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Impact of Meteorological Conditions on Abdominal Aortic Aneurysm Rupture: Evaluation of an 18-Year Period and Review of the Literature

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Abstract

Objective: To examine the influence of local meteorological conditions on the onset of ruptured abdominal aortic aneurysms (AAA). **Methods:** A review of 6551 consecutive days with a total of 191 ruptured AAA was performed between January, 1994 and December, 2011. Days with and without ruptured AAA were compared considering local meteorological data. A systematic review of the literature was performed. **Results:** Atmospheric pressure, cloudiness, relative humidity, precipitation, and water vapor pressure were comparable at event and nonevent days. The 4-day variance of atmospheric pressure prior to event days was significantly higher compared to nonevent days. Maximal and average temperature and water vapor pressure were significant lower at event days. Binary regression analysis identified a higher 4-day variance in atmospheric pressure as an independent factor for ruptures. **Conclusions:** Further studies—collected at different geographic and climate areas—are necessary to prove that meteorological conditions may trigger the incidence of ruptured AAA.

Keywords

ruptured abdominal aortic aneurysm, weather conditions, biometeorology, emergency, atmospheric pressure

Background

Ruptured abdominal aortic aneurysm (AAA) is the most disastrous emergency situation in vascular surgery, associated with high morbidity and mortality rate, even if the patient reaches the emergency department early.[1-3] Patient's inherent risk factors for development of AAA have been analyzed and comprise age, gender, family history, smoking, coronary heart disease, and arterial hypertension.[3] The current literature supports the hypothesis that distinct meteorological conditions, especially low atmospheric pressure, are associated with a higher rate of ruptured AAA.[4-8] However, other publications have failed to reveal any relation between weather and the occurrence of ruptured aortic aneurysm.[9-12] Several publications demonstrated a seasonal peak in the incidence of AAA ruptures,[5,6,12-18] whereas other publications could not find any significant effect concerning seasonality.[7-10,19-21]

Taken together, convincing evidence assessing the relation between rupture rate, weather, and seasonality is poor, because all studies published so far differ extremely in patient population, geographic location, local climate, study design, and statistical methodology. Therefore, the aim of the present study was to investigate a possible association between meteorological data and the rupture rate of AAA by analyzing data of a tertiary referral center over an 18-year period.

Methods

The database comprised all consecutive patients operated in our department for ruptured AAA between January 1, 1994, and December 8, 2011. Operation records of all patients were evaluated using the hospital information system SAP/ish.med (SAP, St Leon-Rot, Germany).

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Meteorological Data

Daily regional meteorological data were obtained online from German's National Meteorological Service (Deutscher Wetterdienst, Offenbach, Germany).[22] The following parameters were analyzed: atmospheric pressure (hPa), mean, minimum, and maximum of air temperature (°C), humidity (percentage), water vapor pressure (hPa), precipitation (mm), wind speed (m/s), and cloud cover (given as *oktas* or eighths). In order to illustrate weather fluctuations with regard to event days, the variance of these meteorological parameters 4 and 7 days prior to events was calculated as the ratio of standard deviation and mean. Temporal patterns in ruptured AAA were assessed considering the total counts per month and season (spring: March 21-June 20, summer: June 21-September 22, autumn: September 23-December 20, and winter: December 21-March 20).

Statistical Analysis

All values are expressed as means ±standard error of the mean. Univariate analysis: After proving the assumption of normality and homogeneity of variance across groups, differences between the groups were calculated using the unpaired Student *t* test. For more than 2 groups, the analysis of variance test was used followed by the post hoc Student-Newman-Keuls test. For nonnormally distributed data, the groups were compared using Mann-Whitney *U* test or Wilcoxon rank test. For binary logistic regression, event days were determined as dependent variable. Based on the results of the current literature, it was assumed that small changes in meteorological variables would not influence the rupture rate, so that each meteorological variable being significant in the univariate analysis on the .05 level was visually classified in 10 equal groups or deciles and defined as independent variable. Differences were considered significant at $P < .05$. Data collection and statistical analysis were performed using the software package SPSS 15 (SPSS, Chicago).

Results

During the study period, 58 997 operations in general, visceral, or vascular surgery were performed in our department. Of the 6551 days evaluated, there were 189 (3%) days with emergency operations due to perforated aortic aneurysms. On 187 days, 1 patient was admitted to the hospital, whereas on 2 days, 2 ruptures occurred. There were 165 (86.4%) male patients and 26 (13.6%) female patients. Mean age of the patients was 73.1 ± 0.6 years ranging from 49 to 94 years. There was a significant age difference between female (77.6 ± 1.6 years) and male (72.4 ± 0.6 years; $P < .01$) patients.

Local Climate and Weather Data

The University Hospital of Saarland represents a tertiary referral center for about 1 million people and is located in the south west of Germany, 233 m above the sea level. Local climate is fully humid (C), characterized by warm temperature (f) and warm summers (b); thus, it is classified as "Cfb" climate according to Koeppen and Geiger.[23] Local climate data over the observation period are given in Table 1.

Table 1. Overview of Meteorological Variables between January 1, 1994 and December 8, 2011 for the Region of Homburg/Saar.[a]

Variable	Mean	Range	Variance
Atmospheric pressure, hPa	978.8 ± 0.10	942.1-1000.9	62.9
Average temperature, °C	9.8 ± 0.09	−13.7-28.7	51.9
Minimal temperature, °C	5.8 ± 0.08	−18.7-21.9	40.9
Maximal temperature, °C	14.1 ± 0.10	−10.6-37.1	71.6
Cloudiness, eighths	5.4 ± 0.03	0.0-8	5.0
Relative humidity, %	78.8 ± 0.16	33.8-100	172.0
Water vapor pressure, hPa	10.0 ± 0.05	1.8-23.1	16.1
Average precipitation, mm	2.4 ± 0.06	0.0-58.7	24.5
Average windspeed, m/s	3.5 ± 0.02	0.2-13.2	2.9

[a] Adapted from German Weather Service.[22]

Mean atmospheric pressure during the observation period was 978.8 ± 0.1 hPa, ranging from 942.1 hPa to 1000.9 hPa. Compared to the preceding day, falling barometric pressure was recorded 3331 (49.1%) times, whereas pressure was constant or rising on 3320 (50.9%) days. No significant atmospheric differences were recorded between days with ruptured AAA (978.7 ± 0.6 hPa) and days without rupture (978.8 ± 0.1 hPa; $P = .791$; Table 2).

Average temperature, maximal temperature, and water vapor pressure were significantly lower on days with ruptured AAA compared to days with no ruptures (Table 2). The 4-day variance of atmospheric pressure prior to the rupture events was significantly higher compared to those days without ruptures, whereas the 7-day variance was not statistically different between both the groups. No other climate variables were found to be significantly different in event days compared to nonevent days. Falling pressure tendency and change in absolute atmospheric pressure was similar in both the groups (Table 2).

In binary regression analysis (Table 3), only the change in 4-day atmospheric pressure variance prior to event days could be identified as an independent variable that may influence rupture events. Figure 1 illustrates the cumulative number of days with rupture events based on the specific meteorological variables (each with 10 subgroups; deciles).

Circadian and Seasonal Pattern

Most patients were operated between 6:00 AM and 5:59 PM (61.8%), with a first peak between noon and 3:00 PM and a second peak between 4:00 and 5:00 PM. Seasonal distribution of the 189 days with at least 1 rupture event was similar in all the 4 seasons, with a slight peak in autumn and a nadir in summer (Table 4).

Discussion

Due to the high mortality of ruptured AAA, disease-associated risk factors have been investigated extensively. Although the

Table 2. Summary of Climatic Characteristics During the Evaluation Period Between January 1, 1994, and December 8, 2011. Comparison of Days With Ruptured AAA (n = 189) and Days Without Ruptured AAA.[a]

Variable	Days With Rupture	Days Without Rupture	*P* Value
Atmospheric pressure, hPa	978.7 ± 0.6	978.8 ± 0.1	.791
Variance 4 days before	21.0 ± 1.7	17.0 ± 0.3	.020
Variance 7 days before	31.8 ± 2.3	27.5 ± 0.4	.065
Low pressure (cutoff = median)	49.8%	50.2%	.507
Falling pressure tendency	49.1%	50.9%	.556
Average temperature, °C	8.8 ± 0.5	9.8 ± 0.1	.031
Variance 4 days before	3.2 ± 0.2	3.3 ± 0.04	.511
Variance 7 days before	5.2 ± 0.3	5.4 ± 0.1	.728
Minimal temperature, °C	5.1 ± 0.04	5.8 ± 0.1	.070
Variance 4 days before	3.8 ± 0.3	4.0 ± 0.1	.079
Variance 7 days before	5.8 ± 0.4	6.1 ± 0.1	.371
Maximal temperature, °C	12.9 ± 0.6	14.1 ± 0.1	.045
Variance 4 days before	4.7 ± 0.3	5.1 ± 0.1	.449
Variance 7 days before	7.6 ± 0.4	7.8 ± 0.1	.654
Humidity, %	79.0 ± 1.0	78.8 ± 0.2	.801
Variance 4 days before	44.1 ± 3.5	47.8 ± 0.6	.133
Variance 7 days before	61.9 ± 4.1	65.7 ± 0.7	.187
Cloudiness, eighths	5.5 ± 0.2	5.4 ± 0.028	.256
Variance 4 days before	2.0 ± 0.2	2.1 ± 0.03	.254
Variance 7 days before	2.7 0.2	2.8 ± .0277	.388
Precipitation, mm	2.5 ± 0.36	2.4 ± 0.06	.62
Water vapor pressure	9.3 ± 0.26	10.1 ± 0.05	.02
Variance 4 days before	1.598 ± 0.03	1.729 ± 0.14	.1
Variance 7 days before	2.368 ± 0.167	2.6 ± 0.02	.074

Abbreviations: AAA, abdominal aortic aneurysms; SEM, standard error of the mean.
[a] Values are given as Mean ± SEM or percentage.

size of the aneurysm, female sex as well as current smoking, rapid growth, and hypertension have been identified as independent variables, little is known on how external circumstances may trigger AAA rupture.[1,21,24-29]

Although several studies aimed to find a relation between weather conditions and the incidence of major cardiovascular emergencies,[9,30,31] there is only little evidence on how far the meteorological parameters may contribute to aortic ruptures. In recently published studies, Verberkmoes et al.[30] and Ishikawa et al.[9] report that the number of daily admissions due to type A dissections and acute myocardial infarction were triggered by low temperature, whereas admissions due to RAAA were independent from meteorological conditions.

So far, several studies aimed to find a potential correlation of weather conditions—especially of low atmospheric pressure—with the rate of ruptured AAA.[5-10,12,14] Amazingly, the great majority of all studies dealing with the topic were conducted in Europe at sea level or in vicinity of the coast, either at the North Sea or in the Mediterranean region[4-10,12] (Table 5). Climate at sea level is associated with higher average atmospheric pressures compared to continental climate. Laplace law—that is under equilibrium conditions the pressure to the circumference of a vessel storing or transmitting fluid related to the product of the pressure across the wall and the radius of the vessel—could explain an increased rupture rate at lower atmospheric pressure levels but not at higher atmospheric pressure levels. It can be hypothesized that coastal populations may have light atmospheric pressure fluctuations much more than populations in a continental climate, which may result in a higher sensibility for higher blood pressure values, and hence atmospheric pressure-related rupture of AAA. Harkin[5] and Smith et al[8] concluded that the occurrence of ruptured AAA is associated with a low atmospheric pressure. In consequence to their conclusions, it had to be assumed that with rising altitude, barometric pressure decreases with a higher incidence of ruptured AAA. However, a large number of humans with known or unknown AAA are often exposed to low atmospheric pressure conditions during ascent to high altitudes or during flights in a pressurized cabin,[32-34] and there is no evidence confirming higher AAA rupture rates in mountain regions or in airplanes, except 1 single case report.[35]

Our study is the first one to evaluate the most common meteorological parameters and, especially important, their variance prior to rupture event days. Univariate analysis identified 4 individual parameters that significantly differ on rupture event days compared to those days without rupture. Since alterations in atmospheric pressure are generally accompanied by alterations in other meteorological parameters, it is extremely difficult to delineate the effect of each component. Logistic regression of climate variables and rupture rates would implicate that each numeric change would be associated with a rising rupture rate. Thus, we included all significant variables in a binary logistic regression analysis and divided each significant variable into 10 equal steps, postulating that small changes in pressure do not lead to higher ruptured AAA incidence. Surprisingly, a higher 4-day variance in atmospheric pressure was the only significant factor influencing rupture events. Pañella-Agustí found that a drop in atmospheric pressure 1 week prior to rupture events,[7] and Killeen and coworkers postulated even a lower atmospheric pressure in the preceding month.[6] Generally, these results seem to be in line with our findings; however, long periods prior to rupture events are difficult to explain, as this would postulate some kind of "aortic memory" of earlier pressure conditions.

Under chronobiological aspects, our results are in line with the data published by Killeen and coworkers,[36] which must be interpreted as a mirror of the well-known circadian variations in blood pressure,[37] especially for patients having both hypertension and AAA. Arterial blood pressure is subjected to chronobiological rhythm showing a rise in blood pressure in the early morning and a peak in the afternoon, directly related to adrenaline, aldosterone, and renin plasma levels. Furthermore, blood pressure shows a summer–winter variation.[31] Although a significant seasonal or monthly peak is shown by several authors,[5,6,13,15,17,18] (Table 5) this could not be confirmed by our own data.

One major drawback of all studies is that meteorological data were considered as a dependent variable, which would implicate that a raw rupture rate (as an independent variable) may

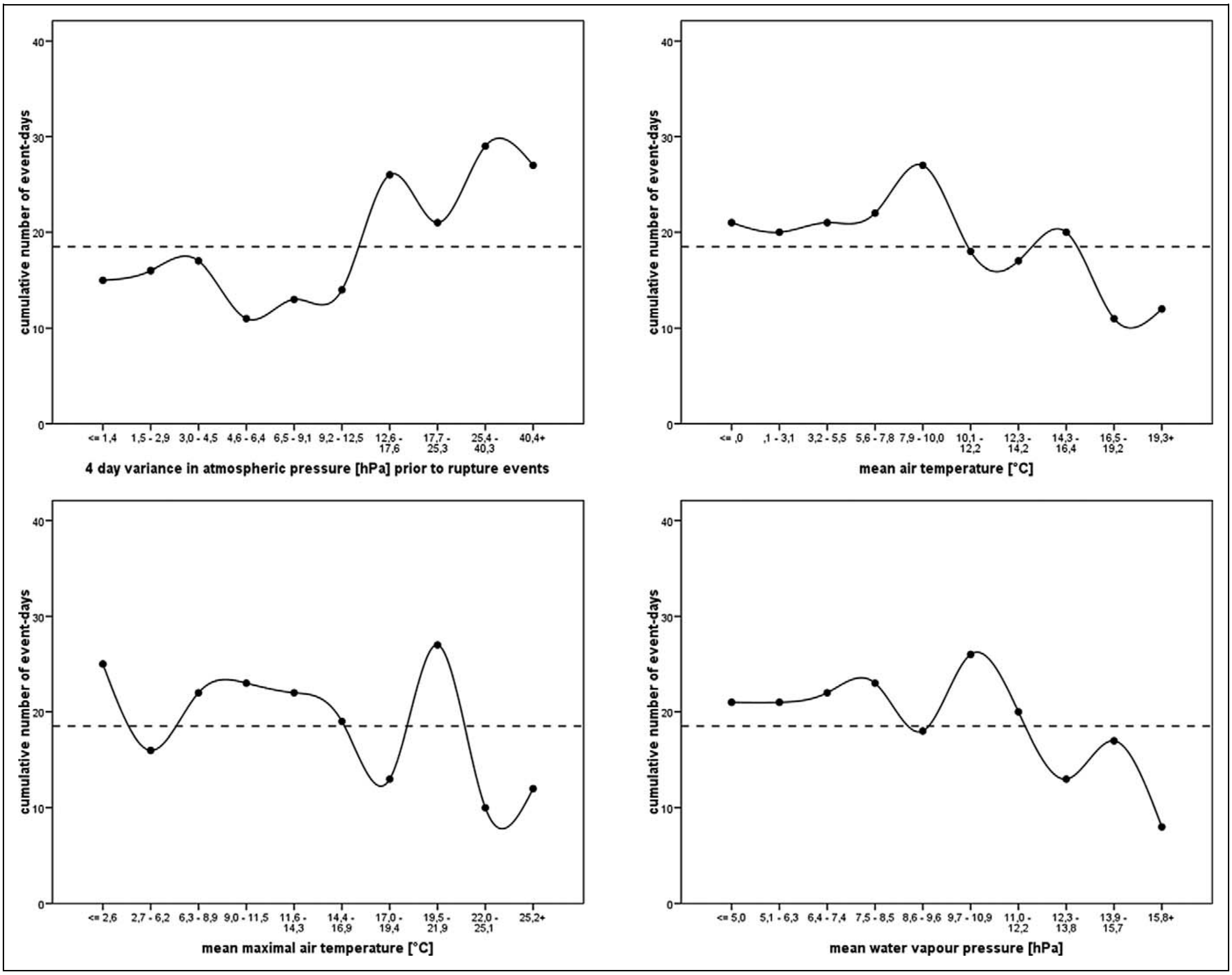

Figure 1. Different meteorological parameters and their influence on abdominal aortic aneurysms ruptures. X-axis indicates the individual meteorological parameter in deciles. Y-axis indicates the number of rupture events per decile. The dotted line indicates the mean number of rupture events overall.

Table 3. Binary Regression Analysis Including all Significant Variables of the Univariate Analysis. Occurrence of Ruptured AAA was set as Independent Variable. All Variables were Split as Deciles, Resulting in 10 Subgroups of Each Meteorological Variable.

					95% Confidence Interval of RR	
Variable	Wald	*df*	Sig	RR	Lower Bound	Upper Bound
4-day variance in atmospheric pressure prior to rupture events	7.7256	1	0.01	1.08	1.02	1.14
Mean air temperature	0.0311	1	0.86	1.03	0.77	1.37
Mean maximal air temperature	0.0016	1	0.97	1.00	0.79	1.25
Water vapor pressure	0.6172	1	0.43	0.95	0.83	1.08

Abbreviations: AAA, abdominal aortic aneurysms; Sig, Significance RR, relative risk; *df*, degrees of freedom.

Table 4. Seasonal Pattern of Days With Rupture Events.

Season	Winter	Spring	Summer	Autumn	Overall
Days at risk	1609	1656	1656	1630	6551
Days with rupture events	49	51	34	55	189
Day-adapted rupture risk, %	3.0	3.1	2.1	3.4	2.9

influence meteorological conditions. Assuming the opposite, that is meteorological conditions influence rare events, the event itself had to be the independent variable and not vice versa. A multivariate analysis of weather conditions is missing in the majority of the studies. In the case of ruptured AAA, rare binary events (day with ruptured AAA vs day without ruptured AAA)

Table 5. Review of the Current Literature Assessing the Link Between Weather and Seasons on Incidence of Ruptured AAA.

Study, year	Location/ Country	Influence of Atmospheric Pressure	Seasonality	Altitude	Near Coastline	Climate	Days With Rupture/No. of Patients	Statistical Method	Period	Mean Atmospheric Pressure
Damnjanović, 2012[19]	Nic/Serbia	na	–	192 m	–	Continental	55	Chi-square test and Student *t* test	2008-2011	na
Ishikawa, 2011[9]	Okazaki/ Japan	–	–	Sea level	+	na	16/17	Student *t* test, Pearson correlation, and multiple logistic regression	January 2004-December 2005	1015
Killeen, 2008[6]	Cork/Ireland	Lower atmospheric pressure on preceding month, similar atmospheric pressure on days with rupture compared to days without rupture	Peak in December, May, and June	Sea level	+	Oceanic/ North Sea	201	Pearson correlation	January 1988-December 2002	994.4
Smith, 2008[8]	Liverpool/ Chester/ Wrexham	Lower atmospheric pressure on days with rupture and higher range of atmospheric pressure on days with rupture	–	Sea level	+	oceanic/ north sea	180/182	Student *t* test/ ANOVA, linear regression, and multiple logistic regression	January 2001-December 2005	1014.3
Harkin, 2005[5]	Belfast/ Ireland	Lower atmospheric pressure on days with rupture and those days before	Seasonality: peak in April	Sea level	+	Oceanic/north sea	127	Chi-square test and Student *t* test	April 1998-March 2001	1013.25
Pañella-Agustí, 2004[7]	Tarragona/ Spain	Significant drop in atmospheric pressure 1 week prior to the event	No significant seasonality: peak in November	Sea level	+	Mediterranean	55	Student *t* test and Pearson correlation	January 1998-December 2002	1016
Kurtoglu, 2004[10]	Istanbul/ Turkey	–	–	Sea level	+	Mediterranean	24	Fisher exact test	January 1995-May 2003	na
Bown, 2003[4]	Leicester/ Enlgand	Lower atmospheric pressure on days with rupture	Monthly variation in admission rates	Sea level	–	Oceanic/north sea	223	Pearson correlation	January 1991-December 2000	1015
Upshur, 2000[20]	Ontario (region)/ Canada	na	No significant seasonality, peak in winter, troughs in summer	na	na	Continental	Retrospective analysis of 2373 cases	Spectral analysis	1988-1997	na
Ballaro, 1998[13]	England/ Wales	na	Significant peak in winter	na	+	Oceanic/north sea	Autopsy study: 19 599 patients with RAAA		January 1991-December 1995	na
Kakkos, 1997[16]	Patras/ Greece	na	Majority of ruptures in October and April	sea level	+	Mediterranean	46	na	1991-1995	na
Sterpetti, 1995[12]	Rome/Italy	–	Seasonality: peak in autumn, May, and July	Sea level	na	Mediterranean	77		January 1956-March 1986	na

(continued)

Table 5. (continued)

Study, year	Location/ Country	Influence of Atmospheric Pressure	Seasonality	Altitude	Near Coastline	Climate	Days With Rupture/No. of Patients	Statistical Method	Period	Mean Atmospheric Pressure
Liapis, 1992[17]	Athens/ Greece	na	Seasonality: peak in autumn	Sea level	+	Mediterranean	224 patients	na	December 1968-December 1990	na
Castleden, 1985[15]	Western Australia (region)	na	Seasonality: peak in winter	na	na	Desert/ subtropical/ grassland	253 emergency operations/123 autopsies	Chi-square test	January 1971-December 1981	na
Brown, 1999[21]	93 Centres/ England	na	Nadir in September and October	na	na	Oceanic/north sea	103 patients with rupture events	na	1991-1998	na
Manfredini, 1997[18]	Ferrara/Italy	na	Significant peaks in spring and autumn	9 m	+	Mediterranean	54 patients	na	1982-1994	na
Present study	Homburg/ Germany	Higher variance in the 4-day period prior to rupture	–	233	–	Oceanic	189/191	Mann-Whitney *U* test, Student *t* test, and multiple logistic regression	January 1994-December 2011	978.8

Abbreviations: AAA, abdominal aortic aneurysms; ANOVA, analysis of variance; na, not applicable.

are investigated with a very large number of nonevents. Due to the law of small numbers,[38] such rare events with many known trigger variables are difficult or nearly impossible to predict.

Admittedly, some shortcomings of the present study have to be faced. By including surgical data only, a bias on the accuracy of incidence of ruptured AAA may result, because only patients who are admitted alive to the hospital were included. Furthermore, the individual climatic exposition of patients having ruptured AAA at their home location before admission to the emergency department is impossible to record. Our retrospective database does not comprise information concerning symptom onset or possible hypertensive problems of the patients.

All in all, rupture events are more dependent on patient-related factors than to external circumstances such as meteorological, seasonal, or other reasons.[39] Although most other studies dealing with the topic so far considered the relationship between RAAA and single meteorological parameters, we are the first group to evaluate multiple parameters of weather in a large cohort over a long observation period. Our data show a significant relationship between 1 distinct meteorological condition, that is 4-day variance in barometric pressure and rupture rate of AAA. To draw a final conclusion and to highlight the clinical impact of small changes in weather conditions on aortic rupture, a nationwide link between screening[3] and surveillance programs[21] on one hand and death statistics and meteorological data on the other hand is mandatory.

Declaration of Conflicting Interests

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References

1. Alexander S, Bosch JL, Hendriks JM, Visser JJ, Van Sambeek MR. *The 30-day mortality of ruptured abdominal aortic aneurysms: influence of gender, age, diameter and comorbidities.* J Cardiovasc Surg *(Torino).* 2008;49(5):633-637.
2. Anjum A, von Allmen R, Greenhalgh R, Powell JT. Explaining the decrease in mortality from abdominal aortic aneurysm rupture. *Br J Surg*. 2012;99(5):637-645.
3. Eckstein HH, Böckler D, Flessenkämper I, Schmitz-Rixen T, Debus S, Lang W. Ultrasonographic screening for the detection of abdominal aortic aneurysms. *Dtsch Arztebl Int*. 2009;106(41):657-663.
4. Bown MJ, McCarthy MJ, Bell PR, Sayers RD. Low Atmospheric Pressure is Associated with Rupture of Abdominal Aortic Aneurysms. *Eur J Vasc Endovascu Surg*. 2003;25(1):68-71.
5. Harkin DW, O'Donnell M, Butler J, Blair PH, Hood JM, Barros D'Sa AA. Periods of low atmospheric pressure are associated with high abdominal aortic aneurysm rupture rates in Northern Ireland. *Ulster Med J*. 2005;74(2):113-121.
6. Killeen SD, O'Sullivan MJ, Coffey JC, Redmond HP, Fulton GJ. Atmospheric pressure variations and abdominal aortic aneurysm rupture. *Ir J Med Sci*. 2008;177(3):217-220.
7. Pañella-Agustí F, Hernández-Osma E, Díaz-Torrens J, et al. Abdominal aortic aneurysms. the influence exerted by atmospheric pressure and the season of the year on their rupture. *Angiologia*. 2004;56(1):39-45.
8. Smith RA, Edwards PR, Da Silva AF. Are periods of low atmospheric pressure associated with an increased risk of abdominal aortic aneurysm rupture? *Ann R Coll Surg Engl*. 2008;90(5):389-393.
9. Ishikawa K, Niwa M, Tanaka T. Difference of intensity and disparity in impact of climate on several vascular diseases. *Heart Vessels*. 2011;27(1):1-9.
10. Kurtoglu M, Yanar H, Aksoy M, et al. Seasonality in the incidence of abdominal aortic aneurysm ruptures: a review of eight years. *Ulus Travma Acil Cerrahi Derg*. 2004;10(1):39-41.
11. Repanos C, Chadha NK. Is there a relationship between weather conditions and aortic dissection? *BMC Surg*. 2005;5:21.
12. Sterpetti AV, Cavallari N, Allegrucci P, Agosta F, Cavallaro A. Seasonal variation in the incidence of ruptured abdominal aortic aneurysm. *J R Coll Surg Edinb*. 1995;40(1):14-15.
13. Ballaro A, Cortina-Borja M, Collin J. A seasonal variation in the incidence of ruptured abdominal aortic aneurysms. *Eur J Vasc Endovasc Surg*. 1998.15(5):429-431.
14. Brown HK, Simpson AJ, Murchison JT. The influence of meteorological variables on the development of deep venous thrombosis. *Thromb Haemost*. 2009;102(4):676-682.
15. Castleden WM, Mercer JC. Abdominal aortic aneurysms in Western Australia: descriptive epidemiology and patterns of rupture. *Br J Surg*. 1985;72(2):109-112.
16. Kakkos SK, Tsolakis JA, Katsafados PG, Androulakis JA. Seasonal variation of the abdominal aortic aneurysm rupture in southwestern Greece. *Int Angiol*. 1997;16(3):155-157.
17. Liapis C, Sechas M, Iliopoulos D, et al. Seasonal variation in the incidence of ruptured abdominal aortic aneurysm. *Eur J Vasc Surg*. 1992;6(4):416-418.
18. Manfredini R, Portaluppi F, Gallerani M, et al. Seasonal variations in the rupture of abdominal aortic aneurysms. *Jpn Heart J*. 1997;38(1):67-72.
19. Damnjanović Z, Milan Jovanović, Predrag Đordević, et al. Seasonal variations of the incidence of ruptured abdominal aortic aneurysm at the territory of the South Serbia. *Acta Fac Med Naissensis*. 2012;29(3):133-137.
20. Upshur RE, Mamdani MM, Knight K. Are there seasonal patterns to ruptured aortic aneurysms and dissections of the aorta? *Eur J Vasc Endovasc Surg*. 2000;20(2):173-176.
21. Brown LC, Powell JT. Risk factors for aneurysm rupture in patients kept under ultrasound surveillance. UK small aneurysm trial participants. *Ann Surg*. 1999;230(3):289-96; discussion 296-297.
22. http://www.dwd.de/bvbw/appmanager/bvbw/dwdwwwDesktop?_nfpb=true&_windowLabel=T18360023600136076838543 2&_urlType=action&_pageLabel=_dwdwww_spezielle_nutzer_verkehr_wetterdaten
23. Kottek M, Grieser J, Beck C, Rudolf B, Rubel F. World map of the Koppen-Geiger climate classification updated. *Meteorologische Zeitschrift*. 2006;15(3):259-263.
24. Dueck AD, Johnston KW, Alter D, Laupacis A, Kucey DS. Predictors of repair and effect of gender on treatment of ruptured abdominal aortic aneurysm. *J Vasc Surg*. 2004;39(4):784-787.

25. Dueck AD, Kucey DS, Johnston KW, Alter D, Laupacis A. Survival after ruptured abdominal aortic aneurysm: effect of patient, surgeon, and hospital factors. *J Vasc Surg*. 2004;39(6):1253-1260.
26. Koga Y, Mishima Y, Hara M, Hiraki T, Ushijima K. Prognostic factors associated with mortality in patients undergoing emergency surgery for abdominal aortic aneurysms. *J Anesth*. 2011;25(5):666-671.
27. Powell JT, Brown LC, Greenhalgh RM, Thompson SG. The rupture rate of large abdominal aortic aneurysms: is this modified by anatomical suitability for endovascular repair? *Ann Surg*. 2008;247(1): 173-179.
28. Sakalihasan N, Limet R, Defawe OD. Abdominal aortic aneurysm. *Lancet*. 2005;365(9470):1577-1589.
29. Sweeting MJ, Thompson SG, Brown LC, Powell JT, RESCAN collaborators. Meta-analysis of individual patient data to examine factors affecting growth and rupture of small abdominal aortic aneurysms. *Br J Surg*. 2012;99(5):655-665.
30. Verberkmoes NJ, Soliman Hamad MA, Ter Woorst JF, Tan ME, Peels CH, van Straten AH. Impact of temperature and atmospheric pressure on the incidence of major acute cardiovascular events. *Neth Heart J*. 2012;20(5):193-196.
31. Brennan PJ, Greenberg G, Miall WE, Thompson SG, Seasonal variation in arterial blood pressure. *Br Med J (Clin Res Ed)*. 1982;285(6346):919-923.
32. Kelly PT, Seccombe LM, Rogers PG, Peters MJ. Directly measured cabin pressure conditions during Boeing 747-400 commercial aircraft flights. *Respirology*. 2007;12(4):511-515.
33. Mieske K, Flaherty G, O'Brien T. Journeys to high altitude–risks and recommendations for travelers with preexisting medical conditions. *J Travel Med*. 2011;17(1):48-62.
34. Schommer K, Bartsch P. Basic medical advice for travelers to high altitudes. *Dtsch Arztebl Int*. 2011;108(49):839-847; quiz 848.
35. Shaw KP, Ho BL, Lee WH, Fong JM. Rupture of dissecting aneurysm in a China Airlines co-pilot. *Forensic Sci Int*. 1996; 81(2-3):157-164.
36. Killeen S, Neary P, O'Sullivan M, Redmond HP, Fulton G. Daily diurnal variation in admissions for ruptured abdominal aortic aneurysms. *World J Surg*. 2007;31(9):1869-1871.
37. Millar-Craig MW, Bishop CN, Raftery EB, Circadian variation of blood-pressure. *Lancet*. 1978;1(8068):795-797.
38. Falk M, Hüsler J, Reiss RD. *Laws of Small Numbers: Extremes and Rare Events*. Basel:Springer Basel; 2011:489.
39. Schuld J, Slotta JE, Schuld S, Kollmar O, Schilling MK, Richter S. Popular belief meets surgical reality: impact of lunar phases, Friday the 13th and zodiac signs on emergency operations and intraoperative blood loss. *World J Surg.* 2011;35(9):1945-1949.