, Amin K, Awad MM, et al. The detection of enteropathogens in acute diarrhea in a family cohort population in rural Egypt. *Am J Trop Med Hyg* 1986;35:1013–22.
15. Naficy AB, Abu-Elyazeed R, Holmes JL, Rao MR, Savarino SJ, Kim Y, et al. Epidemiology of rotavirus diarrhea in Egyptian children and implications for disease control. *Am J Epidemiol* 1999;150:770–7.
16. Varavithya W, Vathanophas K, Bodhidatta L, Punyaratabandhu P, Sangchai R, Athipanyakom S, et al. Importance of salmonellae and *Campylobacter jejuni* in the etiology of diarrheal disease among children less than 5 years of age in a community in Bangkok, Thailand. *J Clin Microbiol* 1990;28:2507–10.
17. Khalil K, Lindblom GB, Mazhar K, Khan SR, Kajiser B. Early child health in Lahore, Pakistan: VIII. Microbiology. *Acta Paediatr* 1993;390:S87–94.
18. Yap KL, Yasmin AM, Wong YH, Ooi YE, Tan SC, Jegathesan M, et al. A one year community-based study on the incidence of diarrhoea and rotavirus infection in urban and suburban Malaysian children. *Med J Malaysia* 1992;47:303–8.
19. Coker AO, Dosunmu-Ogunbi O, Odugbemi T, Alabi SA, Macaulay SA. A study on the prevalence of rotavirus diarrhoeas in Ohazora local government area, Imo State, Nigeria, and the Lagos University Teaching Hospital, Lagos, Nigeria. *East Afr Med J* 1987;586–9.
20. Nakano T, Binka FN, Afari EA, Agbodaze D, Aryeetey ME, Mingle JAA, et al. Survey of enteropathogenic agents in children with and without diarrhoea in Ghana. *J Trop Med Hyg* 1990;93:408–12.
21. Oyejide CO, Fagbami AH. An epidemiological study of rotavirus diarrhoea in a cohort of Nigerian infants: II. Incidence of diarrhoea in the

- first two years of life. *Int J Epidemiol* 1988;17:908–12.
22. Tswana SA, Jorgensen PH, Halliwell RW, Kapaata R, Moyo SR. The incidence of rotavirus infection in children from two selected study areas in Zimbabwe. *Cent Afr J Med* 1990;36:241–6.
 23. Molbak K, Wested N, Hojlyng N, Scheutz F, Gottschau A, Aaby P, et al. The etiology of early childhood diarrhea: a community study from Guinea-Bissau. *J Infect Dis* 1994;169:581–7.
 24. Punyaratabandhu P, Vathanophas K, Varavithya W, Sangchai R, Ahipanyakom S, Echeverria P, et al. Childhood diarrhoea in a low-income urban community in Bangkok: incidence, clinical features, and child caretaker's behaviours. *J Diarrhoeal Dis Res* 1991;9:244–9.
 25. Bhan MK, Raj P, Bhandari N, Svensson L, Stintzing G, Prasad AK, et al. Role of enteric adenoviruses and rotaviruses in mild and severe acute enteritis. *Pediatr Infect Dis J* 1988;7:320–3.
 26. Broor S, Husain M, Chatterjee B, Chakraborty A, Seth P. Temporal variation in the distribution of rotavirus electropherotypes in Delhi, India. *J Diarrhoeal Dis Res* 1993;11:14–8.
 27. Racz ML, Candeias JA, Trabulsi JR, Murahowski J. Diarrheal diseases in Brazil: clinical features of rotavirus-associated gastroenteritis in children. *Eur J Epidemiol* 1988;4:382–5.
 28. Stewien KE, da Cunha LC, Alvim A de C, dos Reis Filho SA, Alvim MA, Brandao AA, et al. Rotavirus associated diarrhoea during infancy in the city of S. Luis (MA), Brazil: a two-year longitudinal study. *Revista do Instituto de Medicina Tropical de Sao Paulo* 1991;33:459–64.
 29. Candeias JAN, Racz ML, Travulsi LR, Murahowsky J. Relative prevalence of rotavirus diarrhoea in children attending outpatient departments of hospitals and general practitioners in Sao Paulo, Brazil. *J Diarrhoeal Dis Res* 1989;7:24–7.
 30. Perez-Schael I, Gonzalez R, Fernandez R, Alfonzo E, Inaty D, Boher Y, et al. Epidemiological features of rotavirus infection in Caracas, Venezuela: implications for rotavirus immunization programs. *J Med Virol* 1999;59:520–6.
 31. Dutta SR, Khalfan SA, Baig BH, Philipose L, Fulayfil R. Epidemiology of rotavirus diarrhoea in children under five years in Bahrain. *Int J Epidemiol* 1990;19:722–7.
 32. Pazzaglia G, Bourgeois AL, Araby I, Mikhail I, Podgore JK, Mourad A, et al. Campylobacter-associated diarrhoea in Egyptian infants: epidemiology and clinical manifestations of disease and high frequency of concomitant infections. *J Diarrhoeal Dis Res* 1993;11:6–13.
 33. Herrmann JE, Blacklow NR, Perron-Henry DM, Clements E, Taylor DN, Echeverria P. Incidence of enteric adenoviruses among children in Thailand and the significance of these viruses in gastroenteritis. *J Clin Microbiol* 1988;26:1783–6.
 34. Bingnan F, Unicomb L, Rahim Z, Nahar Banu N, Podder G, Clemens J, et al. Rotavirus-associated diarrhea in rural Bangladesh: two-year study of incidence and serotype distribution. *J Clin Microbiol* 1991;29:1359–63.
 35. Phetsouvanh R, Midorikawa Y, Nakamura S. The seasonal variation in the microbial agents implicated in the etiology of diarrheal diseases among children in Lao People's Democratic Republic. *Southeast Asian J Trop Med Public Health* 1999;30:319–23.
 36. Faruque ASG, Mahalanabis D, Islam A, Hoque SS, Hasnat A. Common diarrhea pathogens and the risk of dehydration in young children with acute watery diarrhea: a case-control study. *Am J Trop Med Hyg* 1993;49:93–100.
 37. Armah GE, Mingle JA, Doodoo AK, Anyanful A, Antwi R, Commey J, et al. Seasonality of rotavirus infection in Ghana. *Ann Trop Paediatr* 1994;14:223–9.
 38. Wu H, Taniguchi K, Urasawa T, Urasawa S. Serological and genomic characterization of human rotaviruses detected in China. *J Med Virol* 1998;55:168–76.
 39. Fang ZY, Yang H, Zhang J, Li YF, Hou AC, Ma L, et al. Child rotavirus infection in association with acute gastroenteritis in two Chinese sentinel hospitals. *Pediatr Int* 2000;42:401–5.
 40. Huilan S, Zhen LG, Mathan MM, Mathew MM, Olarte J, Espejo R, et al. Etiology of acute diarrhoea among children in developing countries: a multicentre study in five countries. *Bull World Health Organ* 1991;69:549–55.
 41. Malik A, Rattan A, Malik MA, Shukla I. Rotavirus diarrhoea of infancy and childhood in a North Indian town—epidemiological aspects. *J Trop Pediatr* 1987;33:243–5.
 42. Brown DW, Mathan MM, Mathew M, Martin R, Beards GM, Mathan VI. Rotavirus epidemiology in Vellore, south India: group, subgroup,

- serotype, and electrophoretotype. *J Clin Microbiol* 1988;6:2410–4.
43. Singh PB, Sreenivasan MA, Pavri KM. Viruses in acute gastroenteritis in children in Pune, India. *Epidemiol Infect* 1989;102:345–53.
 44. Desai HS, Banker DD. Rotavirus infection among children in Bombay. *Indian J Med Sci* 1993;47:27–33.
 45. Chakravarti A, Kumar S, Mittal SK, Broor S. Clinical and epidemiological features of acute gastroenteritis caused by human rotavirus subgroups. *J Diarrhoeal Dis Res* 1992;10:21–4.
 46. Aggarwal P, Singh M, Guha DK. Prevalence of bacterial pathogens and rotavirus in hospitalised children with acute diarrhoea in Delhi, India. *J Diarrhoeal Dis Res* 1988;6:37–8.
 47. Kelkar SD, Purohit SG, Simha KV. Prevalence of rotavirus diarrhoea among hospitalized children in Pune, India. *Indian J Med Res* 1999;109:131–5.
 48. Ballal M, Jyothiratha, Kotigadde S, Venkatesh A, Shivananda PG. Rotavirus and bacterial enteropathogens causing acute diarrhea. *Ind J Pediatr* 1992;59:203–7.
 49. Chakravarti A, Broor S, Natarajan R, Setty VS, Mittal SK. Epidemiological and clinical characteristics of acute diarrhoea in children due to human rotavirus. *J Trop Pediatr* 1992;38:192–3.
 50. Patwari AK, Srinivasan A, Diwan N, Aneja S, Anand VK, Peshin S. Rotavirus as an aetiological organism in acute watery diarrhoea in Delhi children: reappraisal of clinical and epidemiological characteristics. *J Trop Pediatr* 1994;40:214–8.
 51. Husain M, Seth P, Broor S. Detection of group A rotavirus by reverse transcriptase and polymerase chain reaction in feces from children with acute gastroenteritis. *Arch Virol* 1995;140:1225–33.
 52. Singh V, Broor S, Mehta S, Mehta SK. Molecular epidemiology of human rotavirus infections in Chandigarh (India). *Indian J Med Res* 1990;91:9–14.
 53. Ghosh SK, Naik TN. Evidence for a new rotavirus subgroup in India. *Epidemiol Infect* 1989;102:523–30.
 54. Aggarwal P, Srivastav VK, Singh M, Khanna KK. Rotavirus shown to be the main cause of acute childhood diarrhoea in a New Delhi Hospital with a high prevalence in winter. *J Diarrhoeal Dis Res* 1988;6:39–40.
 55. Singh V, Broor S, Mehta S, Mehta SK. Clinical and epidemiological features of acute gastroenteritis associated with human rotavirus subgroups 1 and 2 in northern India. *Indian J Gastroenterol* 1989;8:23–5.
 56. Mathew M, Mathan MM, Mani K, George R, Jebakumar K, Dharamsi R, et al. The relationship of microbial pathogens to acute infectious diarrhoea of childhood. *J Trop Med Hyg* 1991;94:253–60.
 57. Dowe G, King SD, Maitland PB, Swaby-Ellis DE. Laboratory investigations on rotavirus in infantile gastroenteritis in Jamaica. *Trans R Soc Trop Med Hyg* 1988;82:155–9.
 58. Stewien KE, Mos EN, Yanaguita RM, Jerez JA, Durigon EL, Harsi CM, et al. Viral, bacterial and parasitic pathogens associated with severe diarrhoea in the city of Sao Paulo, Brazil. *J Diarrhoeal Dis Res* 1993;11:148–52.
 59. Cardoso D, Martins RM, Kitajima EW, Barbosa AJ, Camarota SC, Azevedo MS. Rotavirus and adenovirus in 0- to 5-year-old children hospitalized with or without gastroenteritis in Goiana, GO, Brazil. *Revista do Instituto de Medicina Tropical de Sao Paulo* 1992;34:433–9.
 60. Teixeira JM, de Figueiredo RB, dos Santos HM, Ferreira MN, Camara GN. Epidemiology of rotavirus infections in the Federal District, Brazil. *Revista Da Sociedade Brasileira de Medicina Tropical* 1991;24:223–30.
 61. Puerto FI, Polanco GG, Gonzalez MR, Zavala JE Jr, Ortega G. Role of rotavirus and enteric adenovirus in acute paediatric diarrhoea at an urban hospital in Mexico. *Trans R Soc Trop Med Hyg* 1989;83:396–8.
 62. Suzuki H, Sato T, Kitaoka S, Tazawa F, Konno T, Amano Y, et al. Epidemiology of rotavirus in Guayaquil, Ecuador. *Am J Trop Med Hyg* 1986;35:372–5.
 63. Urquidi V. Molecular epidemiology of human rotavirus infection in Coro, Venezuela. *Acta Cientifica Venezolana* 1989;40:33–9.
 64. Perez-Schael I, Gonzalez R, Fernandez R, Alfonzo E, Inaty D, Boher Y, et al. Epidemiological features of rotavirus infection in Caracas, Venezuela: implications for rotavirus immunization programs. *J Med Virol* 1999;59:520–6.
 65. Cama RI, Parashar UD, Taylor DN, Hickey T, Figueroa D, Ortega YR, et al. Enteropathogens and other factors associated with severe

- disease in children with acute watery diarrhea in Lima, Peru. *J Infect Dis* 1999;179:1139–44.
66. Shukry S, Zaki AM, DuPont HL, Shoukry I, el Tagi M, Hamed Z. Detection of enteropathogens in fatal and potentially fatal diarrhea in Cairo, Egypt. *J Clin Microbiol* 1986;24:959–62.
 67. el-Mougi M, Amer A, el-Abhar A, Hughes J, el-Shafie A. Epidemiological and clinical features of rotavirus associated acute infantile diarrhoea in Cairo, Egypt. *J Trop Pediatr* 1989;35:230–3.
 68. Aithala G, Al Dhahry SH, Saha A, Elbualy MS. Epidemiological and clinical features of rotavirus gastroenteritis in Oman. *J Trop Pediatr* 1996;42:54–7.
 69. Dagan R, Bar-David Y, Sarov B, Katz M, Kassis I, Greenberg D, et al. Rotavirus diarrhea in Jewish and Bedouin children in the Negev region of Israel: epidemiology, clinical aspects and possible role of malnutrition in severity of illness. *Pediatr Infect Dis J* 1990;9:314–21.
 70. Adkins HJ, Escamilla J, Santiago L, Ranoa C, Echeverria P, Cross JH. Two-year survey of etiologic agents of diarrheal disease at San Lazaro Hospital, Manila, Republic of Philippines. *J Clin Microbiol* 1987;25:1143–7.
 71. Marjoribanks HC, Croxson MC, Potoi N, Bellamy AR. Infantile gastroenteritis in Western Samoa. *New Zealand Med J* 1988;101:195–7.
 72. Pipittajan P, Kasempimolporn S, Ikegami N, Akatani K, Wasi C, Sinarachatanant P. Molecular epidemiology of rotaviruses associated with pediatric diarrhea in Bangkok, Thailand. *J Clin Microbiol* 1991;29:617–24.
 73. Hasegawa A, Mukoyama A, Suzuki H, Inouye S, Chearskul S, Thongkrajai P, et al. Rotavirus infection of Thai infants: antigen detection, RNA electrophoresis and virus cultivation. *J Diarrhoeal Dis Res* 1987;5:165–70.
 74. Bern C, Unicomb L, Gentsch JR, Banul N, Yunus M, Sack RB, et al. Rotavirus diarrhea in Bangladeshi children: correlation of disease severity with serotypes. *J Clin Microbiol* 1992;30:3234–8.
 75. San Pedro MC, Walz SE. A comprehensive survey of pediatric diarrhea at a private hospital in Metro Manila. *Southeast Asian J Trop Med Public Health* 1991;22:203–10.
 76. Doan TN, Nguyen VC. Preliminary study on rotavirus diarrhoea in hospitalized children at Hanoi. *J Diarrhoeal Dis Res* 1986;4:81–2.
 77. Howard P, Alexander ND, Atkinson A, Clegg AO, Gerega G, Javati A, et al. Bacterial, viral and parasitic aetiology of paediatric diarrhoea in the highlands of Papua New Guinea. *J Trop Pediatr* 2000;46:10–4.
 78. Suwatano O. Acute diarrhea in under five-year-old children admitted to King Mongkut Prachomkiao Hospital, Phetchaburi province. *J Med Assoc Thai* 1997;80:26–33.
 79. Hoque SS, Faruque AS, Mahalanabis D, Hasnat A. Infectious agents causing acute watery diarrhoea in infants and young children in Bangladesh and their public health implications. *J Trop Pediatr* 1994;40:351–4.
 80. Mubashir M, Khan A, Baqai R, Iqbal J, Ghafoor A, Zuberi S, et al. Causative agents of acute diarrhoea in the first 3 years of life: hospital-based study. *J Gastroenterol Hepatol* 1990;5:264–70.
 81. Mendis L, de Silva D, Soysa P, Lamabadusuriya SP. Rotavirus infection in children hospitalised with diarrhoea in Sri Lanka. *J Diarrhoeal Dis Res* 1990;8:90–3.
 82. Khan MM, Iqbal J, Ghafoor A, Burney MI. Aetiological agents of diarrhoeal diseases in hospitalised children in Rawalpindi, Pakistan. *J Diarrh Dis Res* 1988;6:228–31.
 83. Yap KL, Wong YH, Khor CM, Ooi YE. Rotavirus electropherotypes in Malaysian children. *Can J Microbiol* 1992;38:996–9.
 84. Sirisanthana V, Leechanachai P, Poocharoen L. A clinical study of rotavirus diarrhea in Thai children. *J Med Assoc Thai* 1987;70:567–73.
 85. Tabassum S, Shears P, Hart CA. Genomic characterization of rotavirus strains obtained from hospitalized children with diarrhoea in Bangladesh. *J Med Virol* 1994;43:50–6.
 86. Albert MJ, Faruque AS, Faruque SM, Sack RB, Mahalanabis D. Case-control study of enteropathogens associated with childhood diarrhea in Dhaka, Bangladesh. *J Clin Microbiol* 1999;37:3458–64.
 87. Nishio O, Matsui K, Oka T, Ushijima H, Mubina A, Dure-Samin A, et al. Rotavirus infection among infants with diarrhea in Pakistan. *Pediatr Int* 2000;42:425–7.
 88. Maneekarn N, Ushijima H. Epidemiology of rotavirus infection in Thailand. *Pediatr Int* 2000;42:415–21.

89. Unicomb LE, Kilgore PE, Faruque SG, Hamadani JD, Fuchs GJ, Albert MJ, et al. Anticipating rotavirus vaccines: hospital-based surveillance for rotavirus diarrhea and estimates of disease burden in Bangladesh. *Pediatr Infect Dis J* 1997;16:947–51.
90. Teka T, Faruque AS, Fuchs GJ. Risk factors for deaths in under-age-five children attending a diarrhoea treatment centre. *Acta Paediatr* 1996;85:1070–5.
91. Mpabalwani M, Oshitani H, Kasolo F, Mizuta K, Luo N, Matsubayashi N, et al. Rotavirus gastro-enteritis in hospitalized children with acute diarrhoea in Zambia. *Ann Trop Paediatr* 1995;15:39–43.
92. Kakai R, Wamola IA, Bwayo JJ, Ndinya-Achola JO. Enteric pathogens in malnourished children with diarrhoea. *East Afr Med J* 1995;72:288–9.
93. Saidi SM, Iijima Y, Sang WK, Mwangudza AK, Oundo JO, Taga K, et al. Epidemiological study on infectious diarrheal diseases in children in a coastal rural area of Kenya. *Microbiol Immunol* 1997;41:773–8.
94. Gomwalk NE, Gosham LT, Umoh UJ. Rotavirus gastroenteritis in pediatric diarrhoea in Jos, Nigeria. *J Trop Pediatr* 1990;36:52–5.
95. Casalino M, Yusuf MW, Nicoletti M, Bazzicalupo P, Coppo A, Colonna B, et al. A two-year study of enteric infections associated with diarrhoeal diseases in children in urban Somalia. *Trans R Soc Trop Med Hyg* 1988;82:637–41.
96. Coker AO, Dosunmu-Ogunbi O, Odugbemi T, Alabi SA, Macaulay SA. A study on the prevalence of rotavirus diarrhoeas in Ohazora local government area, Imo State, Nigeria, and the Lagos University Teaching Hospital, Lagos, Nigeria. *East Afr Med J* 1987;586–9.
97. Tazi-Lakhsassi L, Garbarg-Chenon A, Nicolas JC, Soubhi H, Benbachir M, el Mdaghri N, et al. Epidemiological and clinical study and electrophoretotyping survey of rotavirus acute diarrhoea in a children's infectious disease unit in Casablanca, Morocco. *Annales de l'Institut Pasteur Virol* 1988;139:205–15.
98. Gomwalk NE, Umoh UJ, Gosham LT, Ahmad AA. Influence of climatic factors on rotavirus infection among children with acute gastroenteritis in Zaria, northern Nigeria. *J Trop Pediatr* 1993;39:293–7.
99. Koulla-Shiro S, Loe C, Ekoe T. Prevalence of *Campylobacter enteritis* in children from Yaounde (Cameroon). *Cent Fr J Med* 1995;41:91–4.
100. Cisse MF, Ouangre RA, Gaye A, Boye CS, Sow AI, Mboup S, et al. Causes of infectious gastro-enteritis in children in Dakar. *Presse Med* 1989;18:1827–30.
101. Mefane C, Richard-Lenoble D, Gendrel D, Engonah E. Infantile diarrhea in Libreville (Gabon). Ecological studies. *Arch Fr Pediatr* 1986;43:813–6.
102. Tchambaz M, Messaoudi Z, Meziane O, Ammari H. Detection of rotavirus in the stools of infants aged 0–3 yr (study performed from July 1987 to May 1989). *Arch Inst Pasteur Alger* 1989;57:83–103.
103. Trabelsi A, Peenze I, Pager C, Jeddi M, Steele D. Distribution of rotavirus VP7 serotypes and VP4 genotypes circulating in Sousse, Tunisia, from 1995 to 1999: emergence of natural human reassortants. *J Clin Microbiol* 2000;38:3415–9.
104. Bos P, Mnisi YN, Steele AD. The molecular epidemiology of rotavirus infection in Ga-Rankuwa, southern Africa. *Cent Afr J Med* 1992;38:286–90.
105. Steele AD, Geyer A, Alexander JJ, Crewe-Brown HH, Fripp PJ. Enteropathogens isolated from children with gastro-enteritis at Ga-Rankuwa Hospital, South Africa. *Ann Trop Paediatr* 1988;8:262–7.
106. Griffiths FH, Steele AD, Alexander JJ. The molecular epidemiology of rotavirus-associated gastro-enteritis in the Transkei, Southern Africa. *Ann Trop Paediatr* 1992;12:259–64.
107. Steele AD, Alexander JJ. The relative frequency of subgroup I and II rotaviruses in black infants in South Africa. *J Med Virol* 1988;24:321–7.
108. Steele AD, Bos P, Alexander JJ. Clinical features of acute infantile gastroenteritis associated with human rotavirus subgroups I and II. *J Clin Microbiol* 1988;26:2647–9.
109. Visser LE, Cano Portero R, Gay NJ, Martinez Navarro JF. Impact of rotavirus disease in Spain: an estimate of hospital admissions due to rotavirus. *Acta Paediatr* 1999;88:S72–6.
110. deWit MAS, Koopmans MPG, van der Blig JF, van Duynhoven YTHP. Hospital admissions for rotavirus infection in the Netherlands. *Clin*

Infect Dis 2000;31:698–704.

111. Parashar UD, Holman RC, Clarke MJ, Bresee JS, Glass RI. 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;177:13–7.
112. Mrukowicz JZ, Krobicka B, Duplaga M, Kowalska-Duplaga K, Domanski J, Szajewska H, et al. Epidemiology and impact of rotavirus diarrhoea in Poland. *Acta Paediatr* 1999;88:53–60.
113. Johansen K, Bennet R, Bondesson K, Eriksson M, Hedlund KO, De Verdier Klingenberg K, et al. Incidence and estimates of the disease burden of rotavirus in Sweden. *Acta Paediatr* 1999;426:S20–3.
114. Ryan MJ, Ramsay M, Brown D, Gay NJ, Farrington CP, Wall PG. Hospital admissions attributable to rotavirus infection in England and Wales. *J Infect Dis* 1996;174(Suppl 1):S12–8.
115. Vesikari T, Rautanen T, Bonsdorff CHV. Rotavirus gastroenteritis in Finland: burden of disease and epidemiological features. *Acta Paediatr* 1999;426:S24–30.
116. Carlin JB, Chondros P, Masendycz P, Bugg H, Bishop RF, Barnes GL. Rotavirus infection and rates of hospitalisation for acute gastroenteritis in young children in Australia, 1993-1996. *Med J Aust* 1998;169:252–6.
117. Szucs G, Uj M, Mihaly I, Deak J. Burden of human rotavirus-associated hospitalizations in three geographic regions of Hungary. *Acta Paediatr* 1999;426:S61–5.
118. Ferson MJ. Hospitalizations for rotavirus gastroenteritis among children under five years of age in New South Wales. *Medical Journal of Australia* 1996;164:273–6.
119. Ford-Jones EL, Wang E, Petric M, Corey P, Moineddin R, Fearon M, et al. Rotavirus-associated diarrhea in outpatient settings and child care centers. *Arch Pediatr Adolesc Med* 2000;154:586–93.
120. Rodriguez WJ, Kim HW, Brandt CD, Schwartz RH, Gardner MK, Jeffries B, et al. Longitudinal study of rotavirus infection and gastroenteritis in families served by a pediatric medical practice: clinical and epidemiologic observations. *Pediatr Infect Dis J* 1987;6:170–6.
121. Donelli G, Ruggeri FM, Tinari A, Marziano ML, Caione D, Concato C, et al. A three-year diagnostic and epidemiological study on viral infantile diarrhea in Rome. *Epidem Infect* 1988;100:311–20.
122. Ruggeri FM, Marziano ML, Tinari A, Salvatori E, Donelli G. Four-year study of rotavirus electropherotypes from cases of infantile diarrhea in Rome. *J Clin Microbiol* 1989;27:1522–6.
123. Arista S, Giovannelli L, Pistoia D, Cascio A, Parea M, Gerna G. Electropherotypes, subgroups, and serotypes of human rotavirus strains causing gastroenteritis in infants and young children in Palermo, Italy, from 1985 to 1989. *Res Virol* 1990;141:435–48.
124. Barnes GL, Uren E, Stevens KB, Bishop RF. Etiology of acute gastroenteritis in hospitalized children in Melbourne, Australia, from April 1980 to March 1993. *J Clin Microbiol* 1998;36:133–8.
125. Caprioli A, Pezzella C, Morelli R, Giammanco A, Arista S, Crotti D, et al. Enteropathogens associated with childhood diarrhea in Italy. *Pediatr Infect Dis J* 1996;15:876–83.
126. Superti F, Diamanti E, Giovannangeli S, Dobi V, Xhelili L, Donelli G. Electropherotypes of rotavirus strains causing gastroenteritis in infants and young children in Tirana, Albania, from 1988 to 1991. *Acta Virol* 1995;39:257–61.
127. Muller FM, Onder G, Kamin W, Gutjahr P, Schmitt HJ. Diarrhea in 1,337 children of the Mainz University Clinic: Importance of *Salmonella* and rotaviruses. *Klinische Padiatrie* 1993;205:9–13.
128. Gosciniak G, Sobieszczanska B, Grzybek-Hryncewicz K. Rotavirus diarrhea in children hospitalized in Wroclaw clinics. *Przegląd Lekarski* 1990;47:682–5.
129. Pazdiora P, Taborska J, Mlada L, Kobesova A. Clinical and epidemiologic findings from a study of rotavirus infections in hospitalized children. *Ceskoslovenska Epidemiologie Mikrobiologie Imunologie* 1990;39:149–54.
130. Sadurska E. Studies on the role of rotaviruses in the etiology of acute diarrhea in infants. *Pediatrics Polska* 1989;64:2–8.
131. Begue RE, Neill MA, Papa EF, Dennehy PH. A prospective study of shiga-like toxin-associated diarrhea in a pediatric population. *J Pediatr Gastroenterol Nutr* 1994;19:164–9.

132. Donelli G, Superti F, Tinari A, Marziano ML, Caione D, Concato C, et al. Viral childhood diarrhoea in Rome: a diagnostic and epidemiological study. *Microbiologica* 1993;16:215–26.
133. Grimwood K, Carzino R, Barnes GL, Bishop RF. Patients with enteric adenovirus gastroenteritis admitted to an Australian pediatric teaching hospital from 1981 to 1992. *J Clin Microbiol* 1995;33:131–6.
134. Sack RB, Santosham M, Reid R, Black R, Croll J, Yolken R, et al. Diarrhoeal diseases in the White Mountain Apaches: clinical studies. *J Diarrhoeal Dis Res* 1995;13:12–7.
135. Berner R, Schumacher RF, Hameister S, Forster J. Occurrence and impact of community-acquired and nosocomial rotavirus infections—a hospital-based study over 10 y. *Acta Paediatr Suppl* 1999;88:48–52.
136. Ginevskaya VA, Amitina NN, Eremeeva TP, Shirman GA, Priimagi LS, Drozdov SG. Electropherotypes and serotypes of human rotavirus in Estonia in 1989–1992. *Arch Virol* 1994;137:199–207.
137. Vizzi E, Cascio A, Arista S. Caratterizzazione antigenica di rotavirus umani riscontrati a Palermo negli anni 1989-92. *Igiene Moderna* 1994;102:547–55.
138. Gonzalez FS, Sordo ME, Rowensztein G, Sabbag L, Roussos A, De Petre E, et al. Rotavirus diarrhea. Impact in a pediatric hospital of Buenos Aires. *Medicina (B Aires)* 1999;59:321–6.
139. Uriarte S, Gomez J, Scolaro L. Rotavirus infection in children seen at a greater Buenos Aires hospital. *Rev Argent Microbiol* 1999;31:87–9.
140. Dutta SR, Khalfan SA, Baig BH, Philipose L, Fulayfil R. Epidemiology of rotavirus diarrhoea in children under five years in Bahrain. *Int J Epidemiol* 1990;19:722–7.
141. Milaat WA, el Assouli SM. Epidemiology of diarrhoea in two major cities in Saudi Arabia. *J Communicable Dis* 1995;27:84–91.
142. Mohammed KA, el Assouli SM, Banjar ZM. Human rotavirus subgroups and serotypes in children with acute gastroenteritis in Saudi Arabia from 1988 to 1992. *J Med Virol* 1994;44:237–42.
143. el Assouli SM, Banjar ZM, Mohammed KA, Zamakhchari FT. Rotavirus infection in children in Saudi Arabia. *Am J Trop Med Hyg* 1992;46:272–7.
144. Sethi SK, Khuffash F. Bacterial and viral causes of acute diarrhoea in children in Kuwait. *J Diarrhoeal Dis Res* 1989;7:85–8.
145. Huq MI, Rahman AS, Al-Sadiq A, Al-Shahri A, Alim AR. Rotavirus as an important cause of diarrhoea in a hospital for children in Dammam, Saudi Arabia. *Ann Trop Paediatr* 1987;7:173–6.
146. al-Bwardy MA, Ramia S, al-Frayh AR, Chagla AH, al-Omair AA, el-Hazmi MA, et al. Bacterial, parasitic and viral enteropathogens associated with diarrhoea in Saudi children. *Ann Trop Paediatr* 1988;8:26–30.
147. Khuffash FA, Sethi SK, Shaltout AA. Acute gastroenteritis: clinical features according to etiologic agents. *Clin Pediatr (Phila)* 1988;27:365–8.
148. el Assouli SM, Mohammed KA, Banjar ZM. Human rotavirus genomic RNA electropherotypes in Jeddah, Saudi Arabia from 1988 to 1992. *Ann Trop Paediatr* 1995;15:45–53.
149. el Assouli SM, Banjar ZM, Mohammed KA, Milaat WA, el Assouli MZ. Genetic and antigenic analysis of human rotavirus prevalent in Al-Taif, Saudi Arabia. *J Trop Pediatr* 1996;42:211–9.
150. Sethi S, Khuffash FA, Al-Nakib W. Microbial etiology of acute gastroenteritis in hospitalized children in Kuwait. *Pediatr Infect Dis J* 1989;8:593–7.
151. Kim KH, Suh IS, Kim JM, Kim CW, Cho YJ. Etiology of childhood diarrhea in Korea. *J Clin Microbiol* 1989;27:1192–6.
152. Tam JS, Kum WW, Lam B, Yeung CY, Ng MH. Molecular epidemiology of human rotavirus infection in children in Hong Kong. *J Clin Microbiol* 1986;23:660–4.
153. Chan PK, Tam JS, Nelson EA, Fung KS, Adeyemi-Doro FA, Fok TF, et al. Rotavirus infection in Hong Kong: epidemiology and estimates of disease burden. *Epidemiol Infect* 1998;120:321–5.
154. Biswas R, Lyon DJ, Nelson EA, Lau D, Lewindon PJ. Aetiology of acute diarrhoea in hospitalized children in Hong Kong. *Trop Med Int Health* 1996;1:679–83.

155. Kim KH, Yang JM, Joo SI, Cho YG, Glass RI, Cho YJ. Importance of rotavirus and adenovirus types 40 and 41 in acute gastroenteritis in Korean children. *J Clin Microbiol* 1990;28:2279–84.
156. Vijayan V, Quak SH, Wong HB. Incidence, clinical features and epidemiology of rotavirus gastro-enteritis in hospitalized children. *Ann Trop Paediatr* 1990;10:179–83.
157. Ling JM, Cheng AF. Infectious diarrhoea in Hong Kong. *J Trop Med Hyg* 1993;96:107–12.
158. Seo JK, Sim JG. Overview of rotavirus infections in Korea. *Pediatr Int* 2000;42:406–10.
159. Steele AD, Alexander JJ, Hay IT. Rotavirus-associated gastroenteritis in black infants in South Africa. *J Clin Microbiol* 1986;23:992–4.
160. Bos P, Mnisi YN, Steele AD. The molecular epidemiology of rotavirus infection in Ga-Rankuwa, southern Africa. *Cent Afr J Med* 1992;38:286–90.
161. Steele AD, Geyer A, Alexander JJ, Crewe-Brown HH, Fripp PJ. Enteropathogens isolated from children with gastro-enteritis at Ga-Rankuwa Hospital, South Africa. *Ann Trop Paediatr* 1988;8:262–7.
162. Griffiths FH, Steele AD, Alexander JJ. The molecular epidemiology of rotavirus-associated gastro-enteritis in the Transkei, South Afr *Ann Trop Pediatr* 1992;12:259–64.
163. Steele AD, Alexander JJ. The relative frequency of subgroup I and II rotaviruses in black infants in South Africa. *J Med Virol* 1988;24:321–7.
164. Steele AD, Bos P, Alexander JJ. Clinical features of acute infantile gastroenteritis associated with human rotavirus subgroups I and II. *J Clin Microbiol* 1988;26:2647–9.

Appendix B [online only]

Table. Country-specific estimates of deaths from diarrhea and rotavirus in children.

Country	GNP per capita (US \$) ^a	Deaths of children <5 y (x1,000) ^b	Estimated deaths from diarrhea ^c	Estimated deaths from rotavirus ^d
Afghanistan	250	293	61,530	12,306
Albania	870	2	340	85
Algeria	1,550	36	6,120	1,530
Angola	220	176	36,960	7,392
Antigua and Barbuda	8,520	0	–	–
Argentina	7,600	16	1,440	446
Armenia	490	1	210	42
Australia	20,050	1	10	3
Austria	25,970	0	–	–
Azerbaijan	550	5	1,050	210
Bahamas	12,400	0	–	–
Bahrain	7,640	0	–	–
Bangladesh	370	312	65,520	13,104
Barbados	6,610	0	–	–
Belarus	2,630	3	510	128
Belgium	24,510	1	10	3
Belize	2,730	0	–	–
Benin	380	38	7,980	1,596
Bhutan	510	8	1,680	336
Bolivia	1,010	22	3,740	935
Bosnia and Herzegovina	b	1	170	43
Botswana	3,240	3	270	84
Brazil	4,420	134	12,060	3,739
Brunei Darussalam	24,630	0	–	–
Bulgaria	1,380	1	170	43
Burkina Faso	240	105	22,050	4,410
Burundi	120	48	10,080	2,016
Cambodia	260	44	9,240	1,848
Cameroon	580	88	18,480	3,696
Canada	19,320	2	20	7
Cape Verde	1,330	1	170	43
Central African Republic	290	23	4,830	966
Chad	200	64	13,440	2,688
Chile	4,740	3	270	84
China	780	813	138,210	34,553
Colombia	2,250	31	5,270	1,318
Comoros	350	2	420	84
Congo	670	13	2,730	546
Congo, Dem. Republic	110	475	99,750	19,950
Costa Rica	2,740	1	170	43

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Côte d'Ivoire	710	92	19,320	3,864
Croatia	4,580	0	–	–
Cuba	1,170	1	170	43
Cyprus	11,960	0	–	–
Czech Republic	5,060	0	–	–
Denmark	32,030	0	–	–
Djibouti	790	3	510	128
Dominica	3,170	0	–	–
Dominican Republic	1,910	10	1,700	425
Ecuador	1,310	11	1,870	468
Egypt	1,400	89	15,130	3,783
El Salvador	1,900	7	1,190	298
Equatorial Guinea	1,170	3	510	128
Eritrea	200	16	3,360	672
Estonia	3,480	0	–	–
Ethiopia	100	475	99,750	19,950
Fiji	2,210	0	–	–
Finland	23,780	0	–	–
France	23,480	4	40	14
Gabon	3,350	6	540	167
Gambia	340	4	840	168
Georgia	620	2	420	84
Germany	25,350	4	40	14
Ghana	390	73	15,330	3,066
Greece	11,770	1	10	3
Grenada	3,450	0	–	–
Guatemala	1,660	24	4,080	1,020
Guinea	510	56	11,760	2,352
Guinea-Bissau	160	10	2,100	420
Guyana	760	1	170	43
Haiti	460	33	6,930	1,386
Honduras	760	9	1,530	383
Hungary	4,650	1	90	28
Iceland	29,280	0	–	–
India	450	2,400	504,000	100,800
Indonesia	580	240	50,400	10,080
Iran	1,760	64	10,880	2,720
Iraq	2,170	103	17,510	4,378
Ireland	19,160	0	–	–
Israel	17,450	1	10	3
Italy	19,710	3	30	10
Jamaica	2,330	1	170	43
Japan	32,230	5	50	17
Jordan	1,500	8	1,360	340
Kazakhstan	1,230	12	2,040	510
Kenya	360	117	24,570	4,914
Kiribati	910	0	–	–
Korea, Dem. People's Rep.	a	14	2,940	588

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Korea, Republic of	8,490	3	270	84
Kuwait	19,020	0	–	–
Kyrgyzstan	300	8	1,680	336
Lao People’s Dem. Republic	280	23	4,830	966
Latvia	2,470	0	–	–
Lebanon	3,700	2	180	56
Lesotho	550	10	2,100	420
Liberia	490	30	6,300	1,260
Libya	5,540	4	360	112
Lithuania	2,620	1	170	43
Luxembourg	44,640	0	–	–
Madagascar	250	94	19,740	3,948
Malawi	190	105	22,050	4,410
Malaysia	3,400	5	450	140
Maldives	1,160	1	170	43
Mali	240	119	24,990	4,998
Malta	9,210	0	–	–
Marshall Islands	1,560	0	–	–
Mauritania	380	19	3,990	798
Mauritius	3,590	0	–	–
Mexico	4,400	77	6,930	2,148
Micronesia, Fed. States of	1,810	0	–	–
Moldova, Republic of	370	2	420	84
Mongolia	350	5	1,050	210
Morocco	1,200	37	6,290	1,573
Mozambique	230	168	35,280	7,056
Myanmar	220	106	22,260	4,452
Namibia	1,890	4	680	170
Nepal	220	82	17,220	3,444
Netherlands	24,320	1	10	3
New Zealand	13,780	0	–	–
Nicaragua	430	8	1,680	336
Niger	190	137	28,770	5,754
Nigeria	310	781	164,010	32,802
Norway	32,880	0	–	–
Oman	4,940	1	90	28
Pakistan	470	599	125,790	25,158
Panama	3,070	2	180	56
Papua New Guinea	800	17	2,890	723
Paraguay	1,580	5	850	213
Peru	2,390	32	5,440	1,360
Philippines	1,020	87	14,790	3,698
Poland	3,960	4	360	112
Portugal	10,600	1	10	3
Qatar	12,000	0	–	–
Romania	1,520	5	850	213
Russian Federation	2,270	32	5,440	1,360
Rwanda	250	53	11,130	2,226

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Saint Kitts and Nevis	6,420	0	–	–
Saint Lucia	3,770	0	–	–
Saint Vincent/Grenadines	2,700	0	–	–
Samoa	1,060	0	–	–
Sao Tome and Principe	270	0	–	–
Saudi Arabia	6,910	17	1,530	474
Senegal	510	43	9,030	1,806
Seychelles	6,540	0	–	–
Sierra Leone	130	68	14,280	2,856
Singapore	29,610	0	–	–
Slovakia	3,590	1	90	28
Slovenia	9,890	0	–	–
Solomon Islands	750	0	–	–
Somalia	120	106	22,260	4,452
South Africa	3,160	73	6,570	2,037
Spain	14,000	2	20	7
Sri Lanka	820	6	1,020	255
Sudan	330	103	21,630	4,326
Suriname	1,660	0	–	–
Swaziland	1,360	3	510	128
Sweden	25,040	0	–	–
Switzerland	38,350	0	–	–
Syria	970	14	2,380	595
Tajikistan	290	14	2,940	588
Tanzania	240	188	39,480	7,896
TFYR Macedonia	1,690	1	170	43
Thailand	1,960	30	5,100	1,275
Togo	320	26	5,460	1,092
Tonga	1,720	0	–	–
Trinidad and Tobago	4,390	0	–	–
Tunisia	2,100	6	1,020	255
Turkey	2,900	68	11,560	2,890
Turkmenistan	660	9	1,890	378
Uganda	320	142	29,820	5,964
Ukraine	750	10	2,100	420
United Arab Emirates	17,870	0	–	–
United Kingdom	22,640	4	40	14
United States	30,600	30	300	102
Uruguay	5,900	1	90	28
Uzbekistan	720	38	7,980	1,596
Vanuatu	1,170	0	–	–
Venezuela	3,670	13	1,170	363
Viet Nam	370	66	13,860	2,772
Yemen	350	98	20,580	4,116
Yugoslavia	b	3	510	128
Zambia	320	76	15,960	3,192
Zimbabwe	520	32	6,720	1,344
Total		10,630	2,112,020	439,788

^aGNP, gross national product.

^bFigures for total deaths in children <5 y of age are rounded to the nearest thousand; consequently, estimates of diarrhea and rotavirus deaths are not calculated for countries with fewer than 1,000 child deaths.

^cDeaths from diarrhea were derived by multiplying total deaths in children <5 y of age by the estimated proportion of deaths attributable to diarrhea, based on GNP per capita, as follows: GNP < US\$756, 21%; GNP = US\$756–\$2,995, 17%; GNP = US\$2,995–9,625, 9%; GNP > US\$9,625, 1%.

^dDeaths from rotavirus were derived by multiplying total diarrhea deaths in children <5 y of age by the estimated proportion of diarrhea deaths attributable to rotavirus, based on GNP per capita, as follows: GNP < US\$756, 20%; GNP = US\$756–\$2,995, 25%; GNP = US\$2,995–9,625, 31%; GNP > US\$9,625, 34%.