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Haze is an important medium for the spread of rotavirus☆

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A B S T R A C T

This study investigated whether the rotavirus infection rate in children is associated with temperature and air pollutants in Hangzhou, China. This study applied a distributed lag non-linear model (DLNM) to assess the effects of daily meteorological data and air pollutants on the rotavirus positive rate among outpatient children. There was a negative correlation between temperature and the rotavirus infection rate. The impact of temperature on the detection rate of rotavirus presented an evident lag effect, the temperature change shows the greatest impact on the detection rate of rotavirus approximate at lag one day, and the maximum relative risk (RR) was approximately 1.3. In 2015, the maximum cumulative RR due to the cumulative effect caused by the temperature drop was 2.5. Particulate matter (PM) 2.5 and PM10 were the primary air pollutants in Hangzhou. The highest RR of rotavirus infection occurred at lag 1–1.5 days after the increase in the concentration of these pollutants, and the RR increased gradually with the increase in concentration. Based on the average concentrations of PM2.5 of 53.9 $\mu g/m^3$ and PM10 of 80.6 $\mu g/m^3$ in Hangzhou in 2015, the cumulative RR caused by the cumulative effect was 2.5 and 2.2, respectively. The current study suggests that temperature is an important factor impacting the rotavirus infection rate of children in Hangzhou. Air pollutants significantly increased the risk of rotavirus infection, and dosage, lag and cumulative effects were observed.

1. Introduction

Rotavirus is considered the primary pathogen causing severe acute diarrhea among children worldwide, as well a major cause of death in children in developing countries (Mayanskiy et al., 2015). The main transmission route of infectious diarrhea is fecal-oral transmission. Consequently, many studies have conducted analytical investigations of dangerous factors to stop this route of transmission (Dennehy, 2000; Nakawesi et al., 2010; Temu et al., 2012; Wilking et al., 2012); relevant factors include dietary habits, the eating environment, food varieties, eating traditions, food storage conditions, and health and economic conditions. However, our long-term clinical observations have demonstrated that some infectious diarrhea cases are not associated with a suspicious food history or unclean dietary habits. Several studies have shown that some pathogens causing infectious diarrhea, such as enteric adenovirus, rotavirus, and norovirus, can form aerosols through airborne transmission (Verani et al., 2014). The research team led by Professor Jiang from Peking University showed that PM2.5 and PM10 particles carry abundant microorganisms from the environment, of which viruses account for 0.1% (Cao et al., 2014). Therefore, the morbidity of infectious diarrhea may be related to air quality.

To verify the hypothesis, this study applied a distributed lag non-linear model to assess the effects of the daily meteorological data and air pollutants on the risk of rotavirus infection among outpatient children.

2. Objects and methods

2.1. Study subjects

To study the correlation between the air quality and rotavirus diarrhea, a prospective observational study was performed from January 1, 2015, to December 31, 2015. During this period, 100 stool specimens from patients with diarrhea at the pediatric outpatient

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Table 1
Rotavirus infection rate, atmospheric environment and meteorological condition in Hangzhou, 2015.

Variables	Criterion value	Mean	Standard deviation	Minimum	Percentile			Maximum
					25th	50th	75th	
Air pollutions								
AQI	50[b]	79.5	36.6	20.0	55.0	71.0	97.0	272.0
PM2.5 (μg/m^3)	10[b]	53.9	30.6	8.0	32.0	48.0	68.0	224.0
PM10 (μg/m^3)	20[b]	80.6	41.0	11.0	51.5	72.0	100.0	283.0
SO2 (μg/m^3)	20[a]	14.5	6.9	4.0	9.0	13.0	18.0	43.0
NO2 (μg/m^3)	40[b]	44.4	16.2	11.0	33.0	42.0	53.0	96.0
CO(μg/m^3)	10[c]	0.9	0.3	0.4	0.7	0.8	1.0	2.0
Weather								
Minimum temperature (°C)		14.1	8.1	−2.0	6.5	15.0	21.0	28.0
Maximum temperature (°C)		22.1	8.4	3.0	15.0	24.0	29.0	39.0
Mean temperature (°C)		18.1	8.0	2.0	11.3	19.5	24.5	33.5
Temperature variations (°C)		8.0	3.9	1.0	6.0	8.0	10.0	27.0
Relative humidity (%)		73.8	14.5	28.0	64.0	75.0	87.0	97.0
Amount of precipitation (mm)		4.0	9.0	0.0	0.0	0.0	4.0	86.0
Disease								
Rotavirus positive rate (%)		16.6	13.0	4.8	8.0	11.0	20.0	42.0

[a] 24-h mean from “WHO Air quality guidelines”.
[b] annual mean from “WHO Air quality guidelines”.
[c] maximum daily eight hour mean from “on ambient air quality and cleaner air for Europe”. Temperature variance refers to the daily temperature difference.

department in Hangzhou were collected per day, and the positive rate of rotavirus in these samples was detected by immunochromatography using a double antibody sandwich method. Meteorological data and atmospheric pollutant data of Hangzhou released by the online air quality detection analysis platform (http://www.aqistudy.cn/) were collected. The meteorological data include the daily maximum temperature, minimum temperature, average temperature, temperature variance and relative humidity. Atmospheric pollutant data include the daily AQI index and PM2.5, PM10, CO, NO_2 and SO_2 concentrations. A statistical method was used to assess the effects of the daily meteorological data and air pollutants on the risk of rotavirus infection among outpatient children.

2.2. Method for the detection of human rotavirus

In this study, immunochromatography using a double antibody sandwich method was adopted for the detection of rotavirus. Group-A rotavirus antibody was coated on the detection zone of the nitrocellulose membrane, and the group-A rotavirus monoclonal antibody was labeled with colloidal gold. During detection, 100 mg of stool specimen was added into the diluent for dilution and mixing, and then 80 μl of liquid supernatant was collected and added to the detection and sample region. When group A rotavirus was present in the tested sample, the virus in the sample combined with the “colloidal gold-antibody” at the front of the test card to form an immune complex. The immune complex moved along the nitrocellulose membrane, and if a red line appeared in the antibody-coated detection zone, the sample was positive. If there was no group A rotavirus in the sample, no red lines appeared in the detection zone, and the sample was negative.

2.3. Statistical analysis

The distributed lag non-linear model is a time sequence model based on generalized linear models and generalized additive models and is more advantageous for analyzing the lag effect and cumulative effect in non-linear processes. Consequently, this model was adopted for fitting. Please refer to reference (Gasparrini and Leone, 2014) for details.

The rotavirus detection positive rate for daily detection was taken as the dependent variable, and a cross matrix was established for the daily pollutant concentration/temperature and lag time. The confounding effects of holiday effects, relative humidity, day of the week and long-term trends were controlled to analyze the relationship between the daily pollutant concentration/temperature and the rotavirus detection positive rate to eliminate their effect on the analysis. The model formula was as follows: LogE [Yt] = acrossbasis1+ ns (X1, df) + a2crossbasis2 + a3crossbasis3 + a4crossbasis4 + a5crossbasis5 + a6crossbasis6 + β1x2 + γ1x3 + γ2x4 + δ, in which Yt is the positive rate of rotavirus detection on the observation date t, and crossbasis1 is the cross matrix established for the daily pollutant concentration/temperature and maximum lag days with the DLNM software package. The daily average temperature and concentration of PM2.5, PM10, SO_2, NO_2 and CO were substituted. “ns” is the natural cubic spline function, df is the degree of freedom confirmed by the akaike information criterion (AIC), and x1 is the time sequence variable for controlling the long-term trend. Crossbasis 2–6 are five additional variables excluding the variable substituted for dividing crossbasis1. X2 describes the relative humidity of the same period, and β1 is its coefficient. X3 is the dummy variable describing the day of week, and γ1 is its coefficient. X4 is the variable describing whether t is a holiday, and it was coded by referring to the holiday arrangements in the website of the Chinese government, including legal holidays such as the Spring Festival, National Day, and Tomb-sweeping Day, and γ2 was its coefficient. “δ” is the constant of the model. Data manipulation and all statistical analyses were performed using SPSS18.0 statistical software and statistical environment R 3.2.3 (DLNM 2.1.3 package).

Relative risk is the ratio of the probability of rotavirus infection occurring in an exposed group to the probability of the event occurring in a comparison, non-exposed group.

3. Results

3.1. Characteristics of rotavirus-infected patients, atmospheric environment and meteorological conditions of Hangzhou in 2015

The average temperature of Hangzhou in 2015 was 18.1°C, the minimum temperature was −2°C, and the maximum was 39°C. The average relative humidity throughout the year was 73.8. The major air pollutants were PM2.5 and PM10, which were more than 5