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Rotavirus Gastroenteritis and Weather

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During 5.5 years of a study in Washington, D.C., hospitalizations of children for rotavirus gastroenteritis tended to be more common after a month of cold or dry weather than after a corresponding calendar month of warm or wet weather. Overall, there were 84% more (178 versus 97) inpatients with rotavirus gastroenteritis after a set of relatively colder individual months taken as a group than after an equal number of warmer corresponding calendar months taken as a group. Comparable differences were not seen with nonrotavirus gastroenteritis patients. There also were 45% more rotavirus hospitalizations after the set of months with the least depth of precipitation compared with the set of corresponding calendar months with the greatest depth of precipitation. Rotavirus infection in young infants, the children least likely to be directly exposed to outdoor conditions, showed some of the most marked weather-associated effects. These findings suggest that weather-related low indoor relative humidity and indoor crowding may be key factors in the epidemiology of rotavirus disease.

In temperate climates, rotavirus gastroenteritis tends to be very common in winter and uncommon to virtually absent in summer (3, 4, 6, 7, 9, 11), which suggests that a low outdoor temperature might in some way encourage rotavirus disease. In tropical areas, rotavirus infections apparently are common year round, but seem to be increased during periods of low rainfall or low humidity, decreased during periods of high rainfall or high humidity, or both (1, 4, 13, 15).

In an effort to see whether meteorological conditions might influence the prevalence of rotavirus gastroenteritis in metropolitan Washington, D.C., we attempted to relate hospitalizations for rotavirus disease to meteorological conditions in the preceding month.

MATERIALS AND METHODS

The study population included virtually all infants and young children with acute gastroenteritis who were hospitalized at Children's Hospital National Medical Center, Washington, D.C., in the months when rotaviruses tended to be active (November through May) during the period January 1974 through May 1979 and also in early 1980. Most of our epidemiological and virological methods have been described previously (2, 3). All rotavirus-positive patients had typical virus particles demonstrated by electron microscopy in one or more fecal samples generally taken on the first or second hospital day. The identity of the virus particles was further confirmed by rotavirus group-specific, or what is now (5) recognized as subgroup-specific, enzyme-linked immunosorbent assay. The meteorological findings used were those published by the U.S. Department of Commerce, National Climatic Center, Asheville, N.C., and were measured at National Airport, Washington, D.C.

For each climatological variable studied, two comparative cells were created which contained equal numbers of the same calendar months. Patient data were then organized by calendar month in relation to higher or lower mean temperature, greater or lesser depth of precipitation (as rain or water equivalent), or more or fewer days with at least 0.025 cm of precipitation (as rain or water equivalent) in the month preceding hospitalization. Thus, for example, patients hospitalized in the six Januaries under study were subdivided on the basis of the three coldest Decembers and the three warmest Decembers. Similarly, patients hospitalized in the five Decembers under study were subdivided on the basis of the two coldest Novembers and the two warmest Novembers (data from the unpaired month were not counted in either group).

RESULTS

Among the study patients, there tended to be both a larger number and a higher percentage of rotavirus infections in the month after a month of colder or dryer weather than after a corresponding calendar month of relatively warmer or wetter weather (Table 1). Overall, 178 (54%) of 331 gastroenteritis inpatients hospitalized after the set of colder Novembers, Decembers, etc., had rotavirus infection, compared with 97 (40%)

TABLE 1. Rotavirus infections in hospitalized gastroenteritis patients by month in relation to mean temperature, number of days with precipitation, and depth of precipitation in the previous month for the period January 1974 through May 1979[a]

Month of hospitalization	No. of infections under following meteorological conditions in month before hospitalization:											
	Warmer (mean = 9.6°C)		Colder (mean = 6.1°C)		More days of precipitation (mean = 11.5/month)		Fewer days of precipitation (mean = 7.2/month)		Greater depth of precipitation (mean = 10.9 cm/month)		Lesser depth of precipitation (mean = 4.6 cm/month)	
	No. tested	No. (%) positive	No. tested	No. (%) positive	No. tested	No. (%) positive	No. tested	No. (%) positive	No. tested	No. (%) positive	No. tested	No. (%) positive
November	8	0 (0)	17	7 (41)	13	1 (8)	16	6 (38)	13	1 (8)	16	6 (38)
December	21	7 (33)	20	12 (60)	23	6 (26)	18	8 (44)	23	6 (26)	20	12 (60)
January	61	42 (69)	100	70 (70)	57	36 (63)	104	76 (73)	57	36 (63)	104	76 (73)
February	42	21 (50)	69	42 (61)	42	21 (50)	69	42 (61)	65	36 (55)	46	27 (59)
March	34	13 (38)	64	31 (48)	42	17 (40)	56	27 (48)	52	18 (35)	46	26 (57)
April	46	10 (22)	26	12 (46)	26	12 (46)	46	10 (22)	26	12 (46)	46	10 (22)
May	32	4 (12)	35	4 (11)	22	1 (5)	45	7 (16)	29	3 (10)	38	5 (13)
Total	244	97 (40)[b]	331	178 (54)[b]	225	94 (42)[c]	354	176 (50)[c]	265	112 (42)[d]	316	162 (51)[d]

[a] Data from 4 years were used for patient months November and December (see text); data from 6 years were used for patient months January through May.

[b] $\chi^2 = 11.068$, $P = <0.001$.

[c] $\chi^2 = 3.484$, $P = >0.05$.

[d] $\chi^2 = 4.686$, $P = <0.05$.

TABLE 2. Rotavirus infections in hospitalized gastroenteritis patients by age in relation to mean temperature, number of days with precipitation, and depth of precipitation in the previous month

Patient age (month)	No. of infections under following meteorological conditions in month before hospitalization:											
	Warmer		Colder		More days of precipitation		Fewer days of precipitation		Greater depth of precipitation		Lesser depth of precipitation	
	No. tested	No. (%) positive	No. tested	No. (%) positive	No. tested	No. (%) positive	No. tested	No. (%) positive	No. tested	No. (%) positive	No. tested	No. (%) positive
0–3	57	6 (11)	80	31 (39)	51	13 (25)	85	24 (28)	61	15 (25)	75	23 (31)
4–6	32	13 (41)	55	26 (47)	32	7 (22)	58	31 (53)	40	11 (28)	51	28 (55)
7–9	47	21 (45)	48	35 (73)	36	21 (58)	58	34 (59)	37	21 (57)	56	34 (61)
10–12	27	18 (67)	48	32 (67)	31	18 (58)	43	30 (70)	34	20 (59)	42	30 (71)
13–24	41	27 (66)	48	36 (75)	41	28 (68)	49	33 (67)	45	28 (62)	46	34 (74)
≥25	40	12 (30)	52	18 (35)	34	7 (21)	61	24 (39)	48	17 (35)	46	13 (28)
Total	244	97[a] (40)	331	178[b] (54)	225	94[c] (42)	354	176[b] (50)	265	112[a] (42)	316	162[b] (51)

[a] Median age, 11 months.
[b] Median age, 9 months.
[c] Median age, 10 months.

of 244 after the set of relatively warmer Novembers, Decembers, etc. (χ^2 = 11.068, P = <0.001). Interestingly, the number of nonrotavirus gastroenteritis cases showed virtually no temperature-related change (153 patients after the set of colder months and 147 patients after the set of warmer months). The overall mean temperature during the relatively colder months was 6.1°C, compared with 9.6°C for the relatively warmer set, a difference of only 3.5°C. This suggests that relatively modest changes in temperature may be associated with appreciable changes in the number of patients hospitalized with rotavirus gastroenteritis.

A total of 162 (51%) of 316 gastroenteritis inpatients hospitalized after study months with the lesser depth of precipitation had rotavirus infection (Table 1), compared with 112 (42%) of 265 after study months with the greater depth of precipitation (χ^2 = 4.686, P = <0.05). Despite an excess of 50 rotavirus-positive patients (162 versus 112) in the months associated with lesser as compared with greater depth of precipitation, the number of nonrotavirus patients in the two corresponding groups was almost identical (154 and 153 patients, respectively).

A greater number (176 versus 94) and a nearly significantly higher percentage (50 versus 42%) of gastroenteritis patients with rotavirus infection were seen after months with the fewest days of precipitation compared with months with the most days of precipitation (Table 1). Thus, relatively dryer weather in a preceding month tended to be associated with increased rotavirus disease.

In most age groups, a higher percentage of gastroenteritis patients (and in all age groups, a larger number of gastroenteritis patients) tended to be hospitalized with rotavirus disease in the month after the colder Januaries, etc., than in the month after the warmer Januaries, etc. The difference was most evident among infants in the first 3 months of life, who presumably would have been minimally exposed to outdoor conditions (Table 2). There also was a marked tendency for more (and a higher percentage of) rotavirus-positive patients of any age to be hospitalized after months with fewer days or lesser depth of precipitation. As a result of the disproportionately large number of young infants who were hospitalized with rotavirus infection after colder or dryer months, the median age of rotavirus-positive patients was 9 months for those hospitalized after the colder or dryer months, compared with 10 or 11 months for those hospitalized after the warmer or wetter months (Table 2).

Subgroup 1 and subgroup 2 rotavirus infections both showed the same kinds of temperature- and precipitation-related effects as were found for the rotaviruses collectively (data not shown).

DISCUSSION

Hospitalizations for rotavirus gastroenteritis in this locale tended to be more common after a cold or dry month than after a warm or wet corresponding calendar month. Also, the weather-related effects were especially evident in young infants, the age group least likely to be directly exposed to extremes of outdoor weather. Furthermore, both rotavirus subgroups (5) thus far recognized in our study population (3) showed the same types of weather-related effects.

These data would seem to make the best sense if one assumes that the transmission of rotaviruses is encouraged by individuals living in close proximity to each other (crowding) and that the transmission of rotaviruses or the severity of dehydration resulting from the rotavirus infection or both is increased by low indoor relative humidity. The cold-weather effect could then be explained as one which both encourages the family to stay indoors in a tightly closed residence (where contaminated air might readily be breathed and contaminated surfaces might readily be touched) and lowers the indoor relative humidity as outside air is brought in and heated (8). An important effect of low relative humidity might be on aerosol formation or particle size (8). Dry conditions would tend to encourage the formation of virus-laden dust from fecally contaminated diapers, bedding, and clothing. Also, small (dry) particles would tend to stay suspended in the air and thus reach a susceptible individual. With increased humidity, less aerosol would be formed, and the particles would generally be larger and thus would settle more rapidly to the floor. It seems less likely that any humidity effect is on virus viability, since rotaviruses appear to be rather resistant to physical and chemical methods of inactivation (6, 10, 12). Low indoor humidity would also tend to exaggerate the dehydration resulting from diarrhea and vomiting by increasing the normal water loss from the respiratory tract and skin, but how important such an effect would be and whether such an effect could selectively spare victims of nonrotavirus gastroenteritis in winter are not clear.

Neither respiratory nor fecal-oral means of transmission of the rotaviruses are proven or ruled out by our findings, although the rotavirus peak at the height of the respiratory disease season, the common finding of at least mild respiratory disease symptoms in patients with rotavirus gastroenteritis (9, 14), and the apparently considerable influence of low indoor relative humidity would be consistent with at least some respiratory transmission.

If crowding and low indoor relative humidity do increase rotavirus disease, then precipitation would tend to have a complex effect: it would encourage crowding by keeping family members indoors, but also would raise the indoor relative humidity.

In the cold, dark days of winter, when the family and other contacts of a young child would especially tend to remain indoors, the more important effect of precipitation in this locale apparently is to raise the indoor humidity and thus to reduce the transmission or severity of rotavirus infection.

Since January 1974, when rotaviruses were first observed in our study patients, rotavirus activity usually peaked in the month of January, and until 1980 there never had been a sharp increase in the number of inpatients with rotavirus disease in February as compared with January. During the 1979–1980 epidemic year, outdoor temperatures were unusually high from November until 24 January, at which time outdoor temperatures became lower than average for 3 weeks. Consistent with our expectations that such weather might be associated with an unusual pattern of rotavirus disease, there was remarkably little rotavirus activity until the end of January 1980; then the highest February peak in rotavirus activity since we began to identify such infections occurred. Furthermore, the 34 gastroenteritis patients hospitalized with rotavirus infections in February 1980 had a remarkably low median age of only 7 months, which also is consistent with the temperature-related data shown in Table 2.

These findings support the view that meteorological factors indirectly but importantly influence the complex epidemiology of human rotavirus infection. In particular, low temperature and low indoor relative humidity may be key factors behind the common observation in temperate zones that rotavirus infection tends to peak in midwinter. These same weather-related factors may also help explain some of the geographic and year-to-year variations in serious rotavirus disease.

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