Association of meteorological factors with pediatric acute appendicitis in China
A 7-year retrospective analysis

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Abstract
Acute appendicitis (AA) affects about 7% and 8% of the world population and is one of the most common general surgical emergencies. The concept of seasonal patterns in the incidence of AA remains controversial. Thus, this study aimed to investigate whether meteorological factors are related to variations in the rate of pediatric AA cases at the Children’s Hospital in Chongqing, China.

In total, in this retrospective survey, 3436 children younger than 18 years who had been hospitalized with AA from January 1, 2008 to December 31, 2013 were enrolled, and the meteorological factors during this period were collected.

Patients with AA showed a male/female ratio of 1.81:1; the highest incidence age ranged from 6 to 12 years old ($P < .0001$). The highest incidences of pediatric AA occurred in summer and autumn, with a peak in September and a trough in February. Pearson correlation analysis showed that the monthly mean temperature ($r = 0.357$, $P = .001$), monthly mean relative humidity ($r = -0.357$, $P = .001$), and monthly mean sunshine duration ($r = 0.235$, $P = -0.031$) were relatively weak correlated with pediatric AA. Multiple linear regression analysis indicated that pediatric AA occurrence was positively affected by monthly mean temperature ($P < .0001$) and negatively affected by monthly mean humidity ($P < .0001$) and monthly sum of sunshine ($P < .0001$), while monthly mean air pressure ($P = .092$), monthly wind speed ($P = .143$) and monthly precipitation ($P = .297$) were marginally associated with pediatric AA.

Pediatric AA is associated with climatic factors. Specifically, pediatric AA is more likely related to the following meteorological conditions of high temperature (20°C–30°C), low humidity, and less sunshine.

Abbreviations: AA = acute appendicitis.

Keywords: association, meteorological factors, pediatric acute appendicitis

1. Introduction
Acute appendicitis (AA) affects about 7% and 8% of the world population and is one of the most common general surgical emergencies. Some scholars have reported that the causes of appendicitis are luminal obstruction, several infectious agents, and environmental influences such as air pollution, ozone, and so on. The etiology of AA is still unclear. Some infectious and noninfectious diseases, including cardiovascular and psychological diseases, have been reported to be linked to meteorological factors. Some reports have presented a correlation between the incidence of AA and seasonal changes, but the correlations between countries with different types of climates are unclear.

Gastrointestinal diseases may spread directly to the appendix, which may cause blood flow disorder and inflammation of the appendix, accelerating the occurrence and development of AA. Research shows that appendicitis is associated with viral infection, and the virus has seasonal epidemics. Clinically, we found that the number of pediatric with appendicitis was high in summer and autumn. This leads us to investigate whether appendicitis has a significant seasonality.

Children are 4 times more likely to have appendicitis than the entire population. Given the unique physiological and metabolic features of children and their relatively immature immune system, they are more susceptible to environmental meteorological factors than adults; hence, all kinds of diseases related to climate occur more easily in children. In 2012, the World Health Organization reported that climate-related pneumonia, diarrhea, and malaria are the leading causes of death among children under 5 years of age; an increasing number of studies have focused on the effects of climate on children’s health. However, whether seasonal patterns is associated with the incidence of AA remains unclear.
this study was to investigate the association between meteorological factors and variations in the rate of pediatric AA cases at Children’s Hospital in Chongqing, China and to provide guidance for the prevention of appendicitis.

2. Methods

2.1. Patient data

The study procedure was approved by the Independent Ethics Committee of Chongqing Medical University. The study was conducted in the surgical department of Children’s Hospital of Chongqing Medical between January 1, 2008 and December 31, 2014. In this 7-year period, 3,436 children aged younger than 18 years who had been hospitalized with AA coded as K56.100 were enrolled. The diagnostic criteria for appendicitis meet the international diagnostic criteria. The exclusion criteria were as follows: chronic appendicitis, other diseases complicated with appendicitis, and family address was not in an urban area or in the Chongqing neighborhood. The patients’ general characteristics including age, sex, place of residence, date of onset, admission diagnosis, and discharge diagnosis were collected.

2.2. Meteorological data

Meteorological data from 2008 to 2014 were retrieved from the Chongqing Meteorological Service. We examined meteorological factors including monthly mean temperature, monthly mean air pressure, monthly mean relative humidity, monthly mean wind speed, monthly sum of sunshine and monthly precipitation level.

2.3. Data analysis

We used Microsoft Excel 2013 to create a database and SPSS version 22.0 (IBM, China) to analyze the data. The Mann-Whitney U and Kruskal–Wallis tests were used for analyses of normally and non-normally distributed variables. Continuous variables were shown as mean ± standard deviation; categorical variables were shown as numbers or percentages. Differences in gender, sex, and onset time were compared using a Chi-squared goodness of fit test. Significance of differences in meteorological factors with AA were determined using one-way analysis of variance or Kruskal–Wallis H test when appropriate. Pearson’s and multiple linear regression analyses were used to assess the relationship between incidence of pediatric AA (dependent variable: Y) and climate factors (independent variable: X). We used the Chi-squared goodness of fit test to examine the temperature variation in the pediatric AA incidence rates. P values were considered significant if they were <.05.

3. Results

3.1. Patient data

The overall number of AA patients conforming to the inclusion criteria from January 1, 2008, to December 31, 2014, was 3,436. There were 537 patients younger than 3 years old, 1110 between 3 and 6 years old, 926 between 6 and 9 years old, 652 between 9 and 12 years old, and 211 patients were older than 12 years old (Fig. 1A). The highest incidence age range was 6 to 12 years old, and 211 patients were older than 12 years old. 3,436 children aged younger than 18 years who had been hospitalized with AA coded as K56.100 were enrolled. The diagnostic criteria for appendicitis meet the international diagnostic criteria. The exclusion criteria were as follows: chronic appendicitis, other diseases complicated with appendicitis, and family address was not in an urban area or in the Chongqing neighborhood. The patients’ general characteristics including age, sex, place of residence, date of onset, admission diagnosis, and discharge diagnosis were collected.

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Figure 2. Incidence time distribution of acute appendicitis from 2008 to 2014. (A) Monthly distribution and acute appendicitis cases. (B) Seasonal distribution and acute appendicitis cases.

Table 1
Meteorological data in Chongqing from 2008 to 2014.

| Month     | Temperature, mean (SD), °C | Air pressure, mean (SD), hPa | Relative humidity, mean (SD), (%) | Wind speed, mean (SD), m/s | Sum of sunshine, hours | Precipitation, mm |
|-----------|-----------------------------|-----------------------------|-----------------------------------|---------------------------|------------------------|------------------|
| January   | 7.48 (1.39)                 | 992.88 (1.56)               | 80.70 (5.67)                      | 1.18 (0.07)               | 3.58                   | 4.05             |
| February  | 10.20 (1.93)                | 987.78 (3.38)               | 76.27 (5.63)                      | 1.26 (0.09)               | 7.53                   | 5.21             |
| March     | 14.82 (1.67)                | 985.98 (2.29)               | 71.49 (7.38)                      | 1.44 (0.08)               | 16.61                  | 12.85            |
| April     | 19.09 (1.16)                | 981.95 (1.50)               | 73.26 (8.26)                      | 1.35 (0.09)               | 20.14                  | 24.37            |
| May       | 22.48 (0.93)                | 978.21 (1.09)               | 75.41 (6.60)                      | 1.40 (0.10)               | 19.86                  | 28.33            |
| June      | 25.50 (1.40)                | 974.21 (1.34)               | 77.22 (7.36)                      | 1.36 (0.14)               | 21.65                  | 51.00            |
| July      | 29.50 (0.98)                | 971.74 (1.15)               | 67.90 (5.53)                      | 1.59 (0.16)               | 37.15                  | 21.82            |
| August    | 28.92 (1.63)                | 974.89 (1.10)               | 67.21 (11.38)                     | 1.56 (0.19)               | 37.52                  | 33.72            |
| September | 24.76 (1.27)                | 980.25 (1.34)               | 75.01 (5.87)                      | 1.50 (0.16)               | 20.60                  | 30.73            |
| October   | 19.30 (0.72)                | 987.23 (0.64)               | 82.11 (3.80)                      | 1.23 (0.08)               | 10.71                  | 22.10            |
| November  | 14.33 (1.14)                | 988.83 (1.68)               | 83.03 (3.89)                      | 1.26 (0.16)               | 5.34                   | 13.11            |
| December  | 9.28 (0.36)                 | 992.79 (2.33)               | 82.06 (4.86)                      | 1.28 (0.10)               | 3.89                   | 5.93             |
The monthly number of AA cases was positively correlated with monthly mean temperature ($r=0.357, P=.001$), monthly sum of sunshine ($r=0.235, P=.001$), monthly average atmospheric pressure ($r=0.229, P=.031$), and wind speed ($r=-0.242, P=.027$). Monthly precipitation ($r=0.229, P=.036$) was associated with AA (Table 2).

In stepwise regression analysis of the correlation between the incidence of AA and the meteorological factors, the monthly number of AA was the dependent variable (Y), whereas the monthly mean temperature, monthly mean relative humidity, monthly average atmospheric pressure, monthly sum of sunshine, monthly average wind speed, and monthly precipitation level were the independent variables (X); the alpha level was 0.05.

There was a good degree of matching between the cases and the regression model ($R=0.571, R^2=0.326$, adjusted $R^2=0.301$), and the regression equation was significant ($F=12.905, P<.0001$). Monthly average temperature ($P<.0001$), monthly sunshine duration ($P<.0001$), and mean average humidity ($P<.0001$) significantly affected the incidence of appendicitis in children; thus, the monthly average temperature positively affects the incidence of pediatric AA, whereas the monthly total sum of sunshine and average humidity negatively affects the incidence. Monthly mean wind speed ($P=.141$), mean air...
Table 2
Pearson correlation analysis of the relationship between the monthly number of acute appendicitis cases and meteorological factors.

| Meteorological factors | Pearson correlation analysis |
|------------------------|----------------------------|
|                        | r Value | P value |
| Temperature            | 0.357   | .001   |
| Sum of sunshine        | 0.235   | .031   |
| Humidity               | −0.357  | .001   |
| Air pressure           | −0.303  | .005   |
| Precipitation          | 0.229   | .036   |
| Wind speed             | 0.242   | .027   |

Table 3
Multiple linear regression analysis of the relationship between the monthly number of acute appendicitis cases and meteorological factors.

| Meteorological factors | Multiple linear regression analysis |
|------------------------|------------------------------------|
|                        | B value | t Value | P value |
| Temperature            | 1.442   | 4.792   | <.0001  |
| Sum of sunshine        | −0.698  | −4.208  | <.0001  |
| Humidity               | −1.263  | −4.764  | <.0001  |

4. Discussion

In this retrospective study, we investigated whether meteorological factors are related to variations in the rate of pediatric AA. Here, we enrolled 3436 AA cases over a period of more than 7 years with ages ranging from 3 months to 18 years. Meteorological data are provided by the Chongqing Meteorological Service. Our findings revealed that high temperature was positively associated with AA, whereas the sum of sunshine and precipitation per month were negatively associated.

AA is one of the most common general surgical emergencies in children, with a male/female ratio of 1.81:1, which is consistent with other research findings that men have a higher prevalence,

3.4. Correlation between temperature variation and AA cases

Mean monthly temperatures in Chongqing ranged from 6°C to 30°C. The Chi-squared goodness of fit test showed significant temperature difference at 20°C–30°C (P < .0001), indicating that the incidence of AA in children is more frequent during this temperature (Fig. 4).

The concept of seasonal patterns in the incidence of AA remains controversial. First, our analysis showed that AA occurred particularly in summer months; we found evidence of a peak from May to July in Taiwan,

4.05–51.00 mm, humidity of 50.71%–89.65%, and wind speeds of 1.05–1.87 m/s. We examined the association of climatic factors such as monthly mean temperature, monthly mean humidity, monthly sum of sunshine, monthly mean air pressure, monthly mean wind speeds and monthly precipitation with the occurrence of pediatric AA. We found that AA has an obvious time periodicity. During this 7-year period, AA showed a male/female ratio of 1.81:1, which is consistent with other research findings that men have a higher prevalence,

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AA is one of the most common general surgical emergencies in children, with a male/female ratio of 1.81:1, which is consistent with other research findings that men have a higher prevalence, peaking at ages 6 to 12 years. In general, higher rates of AA cases were associated with higher monthly mean temperatures (20°C–30°C), monthly mean lower humidity, and less sunshine per month (Table 1, Fig. 2).

The concept of seasonal patterns in the incidence of AA remains controversial. First, our analysis showed that AA occurred particularly in summer months; we found evidence of a peak from May to July in Taiwan, whereas in Nigeria, the peak incidence was observed from June to August. The reasons for increased incidence of AA at high temperatures are unclear, but it considered to be due to the effect of dehydration, lower number of bowel movements, infections of the lymphoid tissue in the appendix, and effects of diet and humidity.

Another possible explanation is a lack of accuracy in season and month divisions among countries with different geographical climates. In the same months in different countries and regions, there are some differences in meteorological factors such as temperature, humidity, and sunshine. For example, the temperature in Israel in the summer is similar to the temperature in Taiwan from May to July and the temperature in Nigeria from June to August. It has been reported that air pollution may be exacerbated when the ambient temperature is high.

Kaplan et al. reported that appendicitis may be caused by exposure to polluted air and recommended taking measures to improve air quality to reduce the incidence of appendicitis. In addition, the
5. Conclusion

Pediatric AA is associated with climatic factors. Specifically, AA is more likely to be related to the following meteorological conditions: higher temperature (20°C–30°C), low humidity, and less sunshine. This study could provide a theoretical basis for the prevention and pathogenesis of AA.

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Author contributions

Conceived and designed the experiments: Yao Zhang and Xiang Feng Lyu
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Funding acquisition: Qing Luo.

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Methodology: Yao Zhang.

Software: Quan Kang.

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Writing – review & editing: Qing Luo, Quan Kang.

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