Are periods of low atmospheric pressure associated with an increased risk of abdominal aortic aneurysm rupture?

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ABSTRACT

INTRODUCTION Seasonal variation in rates of abdominal aortic aneurysm (AAA) rupture has previously been described. However, only two studies, to date, have suggested that periods of low atmospheric pressure may account for this observation and both returned apparently contradictory findings. The objective of this study was to demonstrate whether periods of low atmospheric pressure are indeed associated with an increased likelihood of AAA rupture presentation.

PATIENTS AND METHODS A total of 182 cases of ruptured AAA were identified retrospectively from two centres over a 6-year period from January 2000 to December 2005. Local meteorological data for the corresponding period was obtained from the UK Meteorological Office which was recorded daily at a local weather station. Statistical analysis using Student's *t*-test, ANOVA (Kruskal–Wallis), linear regression and multiple logistic regression was conducted to identify significant relationships from the data.

RESULTS Days of rupture presentation were associated with a significantly lower daily mean atmospheric pressure when compared with days when no rupture occurred ($P = 0.025$). Multiple logistic regression demonstrated a significant association between low daily atmospheric pressure and rupture incidence ($P = 0.033$) which appeared to be independent of temperature. A significant seasonal trough in atmospheric pressure was observed in October and November (Kruskal–Wallis, $P < 0.001$); however, there was no corresponding autumnal peak in rupture incidence ($P = 0.232$).

CONCLUSIONS The findings of this study appear to confirm the assertion that low atmospheric pressure is associated with an increased risk of AAA rupture on a day-to-day basis; however, no evidence was identified to support a change in policy regarding prioritising elective surgery based on seasonal risk.

KEYWORDS

Abdominal aortic aneurysm – Rupture – Atmospheric pressure

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Several previous studies have suggested that the incidence of ruptured abdominal aortic aneurysm (AAA) appears to demonstrate significant seasonal variation,^{1–4} with characteristic peak periods of increased frequency in spring and autumn. To date, only two studies have provided evidence implicating periods of low atmospheric pressure as being a significant causative factor in explaining this observation. Bown *et al.*⁵ demonstrated that a low mean daily atmospheric pressure during any given month was associated with an increased rupture incidence during the following month; however, no significant variability in atmospheric pressure was observed on days of rupture presentation compared with days when no rupture

occurred. Harkin *et al.*⁶ did, however, demonstrate a significantly lower mean daily atmospheric pressure on days when rupture presentation was recorded along with significant seasonal variation in both atmospheric pressure and rupture incidence. It has previously been suggested that these observations are of potential clinical significance by virtue of the implications on scheduling elective surgical intervention during potentially 'high-risk' periods of the year.⁶

The objective of this study was to identify whether low atmospheric pressure is indeed a significant risk factor in precipitating AAA rupture and provide additional evidence to refute or support the apparently contradictory results reported to date. In addition, we sought to identify if mean

daily temperature was an independent risk factor in AAA rupture presentation.

Patients and Methods

A retrospective retrieval of patient records was conducted at the Countess of Chester Hospital and Wrexham Maelor Hospital, two vascular units located approximately 15 miles apart in Cheshire and North Wales serving a population of over 500,000. All cases of ruptured or leaking AAA were identified from hospital records over a 6-year period from January 2000 to December 2005 inclusive. The diagnosis was made at laparotomy in 54.5% of cases and the remaining cases managed non-operatively were only included if there was appropriate confirmatory CT imaging or if the clinical presentation left no reasonable doubt as to the underlying diagnosis (*i.e.* shocked patient with abdominal or back pain, palpable expansile abdominal mass, death within 48 h of conservative management).

A total of 182 cases of ruptured or leaking AAA were identified during the study period. The male-to-female ratio was 3:1 and the median age at presentation was 76.0 years (range, 56–95 years). Rupture occurred on 180 days during the study period with only 2 days where more than one patient presented during a single 24-h period.

Atmospheric pressure and temperature data were obtained from the Meteorological Office having been

Figure 1 Mean seasonal atmospheric pressure and rupture frequency.

recorded at a regional weather station situated approximately 5 miles west of Chester and 15 miles north of Wrexham. Minimum and maximum daily atmospheric pressure and temperature recordings were obtained to calculate the mean daily values for each. These values were then used to generate mean monthly and seasonal values for pressure and temperature. Data were incomplete for 48 (2.2%) of the 2192 days during the study period. Cases of

Figure 2 Mean monthly atmospheric pressure and rupture frequency.

rupture occurring on days where meteorological data were incomplete ($n = 4$) were excluded from the analyses.

Statistical analysis

Student's *t*-test, ANOVA (Kruskal–Wallis), linear regression (Pearson) and multiple logistic regression were utilised as part of the statistical analysis and a *P*-value of < 0.05 was taken to reflect significance. Rupture rate was expressed as frequency per month and annual variability assessed in terms of seasons (winter, December–February; spring, March–May; summer, June–August; and autumn, September–November). Values are expressed as mean $\pm$ SEM.

Results

Seasonal variation

The mean daily atmospheric pressure recorded over the entire study period was 1014.3 ± 0.25 mB ranging from 971.8 mB to 1042.5 mB. Figures 1 and 2 demonstrate comparative graphs of seasonal and monthly rupture frequency and mean atmospheric pressure during the study period. A significantly lower mean atmospheric pressure was recorded in autumn when compared with other seasons (Kruskal–Wallis: $df = 3$; $P < 0.001$). Similarly, a significant overall difference in mean monthly atmospheric pressure was also recorded ($df = 11$; $P < 0.001$) but, despite this, no significant corresponding seasonal ($df = 3$; $P = 0.815$) or monthly ($df = 11$; $P = 0.232$) differences in rupture presentation were observed.

Rupture presentation, atmospheric pressure and temperature

The data were analysed in a number of ways to identify any underlying causal relationships between periods of low atmospheric pressure and rupture presentation. Table 1 demonstrates comparative data for mean atmospheric pressure, mean change in atmospheric pressure from the preceding day, mean range of daily atmospheric pressure (*i.e.* from the minimum to maximum value recorded for each day) and mean temperature on days when rupture

occurred compared with days on which no rupture occurred (Student's *t*-test). When analysing the mean change in atmospheric pressure from the previous day (to identify whether an abrupt reduction in atmospheric pressure from one day to the next was associated with rupture likelihood), no significant difference was observed; however, days of rupture demonstrated a significantly greater range in daily atmospheric pressure recordings. An analysis of mean atmospheric pressure during days preceding rupture presentation compared with days on which no rupture occurred also demonstrated a significant difference ($P = 0.023$).

A multiple logistic regression analysis using mean daily atmospheric pressure and temperature as explanatory variables and rupture presentation as the outcome variable demonstrated low mean atmospheric pressure to be significantly associated with rupture presentation ($\beta = -0.046$; $P = 0.033$); however, the R^2 value recorded was only 0.002. No significant association was demonstrated between mean daily temperature and rupture presentation ($\beta = -0.002$; $P = 0.935$).

The data were also analysed sequentially on a month-by-month basis to identify any correlation between mean monthly atmospheric pressure and mean monthly rupture frequency (Pearson). No significant correlation was demonstrated between mean monthly atmospheric pressure and mean rupture frequency for the corresponding month ($r = -0.168$; 95% CI = -0.385 to 0.065 ; $P = 0.079$) or the subsequent month ($r = 0.050$; 95% CI = -0.185 to 0.279 ; $P = 0.342$).

Discussion

The traditional model of predicting risk of AAA rupture based on aortic diameter is derived from Laplace's law, *i.e.* that circumferential wall tension is a linear function of aortic radius and blood pressure (or, more accurately, the pressure gradient across the aortic wall which is dependent on both the intraluminal blood pressure and the opposing extraluminal tissue pressure). Therefore, a drop in extraluminal (atmospheric) pressure increases the overall

Table 1 Comparative data for mean atmospheric pressure and temperature on days of rupture presentation and days when no rupture occurred

	Days of rupture	Days of no rupture	<i>P</i> -value
Mean atmospheric pressure (mB)	1012.6 ± 0.78	1014.5 ± 0.25	0.025
Mean change in atmospheric pressure from preceding day (mB)	-0.06 ± 0.47	-0.04 ± 0.14	0.488
Mean range of daily atmospheric pressure (mB)	7.6 ± 0.41	6.7 ± 0.10	0.034
Mean temperature (°C)	10.4 ± 0.36	10.4 ± 0.11	0.981

Two-tailed *P*-value for Student's *t*-test.

pressure gradient across the aortic wall and, in doing so, potentially results in increased wall tension. Several recent studies have provided evidence to suggest that the Laplace model is a significant over-simplification of the various haemodynamic forces which act on the aneurysm sac and that morphological properties other than aortic diameter in addition to aortic wall composition and thickness are also major factors in determining wall tension/stress.⁷⁻¹¹

Smoking and hypertension have been shown to be associated with the development of abdominal aortic aneurysm¹²⁻¹⁶ and both have also been shown to be independent risk factors for precipitating rupture.^{17,18} Seasonal variation in hypertension has previously been reported with a significant increase commonly seen during winter months.^{19,20} Similar findings have also been demonstrated for haemorheological properties in winter (*i.e.* increased platelet count, red cell count and blood viscosity).²¹

Our results support the assertion that, on a day-by-day basis, periods of low atmospheric pressure appear to be associated with an increased likelihood of AAA rupture presentation; however, the absolute difference between mean atmospheric pressure values on days of rupture compared with days on which no rupture occurred was small (1012.6 mB versus 1014.5 mB) given the overall range in atmospheric pressures seen throughout the study period (from 971.8 mB to 1042.5 mB). Similarly, multiple logistic regression suggested a significant association between low daily atmospheric pressure and rupture presentation (indicated by a negative coefficient and P -value < 0.05); however, the strength of association again appeared small ($R^2 = 0.002$). The results also suggest that days with a greater range in atmospheric pressure readings are associated with an increased rupture likelihood; however, an abrupt drop in mean atmospheric pressure from one day to the next did not appear to be a significant factor.

The results demonstrated the expected significant autumnal troughs in atmospheric pressure during the study period; however, this failed to result in any corresponding peaks in rupture frequency. Although linear regression demonstrated a trend towards an association between lower monthly atmospheric pressures and rupture presentation during the corresponding month, this correlation did not reach statistical significance ($P = 0.079$). Any effect of atmospheric pressure on rupture presentation appears to be independent of temperature and, although the pre-morbid hypertensive status of patients in this study was not assessed, it seems unlikely that seasonal cold-induced hypertension is a significant factor in explaining the previously reported observations.

Our results agree with those of Harkin *et al.*⁶ (from a 5-year prospective study; $n = 144$) with regard to the significantly lower mean atmospheric pressure observed on days of rupture and the correlation between daily atmospheric

pressure and rupture frequency (as evidenced by multiple logistic regression). Despite demonstrating the previously reported autumnal troughs in atmospheric pressure, the results conflict with those of Harkin *et al.*⁶ in that no corresponding seasonal peaks in rupture frequency were observed. Our findings also conflict with those of Bown *et al.*⁵ (from a 10-year retrospective study; $n = 223$) in that no correlation was demonstrated between monthly atmospheric pressure and rupture incidence for the subsequent month.

The proposed interaction between atmospheric pressure and aortic aneurysm rupture might not necessarily be mirrored in other countries with more temperate climates; however, it is perhaps worthwhile noting that two of the three previously referenced studies^{2,4} which have reported autumnal peaks in rupture presentation were conducted in Greece. The association between atmospheric pressure and rupture incidence on a day-to-day basis (rather than a seasonal basis) as demonstrated in this study might, in part, reflect the changeable nature of weather systems seen in the UK when compared with warmer climates where more consistent periods of high or low pressure might be expected.

An additional implication of the proposed link between low atmospheric pressure and aortic aneurysm rupture relates to air travel. The shifts in cabin pressure experienced during a flight might also represent an increased risk of aneurysm rupture; however, no previous epidemiological studies have been conducted to identify whether a potential relationship between air travel and aneurysm rupture exists. One of the authors has previously contacted a number of airlines to request any medical information kept with regard to documented cases of potential AAA rupture during flights. Unfortunately (but perhaps understandably), no airlines were forthcoming in providing any information pertaining to potential medical complications arising as a result of air travel. A review of the literature only identified a single case report of a ruptured thoracic aortic aneurysm which presented in a co-pilot immediately following a short-haul flight.²²

Conclusions

There is little doubt that AAA rupture is a multifactorial event and it remains unclear as to what extent periods of low atmospheric pressure influence risk of rupture; however, an association appears likely. Despite this, no evidence was identified from this study to support a policy of prioritising elective AAA repair during potentially 'high-risk' seasonal periods based on atmospheric pressure trends.

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