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The occurrence of appendicitis varies according to latitudes and seasons

A French national retrospective study

Jean-François Hamel[a,b], Chloé Saint-Dizier[c,d], Antoine Lamer[c,d], Dune Allard[b], Tino Bienvenu[b], Mathieu Levaillant[b], Aurélien Venara[b,e,f,*]

Background: Recent reports indicate that the occurrence of appendicitis follows a seasonal pattern and that there is an association between increased incidence and warmer weather. It is noteworthy that a reduction in the incidence of appendicitis has been observed in the Northern Hemisphere. The objective of this study is to present the epidemiological profile of appendicitis at the national level in France.

Methods: This retrospective observational study, based on data from the French National Discharge Database, encompasses all hospitalizations for appendicitis diagnosis between 2013 and 2022. The progression of appendicitis over time was assessed through time-series models. The incidence of appendicitis was also compared depending on year, gender, age, and latitude.

Results: It is noteworthy that the incidence of appendectomy in France exhibited a significant decrease between 2013 and 2022, with an average reduction of 2.1% annually. There was a significant decrease in the number of appendectomies performed on patients ≤20, while there was an increase in those >60. Furthermore, there was a seasonal pattern in the incidence of appendicitis, with a peak during the summer months. The seasonality remained consistent over time. Furthermore, there was a south-north gradient, with a higher number of appendectomies performed in the south.

Conclusion: Seasonality (summer vs. winter) and latitude (south vs. north) could be considered as a proxy for temperature. However, temperature alone cannot explain the observed variations in appendicitis occurrence, since the latter decreases over time, in parallel with global warming. It is likely that other environmental and ecological parameters may be responsible for these variations.

Keywords: Appendicitis; Environmental parameters; Epidemiology; Data reuse; France

[a]Département de biostatistique, CHU Angers, Angers, France; [b]Faculté de Santé, Département de médecine, Université d'Angers, Angers, France; [c]Fédération régionale de recherche en psychiatrie et santé mentale des Hauts de France (F2RSM Psy), Hauts-de-France, Saint-André-Lez-Lille, France; [d]University Lille, CHU Lille, ULR 2694-METRICS: Évaluation des Technologies de Santé et des Pratiques Médicales, Lille, France; [e]Service de chirurgie viscérale et endocrinienne, CHU Angers, Angers, France; and [f]Nantes Université, CHU Nantes, INSERM, The Enteric Nervous System in Gut and Brain Disorders, IMAD, Nantes, France

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Data are available on reasonable request to the corresponding author.

The study protocol was in accordance with the French reference methodology MR-005 of the French Data Protection Authority (Commission Nationale de l'Informatique et des Libertés).

**Corresponding Author. Address: Department of Visceral Surgery, CHU Angers, Angers University Hospital, 4 rue Larrey 49933, Angers Cedex 09. E-mail: auvenara@chu-angers.fr (A. Venara)*

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Background

Appendicitis is a common emergency characterized by the inflammation of the cecal appendix. The current recommended management of appendicitis is laparoscopic surgical removal of the appendix (appendectomy). The overall lifetime risk of developing appendicitis is estimated to be between 7 and 9%.[1,2] The Global Burden of Disease Study 2021 reports that the age-standardized mortality rate per 100,000 in 2021 was 0.358 (95% uncertainty interval [UI] = 0.311, 0.414).[3] This rate increases from 0.0976 (95% UI = 0.0883, 0.105) in high-income countries to 0.480 (95% UI = 0.348, 0.853) in sub-Saharan Africa.[3] In light of these considerations, the authors hypothesized that the increase of incidence in sub-Saharan Africa is due to an increase in diagnosis, more than to a real increase of the incidence.[3] For the authors, that means that a significant number of individuals may still lack access to quality healthcare, and that countries should prioritize the development of robust healthcare infrastructure to facilitate timely and effective diagnosis and treatment.[3]

To optimize the healthcare infrastructure's ability to cope with the burden of appendicitis, it is essential to gain a deeper understanding of the risk factors associated with this condition.

What this study adds

The prevalence of appendicitis decreases in France with an average annual reduction of 2.1%. There was a seasonal pattern in the incidence of appendicitis. Environmental and ecological parameters other than temperature may be responsible for this seasonality, as evidenced by the discrepancy between the northern and southern regions of France.

Several factors have been identified as potential risk factors for appendicitis, including age between 10 and 19,[1,4,5] male gender, gut microbiota,[6] and dietary habits, as well as environmental factors such as air pollution[7] and atmospheric pressure.[8] However, the evidence supporting these associations is currently limited. The most frequently studied parameters are temperature and season. Recent publications indicate that the occurrence of appendicitis follows a seasonal pattern and that there is an association between increased incidence and warmer weather.[9–11]

Given that warmer weather seems associated with an increase in the occurrence of appendicitis,[9–11] it is surprising to note that the literature reports a stability or even a decrease in the occurrence of appendicitis in the Northern Hemisphere,[12] while the increase in temperatures has been particularly fast in the cold season in Europe.[13] In contrast, Yang et al[12] report a significant increase in the incidence of appendicitis in the southern hemisphere, with rates rising by up to 262.28%. Heat waves being associated with the spread of infectious diseases,[14] we hypothesize that parameters other than the temperature may be involved in the occurrence of appendicitis.

It would be beneficial to explore the hypothesis that temperature may have a role in the occurrence of appendicitis as a potential lead to better understand the kinetics of appendicitis. The objective of this study is to present the epidemiology of appendicitis in France between 2013 and 2022, with a focus on the impact of gender, age, appendicitis characteristics, season, and geography.

Methods

This is a retrospective observational study based on data from the French National Discharge Database (PMSI, Programme de Médicalisation des Systèmes d'Information). The PMSI provides access to data from healthcare institutions and hospital federations. The study was conducted in accordance with the French reference methodology MR-005 of the French Data Protection Authority (Commission Nationale de l'Informatique et des Libertés). As this study does not involve human participants, the requirement for informed consent was waived.

Data source

The PMSI database is a medico-administrative database containing standardized discharge reports for all stays in French public and private hospitals. A unique national identification number enables the linking of each patient's hospital stays. The database contains individual-level data on admission and discharge dates, hospital identifiers, and outcomes (i.e., discharge, hospital transfer, and death), as well as patient sex, age, and place of residence. The principal diagnosis, defined as the main reason for admission, and any associated diagnoses related to comorbidities are also collected and coded in accordance with the French version of the International Statistical Classification of Diseases and Related Health Problems, 10th Revision (ICD-10). The medical procedures are documented using the French terminology of the Classification Commune des Actes Médicaux (CCAM).

Study population and data collected

All hospital stays for appendicitis diagnosis based on ICD-10 codes K37, K35.8, K35.2, K35.4, and CCAM code were included. For each stay, we extracted the hospital identifier, the date of surgery, the patient's age, sex, and place of residence.

A medical treatment for simple appendicitis was defined as an emergency department visit with a diagnosis code of K37 or K35.8, without the need for hospitalization or surgery.

A case of simple appendicitis with surgical treatment was defined as a hospitalization with one of the following CCAM codes: The relevant codes are HHFA011, HHFA001, or HHFA016. Simple (or uncomplicated) appendicitis was defined as appendicitis operated on and for which there was no peritonitis or abscess treated.

Complicated appendicitis was defined as a hospitalization with one of the following diagnoses: The following codes were used to define the various types of appendicitis: K35.2 alone, K35.3 alone, or (K35.8 and [K65 or K65.0c]), or K35 and (K65 or K65.0c), or with one of the following surgical procedure codes: The relevant codes are HHFA020 and HHFA025. Complicated appendicitis was defined by appendicitis operated on and for which there was a peritonitis or an abscess that was observed and treated.

In the present study, simple appendicitis with surgical treatment was considered as a proxy for the whole simple appendicitis, whatever their treatment because of coding reliability reasons.

Statistical analysis

Categorical data were reported as a percentage, and continuous data are reported as a median with an interquartile range.

As the entire French population was the subject of the study, rather than a sample from which results should be extrapolated, a straightforward description was deemed more appropriate for the majority of results, rather than the use of statistical tests because of the possible issues due to overpowering, leading to highlight very significant differences with absolutely no clinical relevance.

The evolution of the monthly appendicitis case counts over time was modeled using Seasonal Autoregressive Integrated Moving Average time-series models, integrating both seasonal and nonseasonal autoregressive and moving average parameters to ascertain whether a seasonal component may influence the incidence rate of appendicitis during the year. The parameters under consideration were selected on the basis of the Akaike Information Criterion.[15] The Seasonal Autoregressive Integrated Moving Average models were validated by analyzing the autocorrelation and partial autocorrelation functions of the residuals.[16]

The impact of time, gender, age and latitude on appendicitis incidence was examined through linear models, explaining the annual number of appendicitis cases by year, gender, age (divided into four groups: <20 years, 20–40 years, 40–60 years and ≥60 years) and quartiles of the latitude of the center where the patient was treated (Group 1 [G1]: between 41.86361°N and 44.66361°N, G2: between 44.68417°N and 46.72833°N, G3: between 46.7778°N and 48.44111°N, and. G4: between 48.52222°N and 50.49361°N). An analysis of the residuals was carried out to ensure the validity of these models.

The analyses were conducted using the R software and the auto.arima function of the forecast library.[17]

Results

Appendectomies and appendicitis

The ratio of appendectomies to cases of appendicitis remained stable between 2013 and 2022, with a range of 99.7% to 99.8% between 2013 and 2022 (Table 1).

Trends of appendicitis between 2013 and 2022

A total of 761,414 patients underwent appendectomy in France between 2013 and 2022 (Table 1). During the period under review, the number of patients undergoing appendectomy decreased from 84,998 in 2013 to 70,248 in 2022 (Figure 1), representing a 17.3% reduction between 2013 and 2022. The average annual reduction in the number of appendectomies was 2.1%.

Characteristics of patients having an appendectomy in France

The median age was 25 years (15, 44), and 53.1% were male. The male-to-female ratio increased steadily from 1.07 to 1.16 between 2013 and 2022 (Table 2 and Figure 2).

Additionally, the median age increased during the period of the study, from 23 years old (14, 42) in 2013 to 29 (16, 48) in 2022. The mean annual increase of the median age was 0.5% (see Table 3). It is noteworthy that the number of appendectomies in patients under 20 years of age decreased by an average of 4.7% annually, while the number of such procedures in patients aged 60 and above increased by an average of 1% annually (Figure 3).

Characteristics of appendicitis in France

During the period, 763,116 appendicitis cases were simple while 309.763 were complicated appendicitis (28.9%). The ratio of complicated appendicitis rose from 27.5% in 2013 to 30.5% in 2022 (Table 4). The ratio of complicated to simple appendicitis increased with age and year (Figure 4).

Table 1.

Number of appendicitis and ratio of appendectomy/appendicitis between 2013 and 2022

Year	Number of appendicitis	Number of appendectomies	Ratio appendectomies/ appendictis	Annual decrease
2013	85,172	84,998	0.998	
2014	83,082	82,901	0.998	0.020
2015	82,437	82,303	0.998	0.007
2016	77,974	77,821	0.998	0.050
2017	77,183	77,062	0.998	0.009
2018	72,889	72,735	0.998	0.050
2019	72,767	72,557	0.997	0.002
2020	71,025	70,829	0.997	0.020
2021	71.852	71,662	0.997	−0.012
2022	70,413	70,248	0.998	0.019

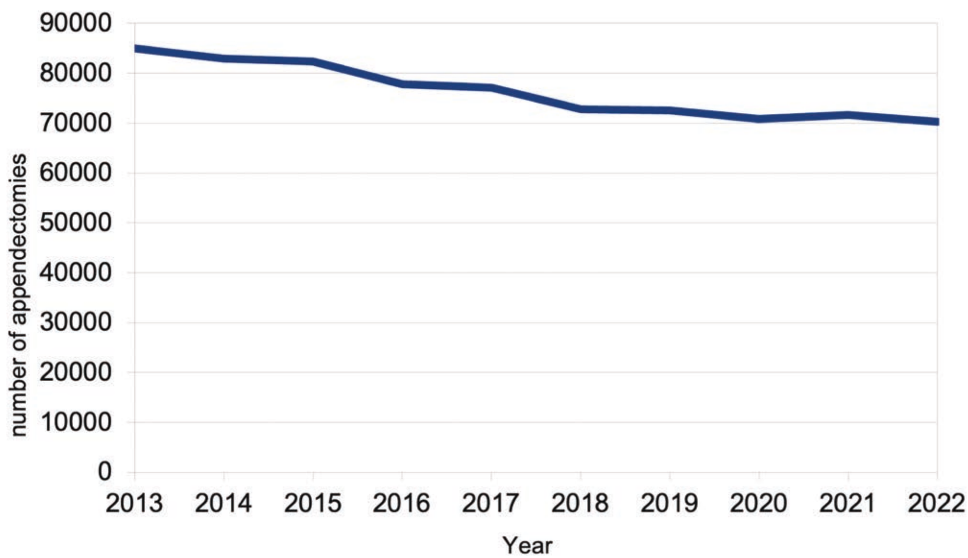

Figure 1. Number of appendectomies according to the year.

Table 2.

Number of appendectomies per year, according to the gender

	Male	Female	Ratio male/female
2013	43,944	41,053	1.07
2014	43,399	39,502	1.10
2015	43,426	38,877	1.12
2016	41,215	36,606	1.12
2017	41,088	35,974	1.14
2018	38,521	34,214	1.13
2019	38,795	33,762	1.15
2020	38,258	32,571	1.17
2021	38,630	33,032	1.17
2022	37,811	32,437	1.17

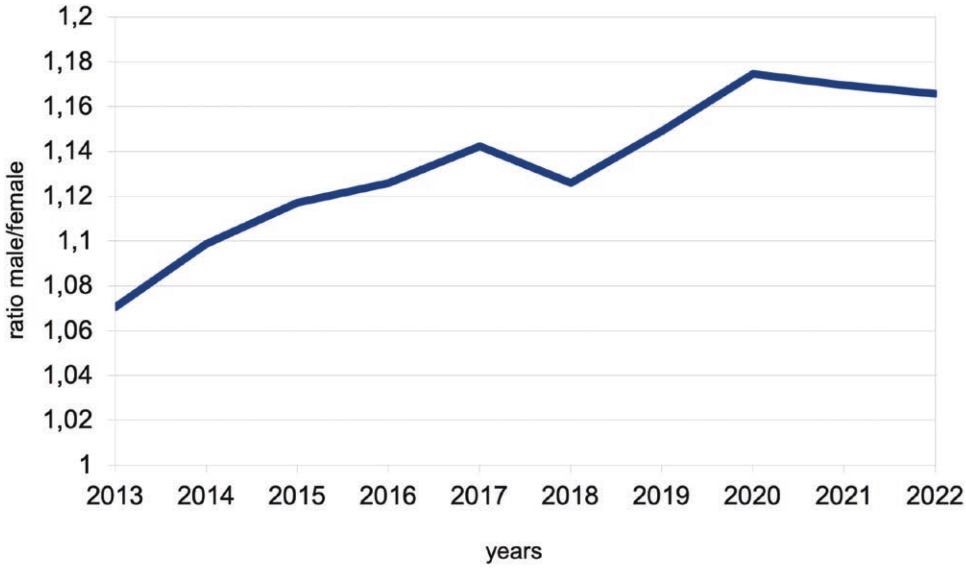

Figure 2. Ratio of male/female experiencing an appendectomy according to the year.

Table 3.

Number of appendectomies per year, according to the class of ages, and means and medians of age according to the year

	Overall	<20	≥20 & <40	≥40 & <60	≥60	Mean age	Median of age
2013	84,998	35,844	26,463	13,369	9322	29.46	23
2014	82,901	34,495	25,801	13,159	9446	29.77	23
2015	82,303	33,183	25,898	13,445	9777	30.39	24
2016	77,821	30,041	25,054	13,082	9644	31.06	25
2017	77,062	29,050	25,087	13,113	9812	31.34	26
2018	72,735	26,826	23,438	12,744	9727	31.85	26
2019	72,557	26,557	23,288	13,003	9709	32.01	27
2020	70,829	25,267	23,126	12,575	9861	32.38	27
2021	71,662	24,968	23,482	13,101	10,111	32.65	28
2022	70,248	23,186	23,493	13,383	10,186	33.35	29

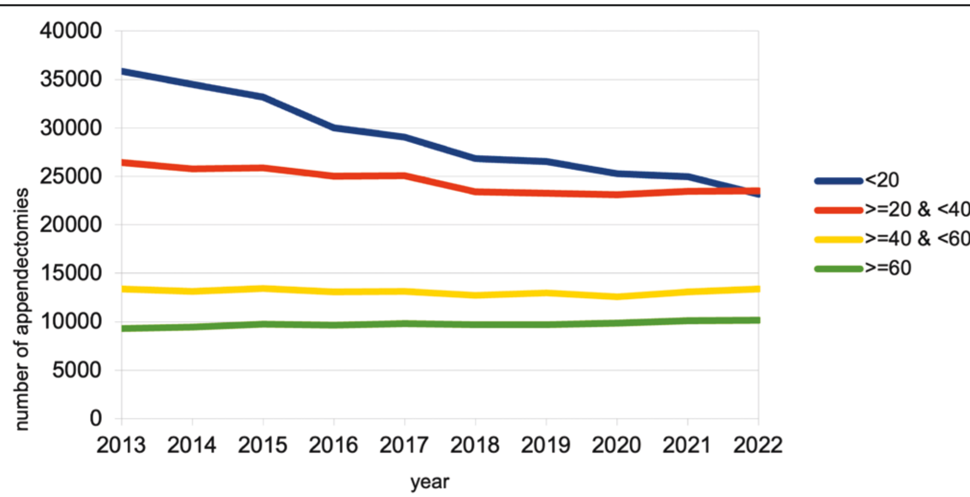

Figure 3. Number of appendectomies per year, according to the age class.

Appendectomies over the months between 2013 and 2022

The time-series model revealed a significant seasonal component (Figure 5). The data revealed a consistent pattern of seasonal occurrence for appendectomies in France, with a peak during the summer months and a decline during the winter (the variation in the number of appendicitis cases due to the seasonal component being 1100 cases in average).

Appendectomies according to the latitude

While the observed trend was consistent (Figure 6), there was a significant discrepancy in the distribution of appendicectomies between the different latitudes. There was no significant difference between the two latitudes in the south, but there was a significant reduction in the number of appendectomies performed per 100,000 inhabitants in the two northern latitudes

Table 4.

Number of simple and complex appendectomy and ratio of simple/complex appendectomy according to the year

	Simple appendectomy	Complex appendectomy	Ratio complex/simple	% of complex appendectomy
2013	84,998	32,183	0.38	0.27
2014	82,901	31,758	0.38	0.28
2015	82,303	32,688	040	0.28
2016	77,821	30,695	0.39	0.28
2017	77,062	30,916	0.40	0.29
2018	72,735	29,627	0.41	0.29
2019	72,557	30,056	0.41	0.29
2020	70,829	30,543	0.43	0.30
2021	71,662	30,507	0.44	0.29
2022	70,248	30,790	0.44	0.30

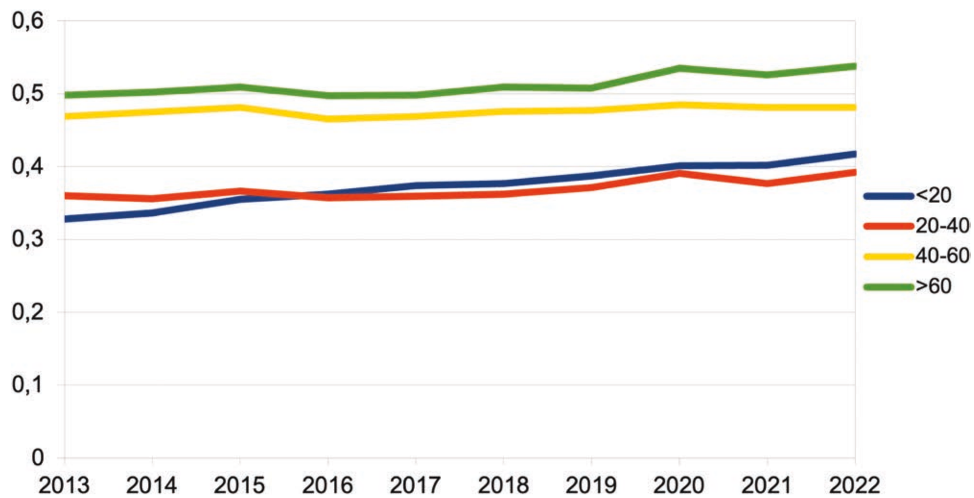

Figure 4. Percentage of complex appendicitis according to the age class, per year.

(on average a difference of 10 appendectomies/100,000 inhabitants between north and south) (Table 5). This discrepancy was not influenced by the year, which was also identified as an independent factor associated with appendectomies (Table 6). It is noteworthy that the impact of time and that of latitude (north vs. south) exhibited a similar magnitude.

Discussion

The number of appendectomies performed in France has decreased on average by 2.1% per year between 2013 and 2022. There was a significant decline in the number of appendectomies performed on patients under the age of 20, while there was an increase in those over the age of 60. The ratio of complicated appendicitis to simple appendicitis increased with age and year. It is noteworthy that there was a seasonal variation in the incidence of appendicitis, with a peak during the summer months. The seasonality remained consistent over time. Furthermore, there was a significant discrepancy between the number of appendectomies performed in the north and south of France, with a higher prevalence in the south.

First, in the present study, the appendectomies were used as a proxy to analyze the trends of appendicitis in France. This choice was made because the ratio between appendicitis and appendectomies remained stable in France, advocating for a stable management of appendicitis. Given that the coding of appendectomies is likely to be more accurate than that of appendicitis diagnoses, the former was used as a proxy for the latter in the subsequent study.

Then, our findings align with the existing literature in terms of the number of appendectomies performed. Indeed, a recent meta-analysis reports a decrease in the number of appendectomies in Western countries since 1990.[18] In France, the number of appendectomies decreased from 162,500 in 1997 to 83,400 in 2012. This decrease may be due to a reduction in the number of false-positive appendectomies resulting from recent recommendations for preoperative imaging.[19,20] However, this explanation is probably insufficient because some reports indicate the risk of false-positive appendectomies to be "only" 8.6–23%.[21–23] Another potential explanation is the increase in the number of randomized controlled studies examining the nonoperative management of simple appendicitis in children[24,25] and adults.[26,27] While appendectomy remains the recommended course of action,[28] the nonoperative management of uncomplicated appendicitis in children is a viable option.[19] This last explanation is not supported by our findings, which show a decrease in both the number of appendicitis cases and the number of appendectomies. However, it should be noted that the coding of appendicitis may be a potential source of bias in this study, as it could be underestimated through unintentionally incorrect coding.

Then, the observed decrease in appendicitis among patients under 20 years of age and the concurrent increase in complicated appendicitis may be partially attributed to a shift in the management of appendicitis towards nonoperative management of noncomplicated cases in children.[19] It is likely that this modification of practice is insignificant in France and does not explain these trends on its own. One potential explanation is the increasing proportion of the elderly population in France, which is associated with an increased prevalence of complicated appendicitis in this age group. In patients aged 65–79 years, the proportion of complicated appendicitis is 43.97%, while in patients aged 75 years and above, it is 56.84–63%.[29,30]

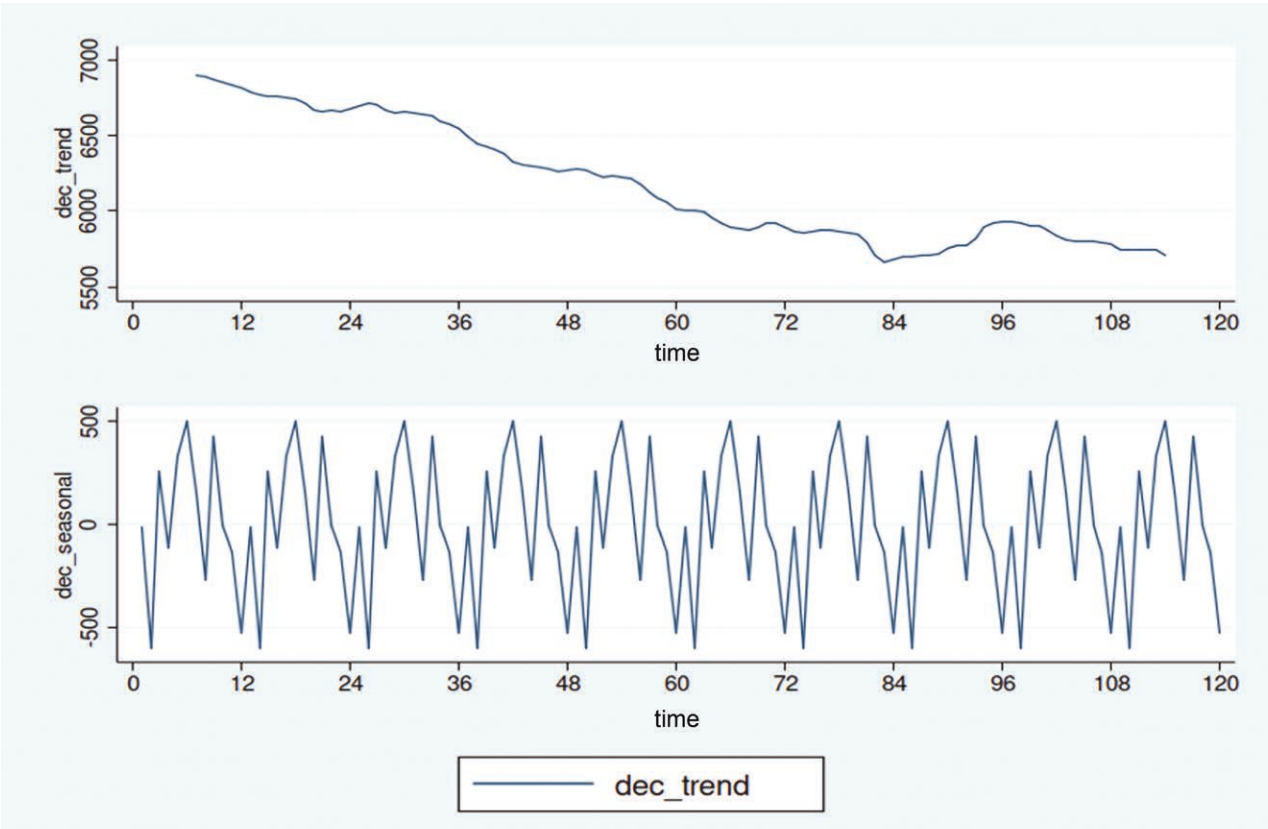

Figure 5. SARIMA time-series models representing the number of appendicitis cases in France, according to the months.

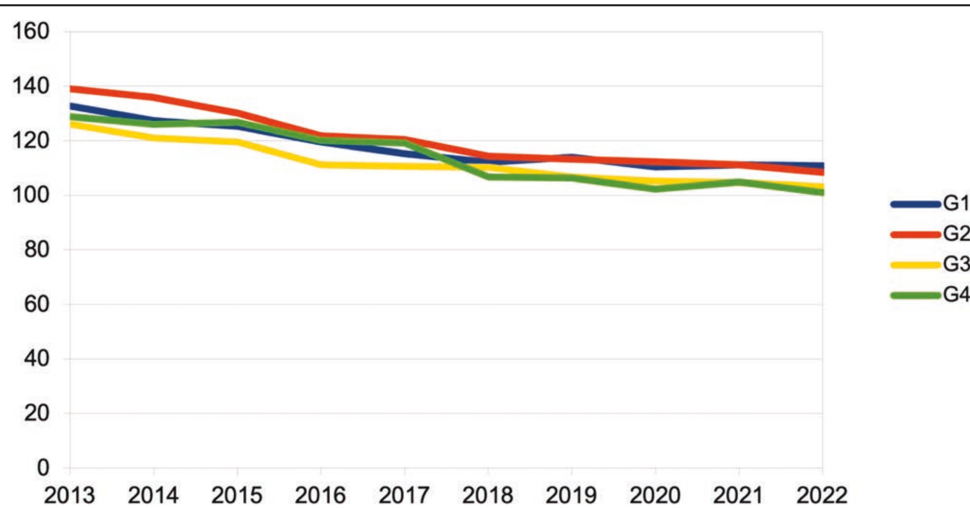

Figure 6. Number of appendectomies per 100,000 inhabitants according to latitude on a yearly basis. G, groupe of latitude.

In terms of seasonal trends, this study aligns with existing literature, indicating a peak during the summer months and a decline during the winter.[5,10,11,31,32] However, our findings do not align with the hypothesis that the incidence of appendicitis is linked to warmer weather. Despite a rise in temperature over the past decade in France, with an increase of 0.3°C in each decade since 1959,[33] there has been a decline in the number of cases of appendicitis. Furthermore, given the accelerated rise in temperatures during the winter months in Europe,[13] it would be reasonable to anticipate an increase in the incidence of appendicitis during this season when compared to summer, which was not observed in this study. This suggests the need to consider the role of other environmental factors in the occurrence of appendicitis. It has been suggested that exposure to air pollution may be associated with an increased risk of appendicitis.[34] This could be a potential area for assessment, given the correlation between air pollution and temperature.[35] Additionally, atmospheric pressure[8] and viral causes[36,37] have been proposed as potential explanatory factors for the occurrence of appendicitis. It is noteworthy that the south of France is a region with mountains and a high population density in tourist areas during the summer holiday season. These last parameters are associated with increased atmospheric pressure (altitude) and higher population density and promiscuity, increasing the risk of pathogen transmission.

Table 5.

Occurrence of appendectomies/100,000 inhabitants, according to the year and the latitude in France

Year	G1	G2	G3	G4
2013	132.61	139.04	126.01	128.88
2014	127.25	135.89	121.09	126.03
2015	125.28	130.19	119.52	126.67
2016	119.47	121.72	111.22	120.13
2017	115.30	120.51	110.66	119.09
2018	112.01	114.36	110.14	106.78
2019	113.93	113.12	106.71	106.29
2020	110.40	112.18	105.24	102.21
2021	111.07	111.14	104.59	104.91
2022	110.72	108.43	103.10	100.89

Table 6.

Multivariate analysis of the impact of years and latitude on the occurrence of appendectomies

	Coef	95% confidence interval	*P* value
Year	–0.000029	–0.000033, –0.000026	$<10^{-4}$
Latitutde (REF : G1)			
G2	0.0000285	–0.00000143, 0.0000585	0.06
G3	–0.0000598	–0.0000897, –0.0000298	$<10^{-4}$
G4	–0.0000362	–0.0000661, –0.00000622	0.02

It should be noted that this study is subject to certain limitations inherent to its medico-administrative character. As this is an analysis of a medico-administrative database, there is no possibility of assessing the quality of the data reported, and some coding may be incorrect. However, this database is used for financial purposes, and regular quality control checks are carried out by the national health authority, which ensures the data is of a high quality. Also, being an observational study, there is no possibility to determine causality between the correlations highlighted.

Our analyses highlight a link between the incidence of appendicitis and latitude; therefore, the French region is considered. It is possible that the highlighted north-south gradient does not reflect an ecological impact on appendicitis but a possible regional healthcare accessibility and healthcare-seeking behavior variation. The same seasonality and latitude might not only reflect temperature differences but also air pollution or hygiene variations. Finally, we considered the appendicitis cases as ascertained from the hospital where the patients were treated, which does not necessarily reflect where they normally resided.

Notwithstanding the aforementioned limitations, this study offers valuable insights into the potential role of environmental factors in the incidence of appendicitis and provides a comprehensive overview of its epidemiology at the national level.

Conclusions

While seasonal fluctuations in appendicitis occurrence have been observed, increasing annual temperature was not associated with national appendicitis rates over the same period. Indeed, the French incidence of appendicitis has been found to decline by an average of 2.1% annually, coinciding with a global rise in temperature. It is likely that other environmental parameters are responsible for this seasonality, as evidenced by the discrepancy between the northern and southern regions of France. Further confirmation of such a difference between the Northern and the Southern regions and correlation with temperature and other environmental parameters are mandatory to improve the comprehension of appendicitis pathophysiology.

Conflicts of interest statement

Aurélien Venara has received speaker and consultant honoraria from Sanofi-Aventis, Thermofisher, Takeda, and Vifor. The other authors declare that they have no conflicts of interest with regard to the content of this report.

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