The effect of climate and air pollution on the development of complicated appendicitis

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Article history: Received: 13.09.2021 Accepted: 26.11.2021 Published: 29.11.2021

ABSTRACT:

Aim: The aim of this study was to examine whether there is a relationship between complicated appendicitis and seasons, weekends, and air pollution.

Materials and methods: Patients who had undergone appendectomy in the last three years due to acute appendicitis were filtered from the database. Patients' demographic features, date of the surgery, pathology reports, data on atmospheric temperatures, atmospheric pressure, relative humidity, and air pollution on the date of the surgery were collected and compared between complicated and non-complicated appendicitis groups.

Results: Out of 360 patients, 238 were men. The median age was 39 years for women and 29 years for men. Complicated appendicitis was seen in 78 (21.7%) patients, and the incidence rates were similar between the sexes (p = 0.69); this rate increased with increasing age (p = 0.001). The day of the week in which the surgery was performed (p = 0.55) and weekdays versus weekends (p = 0.16) did not change the complicated appendicitis incidence rate. This rate was similar among seasons (p = 0.44), temperature (p = 0.81), humidity (p = 0.62), and atmospheric pressure (p = 0.95). There was no difference between the groups for all noxious gases or PM2.5 levels, but for PM10 levels there was a significant difference (p = 0.045). In multivariate analysis, age (p = 0.001) and PM10 air pollution (p = 0.045) significantly affected the development of complicated appendicitis.

Conclusions: Air pollution of PM10 may have a real effect on the incidence of complicated appendicitis.

KEYWORDS: air pollution, climate, complicated appendicitis, weekend effect

ABBRévIATIONS

AA – Acute appendicitis
SRL – Earth System Research Laboratories
hPa – hectopascal
IgA – Immunoglobulin A
IgM – Immunoglobulin M
NO – nitric oxide
NO2 – nitrogen dioxide
NOAA – National Oceanic and Atmospheric Administration
NOx – nitrogen oxide
SO2 – sulfur dioxide

INTRODUCTION

The human appendix is a tubular protrusion of the cecum, at the junction of the small and large intestines. Although its exact function is still unknown, it’s thought to play a role in protecting the body against infections and in maintaining healthy levels of bacteria in the gut during recovery from diarrhea [1].

Acute appendicitis (AA) is the most common surgical emergency of the abdomen. The overall incidence of AA varies from 76 to 227 cases per 100,000 people per year in different countries [1]. Acute appendicitis can be classified into simple acute appendicitis (e.g., uncomplicated early form) and complicated appendicitis (e.g., gangrenous and perforated appendicitis and appendicitis with phlegmon and/or abscess). The most often encountered form in the emergency room is simple AA. Many studies have investigated the etiology of AA, and interestingly a seasonal variation in the incidence rate was seen. This suggested that climatic factors might affect the development of appendicitis. Many researchers have recently reported that AA was seen throughout the year, but more frequently in the summer months [2–4]. The reason why AA cases peak in the summer is still unknown, though many factors – such as gastrointestinal infections, air pollution, dehydration, and low-fiber diet during this hot season – have been cited to explain the higher incidence of appendicitis [2, 5]. Although there are many studies investigating the seasonal variation of acute appendicitis, only a few have reported on complicated appendicitis and climate [6].

AIM

The aim of this study was to examine whether there is a relation between complicated appendicitis and seasons, weekends, and air pollution and to identify possible causes.

MATERIALS AND METHODS

Ethical Approval

This study was approved by the ethics committee of our institution (ID number: 21-05-2020-94). Due to its retrospective nature on anonymized data, the requirement for informed consent was waived. No patients or members of the public were involved in the design, conduct, reporting, or dissemination plans of this study.
Ministry of Environment and Urbanization for the city of Ankara (www.havaizleme.gov.tr). The air pollution data of noxious gases are presented in µg/m³, and the daily hour-weighted means were used in the analysis. The classification of threshold values for each pollutant data set was taken from the Air Quality Evaluation and Management Regulation of the Turkish Ministry of Environment and Urbanization, with pollutant parameters for the year 2020.

Statistical Analysis

We performed a descriptive analysis using variables of gender, perforation status, and patients’ distribution according to the day of the week, month, and season of the surgery. The results are presented as numbers and percentages. Age, date of surgery, atmospheric temperature, atmospheric pressure, relative humidity, and air pollution parameters were compared between the complicated and non-complicated groups. The chi-squared test and Fisher’s exact test were used to analyze categorical variables; an independent sample t-test was used to analyze continuous variables. Multivariate logistic regression models were used to determine the risk factors for complicated appendicitis. P-values lower than 0.05 were considered statistically significant. All analyses were performed with SPSS software (version 21.0; SPSS Inc., Chicago, IL).

RESULTS

Three hundred and sixty patients were included in the study. There were 238 male (66.1%) and 122 female (33.9%) patients. The median ages of the patients with non-complicated appendicitis and complicated appendicitis were 32.8 ± 0.7 years and 40.7 ± 1.9 years, respectively. Although complicated appendicitis rates were similar among the men (22.3%) and women (20.5%) (p = 0.69), this rate increased with increasing age (p = 0.001).
During the study period, the median temperature was 14.5°C in spring (range, 1.4–26.3°C), 24.4°C in summer (range, 17.7–29.9°C), 11.8°C in autumn (range, –0.9 to 21.4°C), and 4.5°C in winter (range, –6 to 15.7°C). The numbers of patients with complicated appendicitis were 18 in spring (23.1%), 20 in summer (25.6%), 24 in autumn (30.8%), and 16 in winter (20.5%). The complicated appendicitis rates were similar between the seasons (p = 0.44). The median temperatures in the group of complicated appendicitis and of non-complicated appendicitis were 13.4 ± 8.2°C and 14.6 ±8.2°C, respectively; it was found that atmospheric temperature was similar in the groups (p = 0.81). When diurnal temperature variation was evaluated, it was found to be 11.3 ± 4.6°C in the complicated appendicitis group and 11.4 ± 4.0°C in the non-complicated appendicitis group; diurnal temperature variation was also similar (p = 0.85). In addition, relative humidity and atmospheric pressure were compared between the groups. Seasonal median humidity was 53.5% (range, 24.5%–87.0%) in spring; 38.6% (range, 19.7%–68.5%) in summer; 60.0% (range, 24.5%–97.8%) in autumn, and 70.3% (range, 37.9%–98.0%) in winter. The median humidity in the complicated appendicitis group was 54.8% ±19.8% and in the non-complicated group 55.9% ± 17.2%; the rate between groups was similar (p = 0.62). The seasonal median atmospheric pressure was 912.3 hPa (range, 904.3–923.7 hPa) in spring, 912.2 hPa (range, 905.8–918.0 hPa) in summer, 916.2 hPa (range, 901.7–925.2 hPa) in autumn, and 912.0 hPa (range, 902.0–921.8 hPa) in winter. Atmospheric pressures were 913.2 ±4.12 hPa and 913.2 ± 4.2 hPa in the complicated appendicitis and non-complicated appendicitis groups, respectively; again, the groups were similar (p = 0.95).

Air pollution parameters were compared between the groups (Tab. I.). There was no difference between the groups for all noxious gases and PM2.5, but for PM10 there was a significant difference (p = 0.045). This means that as the amount of PM10 was rising, the rate of complicated appendicitis also increased significantly, whereas the other air pollutants did not affect it.

In multivariate analysis, it was found that the patients’ age (p = 0.001) and the level of PM10 (p = 0.045) were the parameters that significantly affected the development of complicated appendicitis.

**DISCUSSION**

Acute appendicitis shows marked incidence variations by age and sex. In this series, although we have found the same relationship...
of male predominance in all forms of acute appendicitis, there was no relation between non-complicated and complicated appendicitis in terms of sex. Additionally, the incidence of complicated appendicitis significantly increased with increasing age. Both of these findings are consistent with the literature [1–6].

There are some reports on children indicating that the rate of complicated appendicitis increases significantly on the weekends [5, 7, 8]. In our study on adults, there was no such relationship when patients were divided according to weekday and weekend surgeries. A seasonal variation of acute appendicitis incidence has been reported by several authors [2–6, 9]. In our series, although there was a significantly low frequency of acute appendicitis in winter (Fig. 3.), there was no seasonal variation for cases of complicated appendicitis. The environmental factors mentioned to explain the seasonal variation of acute appendicitis in the literature were temperature, humidity, atmospheric pressure, air pollution, dietary intake, and increased intestinal infections due to higher seasonal temperature [2–6]. Ilves et al., in their study comprising Finland’s entire data set during a 21-year period, reported that an increase of 10°C in temperature increased the incidence of acute appendicitis by 4% [9]. However, in Finland, the difference in median temperatures between the colder and warmer seasons was only 14°C. Oguntola, in his report from southwestern Nigeria, showed the highest incidence in the rainy season, which had higher humidity but lower temperature than the rest of the year [10]. However, in Nigeria there is higher humidity and temperature in the rainy season than in Finland or Ankara because it has a tropical monsoon climate. In other studies done in South Korea, California, USA, India, and Pakistan [6, 11–13], there was a peak of appendicitis cases in the hotter and more humid summer season. These findings made all researchers suggest that temperature and humidity played a role in rising appendicitis cases. In our study, focused on the external causes of complicated appendicitis, we did not find any effect of median temperature, diurnal temperature, relative humidity, atmospheric pressure, or noxious air pollutants on the rate of complicated appendicitis, but there was some relationship between low temperature/high humidity and the lowest acute appendicitis rate in winter. Since the aim of this study was not to investigate the incidence rate of acute appendicitis and environmental factors, it is not possible to show any statistical significance apart from the frequencies. Therefore, considering these frequencies, there was a fluctuation in the acute appendicitis incidence rate: the lowest was in the winter season, while the highest was in spring and autumn. This is consistent with the literature, which indicates a peak in warmer seasons and a low in the colder season [9]. Because people spend more time indoors and dress warmly in the winter, the real effect of low environmental temperatures on the core temperature of the human body should be minor [9].

Additionally, higher air pollution levels of PM10 increased the complication rate in appendicitis. The other air pollutants, like noxious gases and PM2.5 had no effect on the complication rate. It should be stated that PM10 includes all types of air pollutants which have a diameter of 10 µm and smaller, such as coarse particles, fine particles (PM2.5), and ultrafine particles – noxious gases. Particulate matter is made up of particles of solids or liquids that are in the air and may include dust, dirt, soot, smoke, and droplets of liquids from factories, cars, construction sites, power plants, and industrial facilities. Therefore, our finding that the complicated appendicitis rate increased as PM10 increased indicates that the air pollution increases the rate. Particles smaller than 10 µm in diameter (PM10) can invade the lungs after inhalation and can even reach the bloodstream [14]. Many epidemiological studies have been done on the health effects of PM; in addition to the respiratory effects, systemic inflammatory markers (IL-6 and fibrinogen) were found to be elevated as an immediate response to polymorphonuclear cells on the level of IL-6, possibly causing the production of acute phase proteins [15]. However, increases in serum levels of immunoglobulins (IgA and IgM) and the complement component C3 have been observed [15]. Additionally, upregulation of co-stimulatory molecules such as CD80 and CD86 on macrophages was reported, indicating an effect on antigen presentation [16]. Considering all of this research, exposure to particulate matter seems to play a role in increased oxidative stress and inflammation [14–16]. Additionally, multiple cardiovascular effects, such as changes in blood cells, coronary atherosclerosis, hypertension, stroke, myocardial infarction, and heart insufficiency, have been observed after exposure to air pollutants [17–20]. In our study, PM10 led to acute simple appendicitis more easily than to complicated appendicitis, possibly via all or some of these mechanisms.

There was no significant relationship between the incidence of acute appendicitis and levels of air pollution. The daily hour-weighted means of air pollutants peaked in autumn and saw the deep in spring, while acute appendicitis showed biannual peaks in spring and autumn; therefore, air pollution should not affect acute appendicitis incidence rates, despite the reports in the literature [2–4, 6, 9]. Though PM10 possibly directly affected the rate of complicated appendicitis in our series via the aforementioned mechanisms, this may be because air pollution impairs tissue perfusion and affects the inflammatory response of the body. Therefore, the appendicitis would more easily and quickly develop complications such as perforation, abscess, phlegmon, etc. Although we could not identify an effect of air pollution on the etiology of acute appendicitis, air pollution increases the risk of morbidity via increasing the rate of complicated appendicitis, as stated in the national reports of the WHO [21].

Our study has some limitations: it is limited to one center in our study region and our sample size was not very large.

CONCLUSION

In this study, we have shown that air pollution might have a real effect on complicated appendicitis rates with PM10 relation and the age of the patient was the unique personal characteristics affecting. Considering acute appendicitis incidence rates, there was no significant correlation with environmental factors. The topic should be investigated in larger multicenter studies with control groups.

We suggest that surgeons working in highly polluted areas, especially in periods of high air pollution, should pay special attention to the timing of surgery for acute appendicitis.