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Correlation between the season, temperature and atmospheric pressure with incidence and pathogenesis of acute appendicitis

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SUMMARY

Introduction There is very little literature data on the correlation between the seasons, temperature and atmospheric pressure, and pathogenesis of acute appendicitis (AA).

Objective The aim of this research is to investigate the association between the seasons, changes in atmospheric temperature and pressure, and patients' age and severity of the clinical form of AA in the city of Niš.

Methods This study included 395 patients diagnosed with AA, who, during the two-year period, from July 1st 2011 to June 30th 2013, were hospitalized and operated on at the Department of General Surgery, Clinical Center in Niš, Serbia.

Results The increased average daily values of barometric pressure by 1 millibar on the day when the event took place was associated ($p < 0.05$) with the decrease of total risk of the occurrence of appendicitis by 2.2% (0.2–4.1%). In all observed patients, each increase of the mean daily temperature by 1°C three days before the event took place (Lag 3) was associated ($p < 0.05$) with the increase of total risk of the occurrence of appendicitis by 1.3% (0.1–2.5%).

Conclusion According to the results of this research, we can conclude that patients' sex, age and severity of the clinical form of AA are not in connection with the seasons, while there are certain connections between appendicitis occurrence and atmospheric temperature and pressure.

Keywords: seasons; temperature; atmospheric pressure; acute appendicitis

INTRODUCTION

Acute appendicitis (AA) is the most frequent cause of acute surgical abdomen. Its course is marked as a nonspecific bacterial process. The complications of AA can be the forming of abscess and perforation, which lead to localized or generalized peritonitis with possible fatal outcome [1].

The incidence of appendicitis varies according to country, geographical region, race, sex, age, food culture, and seasons [2–5]. Most of literature data confirms the seasonal pattern of AA occurrence [3, 4, 6–12], though there are data that denies the correlation [13].

There are no literature data on the correlation between patients' age, gender, and severity of the clinical form of AA and the seasons in the city of Niš. Also, there are no literature data on the influence of changes in atmospheric temperature and pressure on the hospitalization of AA.

OBJECTIVE

The aim of this research is to investigate the association between the seasons, changes in atmospheric temperature and pressure and patients' age and severity of the clinical form of AA in the city of Niš.

METHODS

This retrospective study included 395 patients diagnosed with AA, who, during a two-year period, from July 1st 2011 to June 30th 2013, were hospitalized and operated on at the Department of General Surgery, Clinical Center in Niš, Serbia.

The research included only patients who were residents of Niš, whose symptoms of AA started on the day of their operation.

The patients were divided into groups according to sex, age, and severity of the clinical form of AA. According to age, they were divided into two groups: the group of patients under the age of 30 years, and the group of patients aged 30 years or older. The research included only patients over the age of 18.

The severity of the clinical form of AA was defined intra-operatively. Less severe form included catarrhal and phlegmonous AA, while more severe forms included gangrenous and perforated forms of AA.

The mean daily temperature and atmospheric pressure values for the city of Niš, Serbia, were obtained from the National Meteorological Department. The range of average daily values of temperature was 13.25 ± 9.73°C. The range for the daily average values of barometric pressure was 992.49 ± 6.43 millibars (mBar).

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Statistical analysis

The data presentation for this article consists of descriptive statistics including means and standard deviations for continuous variables and frequency counts, and percentages for categorical variables. To compare frequencies, χ^2 test was performed. To compare patients' years of age across four seasons, one-way analysis of variance (one-way ANOVA) was used.

To investigate the association between the appendicitis related hospitalizations and the barometric pressure, we used the negative binomial regression model. A negative binomial model was used to account the overdispersion (mean daily number of appendicitis related hospitalizations for the investigated period was 0.48 ± 0.50), as well as the number of days with zero cases (from 823 days of investigated period there were 429 days without appendicitis related hospitalizations). This model included daily appendicitis counts as the dependent variable, and average daily values of barometric pressure as the independent variable:

$$\textit{daily appendicitis counts} = e^{\textit{intercept + b (average daily values of barometric pressure)}}$$

where e is a natural number (approximately equal to 2.72) while b is a regression coefficient.

Appendicitis occurrence rate ratios for a 1 mBar change in daily average values of barometric pressure are obtained by exponentiation of the regression coefficients, that is, exp[b]. For ease of interpretation, expression 100 × (exp[b] - 1) tells us the percentage change in risk of appendicitis for each unit increase in barometric pressure.

The relationship between barometric pressure and the appendicitis risk after lags for 0, 3, and 7 days, as well as the cumulative lags for 0–3 and 0–7 days, was examined.

To investigate the association between the appendicitis related hospitalizations and the temperature, we used the negative binomial regression model that included daily appendicitis counts as the dependent variable and daily values of maximum, minimum or mean temperature as the independent variable:

$$\textit{daily appendicitis counts} = e^{\textit{intercept + b (average daily values of temperature)}}$$

The relationship between temperature and the appendicitis risk after lags for 0, 3, and 7 days, as well as the cumulative lags for 0–3 and 0–7 days, was examined.

Analyses were performed using R, a language and environment for statistical computing, version 2.12.0 (R Foundation for Statistical Computing, Vienna, Austria). A p-value less than 0.05 was considered significant in all comparisons.

RESULTS

Relationship between average age, sex, and severity of appendicitis and seasons, regarding patients with appendicitis, is shown in Table 1.

Table 1. Relationship between average age, sex, and severity of appendicitis and seasons, in patients with appendicitis

Characteristic	Total	Winter	Spring	Summer	Autumn
Age (years)	35.38 ± 17.86	35.71 ± 17.84	36.85 ± 18.74	33.68 ± 16.89	34.98 ± 17.84
Male	181 (45.8%)	39 (44.8%)	56 (47.9%)	40 (42.1%)	46 (47.9%)
Female	214 (54.2%)	48 (55.2%)	61 (52.1%)	55 (57.9%)	50 (52.1%)
Less severe	231 (58.5%)	50 (57.5%)	62 (53.0%)	61 (64.2%)	58 (60.4%)
More severe	164 (41.5%)	37 (42.5%)	55 (47.0%)	34 (35.8%)	38 (39.6%)

Table 2. Appendicitis occurrence rate ratios (95% confidence interval) for 1 mBar increase in barometric pressure by age group

Age and Lag period	Total	Less severe	More severe
All ages			
Lag 0	0.978 (0.959–0.998)*	0.994 (0.973–1.017)	0.975 (0.951–0.999)*
Lag 3	0.988 (0.968–1.008)	0.999 (0.977–1.021)	0.983 (0.959–1.008)
Lag 7	0.995 (0.976–1.015)	0.994 (0.973–1.016)	1.001 (0.977–1.026)
Lag 0–3	0.974 (0.952–0.997)*	0.992 (0.967–1.017)	0.972 (0.944–0.999)*
Lag 0–7	0.979 (0.954–1.005)	1.000 (0.972–1.028)	0.970 (0.939–1.002)
<30 years			
Lag 0	0.979 (0.960–0.999)*	0.983 (0.958–1.009)	0.978 (0.941–1.016)
Lag 3	0.997 (0.974–1.021)	1.003 (0.977–1.030)	0.986 (0.949–1.026)
Lag 7	0.995 (0.973–1.018)	0.991 (0.966–1.017)	1.005 (0.967–1.045)
Lag 0–3	0.981 (0.955–1.007)	0.988 (0.958–1.017)	0.974 (0.931–1.018)
Lag 0–7	0.985 (0.956–1.015)	0.993 (0.960–1.027)	0.973 (0.926–1.023)
≥30 years			
Lag 0	0.992 (0.969–1.015)	1.011 (0.979–1.044)	0.977 (0.949–1.007)
Lag 3	0.985 (0.962–1.009)	0.991 (0.959–1.023)	0.984 (0.955–1.014)
Lag 7	0.998 (0.975–1.021)	0.997 (0.965–1.029)	0.999 (0.970–1.029)
Lag 0–3	0.984 (0.957–1.010)	0.999 (0.962–1.036)	0.975 (0.942–1.009)
Lag 0–7	0.986 (0.957–1.017)	1.006 (0.965–1.049)	0.973 (0.936–1.011)

*$p < 0.05$

Table 3. Appendicitis occurrence rate ratios (95% confidence interval) for 1 mBar increase in barometric pressure by gender

Gender and Lag period	Total	Less severe	More severe
Females			
Lag 0	0.982 (0.960–1.005)	0.989 (0.964–1.014)	0.976 (0.941–1.013)
Lag 3	0.994 (0.971–1.017)	0.996 (0.970–1.022)	0.991 (0.955–1.029)
Lag 7	0.998 (0.976–1.020)	0.995 (0.970–1.020)	1.005 (0.969–1.043)
Lag 0–3	0.981 (0.956–1.007)	0.984 (0.956–1.014)	0.982 (0.941–1.024)
Lag 0–7	0.986 (0.958–1.016)	0.993 (0.961–1.026)	0.978 (0.933–1.026)
Males			
Lag 0	0.990 (0.967–1.014)	1.007 (0.974–1.041)	0.979 (0.949–1.009)
Lag 3	0.990 (0.966–1.014)	1.004 (0.971–1.038)	0.981 (0.951–1.011)
Lag 7	0.997 (0.973–1.020)	0.995 (0.963–1.028)	0.999 (0.969–1.029)
Lag 0–3	0.985 (0.959–1.013)	1.008 (0.970–1.047)	0.969 (0.941–0.998)*
Lag 0–7	0.987 (0.957–1.018)	1.011 (0.969–1.055)	0.970 (0.932–1.009)

*p < 0.05

Table 4. Appendicitis occurrence rate ratios (95% confidence interval) for 1°C increase in mean daily temperature by age group

Age and Lag period	Total	Less severe	More severe
All ages			
Lag 0	1.010 (0.997–1.022)	1.008 (0.994–1.021)	1.004 (0.989–1.019)
Lag 3	1.013 (1.001–1.025)*	1.007 (0.993–1.020)	1.010 (0.995–1.025)
Lag 7	1.010 (0.998–1.022)	1.001 (0.988–1.015)	1.013 (0.997–1.028)
Lag 0–3	1.013 (1.001–1.026)*	1.010 (0.996–1.024)	1.007 (0.992–1.023)
Lag 0–7	1.013 (1.001–1.026)*	1.006 (0.992–1.021)	1.010 (0.994–1.027)
<30 years			
Lag 0	1.007 (0.993–1.021)	1.007 (0.991–1.023)	1.004 (0.981–1.028)
Lag 3	1.006 (0.992–1.020)	1.004 (0.989–1.020)	1.008 (0.984–1.032)
Lag 7	1.009 (0.995–1.023)	1.002 (0.987–1.018)	1.021 (0.997–1.046)
Lag 0–3	1.010 (0.995–1.024)	1.009 (0.992–1.025)	1.008 (0.984–1.033)
Lag 0–7	1.009 (0.994–1.024)	1.006 (0.990–1.023)	1.012 (0.987–1.037)
≥30 years			
Lag 0	1.005 (0.991–1.019)	1.006 (0.986–1.026)	1.003 (0.985–1.021)
Lag 3	1.010 (0.996–1.024)	1.008 (0.988–1.028)	1.009 (0.991–1.028)
Lag 7	1.003 (0.988–1.017)	0.998 (0.979–1.017)	1.006 (0.988–1.024)
Lag 0–3	1.007 (0.993–1.022)	1.008 (0.988–1.028)	1.005 (0.987–1.024)
Lag 0–7	1.007 (0.992–1.022)	1.004 (0.983–1.024)	1.008 (0.989–1.027)

*p < 0.05

There was no statistically significant association between the patients' age, sex, and severity of the clinical form of AA and the seasons.

Appendicitis occurrence rate ratios for 1 mBar increase in barometric pressure by age group are shown in Table 2.

In all observed patients each increase of the average daily value of barometric pressure by 1 mBar on the day when the event took place was associated ($p < 0.05$) with the decrease of total risk of the occurrence of appendicitis by 2.2% (0.2–4.1%), as well as with the occurrence of more severe appendicitis ($p < 0.05$) by 2.5% (0.1–4.9%). The increase of the average barometric pressure by 1 mBar on the day when the event took place and three days before it (Lag 0–3) was associated with the decrease of the risk of the occurrence of appendicitis ($p < 0.05$) by 2.6% (0.3–4.8%), as well as of the occurrence of more severe appendicitis ($p < 0.05$) by 2.8% (0.1–5.6%).

In the <30 years age group each increase of the average daily values of barometric pressure by 1 mBar on the day when the event took place was associated ($p < 0.05$) with the decrease of total risk of the occurrence of appendicitis by 2.1% (0.1–4.0%). In the ≥30 years age group no significant association between barometric pressure and appendicitis occurrence risk was confirmed.

Appendicitis occurrence rate ratios for 1 mBar increase in barometric pressure by sex are shown in Table 3.

In males, the increased average daily values of barometric pressure by 1 mBar on the day when the event took place and three days before it (Lag 0–3) was associated with the decrease of the risk of the occurrence of more severe appendicitis ($p < 0.05$) by 3.1% (0.2–5.9%). In females, no significant association between barometric pressure and appendicitis occurrence was confirmed.

Appendicitis occurrence rate ratios (95% confidence interval) for 1°C increase in mean daily temperature by age group are shown in Table 4.

In all observed patients, each increase of the mean daily temperature by 1°C three days before the event took place (Lag 3) was associated ($p < 0.05$) with the increase of total risk of the occurrence of appendicitis by 1.3% (0.1–2.5%). The increase of the mean daily temperature by 1°C on the day when the event took place and three days before it (Lag 0–3), as well as mean daily temperature on the day when the event took place and seven days before it (Lag

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Table 5. Appendicitis occurrence rate ratios (95% confidence interval) for 1°C increase in mean daily temperature by gender

Gender and Lag period	Total	Less severe	More severe
Females			
Lag 0	1.012 (0.998–1.026)	1.012 (0.996–1.028)	1.007 (0.985–1.030)
Lag 3	1.010 (0.996–1.024)	1.008 (0.992–1.024)	1.010 (0.987–1.033)
Lag 7	1.008 (0.994–1.022)	1.004 (0.988–1.019)	1.014 (0.991–1.037)
Lag 0–3	1.015 (1.001–1.030)*	1.014 (0.998–1.031)	1.011 (0.988–1.035)
Lag 0–7	1.013 (0.998–1.028)	1.010 (0.994–1.027)	1.013 (0.989–1.037)
Males			
Lag 0	0.999 (0.985–1.014)	0.997 (0.977–1.017)	1.001 (0.983–1.019)
Lag 3	1.006 (0.992–1.021)	1.002 (0.982–1.022)	1.008 (0.990–1.027)
Lag 7	1.004 (0.990–1.019)	0.997 (0.977–1.017)	1.010 (0.991–1.028)
Lag 0–3	1.001 (0.987–1.016)	0.999 (0.978–1.020)	1.003 (0.984–1.022)
Lag 0–7	1.003 (0.988–1.018)	0.997 (0.976–1.018)	1.007 (0.988–1.027)
Lag 0	0.999 (0.985–1.014)	0.997 (0.977–1.017)	1.001 (0.983–1.019)

*$p < 0.05$

0–7) were associated with the increase of the risk of the occurrence of appendicitis ($p < 0.05$) by 1.3% (0.1–2.6%).

Appendicitis occurrence rate ratios (95% confidence interval) for 1°C increase in mean daily temperature by sex are shown in Table 5.

In females, each increase of the mean daily temperature by 1°C on the day when the event took place and three days before it (Lag 0–3) was associated with the increase of the risk of the occurrence of appendicitis ($p < 0.05$) by 1.5% (0.1–3.0%). In males, no significant association between appendicitis occurrence and mean daily temperature was confirmed.

DISCUSSION

The conducted research did not show statistically significant correlation between the patients' age, sex, and severity of the clinical form of AA and the seasons. The lack of the seasonal pattern of AA in this research matches the results of Wolkomir et al. [13], while most of literature data show the summer pattern of the occurrence of AA [3, 4, 8–11]. Also, there are studies that suggest the tendency of the occurrence of appendicitis during winter [14, 15, 16]. The reason for this trend is unclear, but it has been reported that several factors may play a part: 1) the varying effects of bacterial or viral pathogens that cause infections at different temperatures, 2) the effect of allergens during warmer months, 3) nutritional variations, and 4) the effect of migration of tourists during summer [6, 17, 18].

The results of the conducted research showed that changes in daily values of atmospheric pressure on the day of the occurrence of AA, as well as three days before, were accompanied by decreased frequency of AA in all examined patients, including the patients with severe forms of AA. In all examined patients, changes in daily values of atmospheric temperature three days before the occurrence of AA, as well as changes in temperature three and seven days prior to the day of the occurrence of AA, were accompanied by increased occurrence of AA, with no connection to the severity of clinical form. The research conducted by Gallerani et al. [8] in Italy showed a seasonal pattern of the occurrence of AA, which depended on the clinical form of AA. In this research, acute appendicitis accompanied by peritonitis occurred more frequently during the summer [8]. Deng et al. [10] showed in their research that perforative AA had a winter pattern of incidence.

Appendix is classified as a lymphatic organ due to its structure rich in lymph follicles. There are about 200 lymph follicles in human body between the ages of 12 and 20 years. After the age of 30, the number of lymph follicles decreases by half, and after the age of 60, lymph follicles are present only in traces [19, 20]. The lymph follicles play an important role in pathogenesis of AA. Therefore, different pathogenetic mechanisms are expected among different age groups. The results presented in the research show that in patients with AA who were under the age of 30, a change in the average value of atmospheric pressure on the day of the event was accompanied by decreased occurrence of AA, with no connection with the clinical form of AA. In patients with AA aged 30 and over, there was no correlation between a change in the average value of atmospheric pressure and the occurrence and clinical form of AA. The age of patients with AA was not related to changes in the average values of atmospheric temperature. The research of Gallerani et al. [8] showed that in patients under the age of 19, the occurrence of AA was most frequent during the winter, while in patients aged 20 and over, the occurrence of AA was more frequent in the summer.

The research conducted by Sulu et al. [21] shows that AA is most common in males 10–19 years of age, while the research conducted by Noudeh et al. [9] shows that AA is most common in the summer, in men aged 20–29. Körner et al. [22] showed that the occurrence of perforated AA is not gender related. In the conducted research, it is presented that in men a change in the average daily value of atmospheric pressure on the day of the occurrence of AA, as well as three days before it, was accompanied by decreased frequency of only severe forms of AA, while the same correlation was not found in women. In women, a change in the average daily value of atmospheric temperature three days prior to the day of the occurrence of AA, was accompanied by increased occurrence of AA, with no connection to the clinical form of AA, while in men, there was no correlation between a change in the average value of atmospheric temperature and the occurrence and clinical form of AA.

Khaavel' et al. [6] reported the increase of appendicitis occurrence rate during the periods of vast fluctuations of air temperature, increase in air humidity and decrease of actual sun radiance duration. The increase of acute appendicitis occurrence was also noted during the months of great and extremely great magnetic storms [6].

There are no literature data on the mechanism involved in the influence of atmospheric temperature and pressure on the pathogenesis of AA. The results of the study suggest that an increase of atmospheric pressure decreases the occurrence of AA and vice versa. Hypothetically, an increase in temperature, which is always accompanied by peripheral vasodilatation and decreased volume of blood circulating through internal organs, results in decreased blood irrigation of the appendix [23]. Thus, the supply of defense cells like leukocytes in appendix is decreased [23]. This results in decreased perfusion and defense ability of appendix, which further increases the occurrence of AA.

In humans, an increase in hydrostatic pressure of only 5 atmosphere absolute (ATA) causes a significant bradycardia [24]. Mulkey et al. [25] found that neurons in the dorsal motor nucleus of vagus and nucleus tractus solitarius are stimulated by ≤4 ATA of helium. These cardiovascular changes are likely mediated, in part, by a hyperbaric-induced increase in catecholamine secretion [26, 27]. Human studies at relatively high pressures have shown an augmentation of sympathetic nervous system activity, as measured by plasma epinephrine and norepinephrine levels [26]. Hypothetically, we can presume that an increase of pressure affects the sympathetic nervous system, which leads to peripheral vasodilatation under the influence of catecholamine, all of which increases perfusion of internal organs, including the appendix. The increased perfusion, as well as the increased supply of defense cells, could affect the decrease in the occurrence of AA.

It is necessary to point out that this is the very first research dealing with correlation between atmospheric temperature and pressure and pathogenesis of AA. Further research should be aimed at additional clarification concerning the mechanisms of the influence that atmospheric temperature and pressure have on pathogenesis of AA, as well as at examination of association between climatic factors and already known etiological risk factors concerning the occurrence of AA. The data would attribute to additional clarification of pathogenesis of AA.

CONCLUSION

According to the results of this research, we can conclude that patients' sex, age, and severity of the clinical form of AA are not in connection with the seasons, while there are certain connections with changes in atmospheric temperature and pressure.

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Корелација годишњих доба, температуре и атмосферског притиска с патогенезом акутног апендицитиса

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КРАТАК САДРЖАЈ

Увод Постоји врло мало литературних података о повезаности годишњих доба, температуре и атмосферског притиска са патогенезом акутног апендицитиса (АА).

Циљ рада Циљ овог истраживања је да се утврди повезаност годишњих доба, температуре и атмосферког притиска са патогенезом акутног апендицитиса на територији града Ниша.

Методе рада Истраживањем је обухваћено 395 пацијената са дијагнозом АА, који су у периоду од две године, од 1. јула 2011. до 30. јуна 2013, хоспитализовани и оперисани на Клиници за општу хирургију КЦ Ниш.

Резултати Повећање просечног дневног атмосферског притиска за један милибар на дан када су се јавили први симптоми апендицитиса било је повезано са смањењем ризика од појаве апендицитиса за 2,2%. Код свих пацијената свако повећање средње дневне температуре за 1°C три дана пре појаве симптома било је повезано са повећањем ризика од појаве апендицитиса за 1,3%.

Закључак Према нашим резултатима можемо да закључимо да пол, старост пацијента и тежина клиничке форме АА нису повезани са годишњим добима, али постоји повезаност између броја хоспитализација због апендицитиса и атмосферског притиска и температуре.

Кључне речи: годишња доба; температура; атмосферски притисак; акутни апендицитис

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