Atmospheric Pressure Changes and Outdoor Temperature Changes in Relation to Spontaneous Pneumothorax*

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Study aims: To examine the influence of atmospheric pressure (AP) and temperature changes on the incidence of idiopathic spontaneous pneumothorax (SP).

Methods: From December 1991 through November 1993, 115 consecutive SP cases were selected. Patients were included after being in Amsterdam at least 1 full day before contracting the SP. Differences in air temperature and AP (provided hourly by the national weather bureau) for the days of the SP occurrence and the days previous to it were recorded to measure influences of air temperature and AP. The correlation between days with lightning and SP and clustering of SP was evaluated.

Results: SP occurred on 14.7% of the days in the 2-year period. There was no relationship between SP and a rise or fall in AP (Poisson regression). There was an average temperature rise of 0.57°C from the day prior to the day of the SP, compared with a 0.08°C fall on the days without SP. This difference is statistically significant and was consistent over the four seasons and both years. Seventy-three percent of the SP cases were clustered. A relationship between SP and thunderstorms was found.

Conclusions: AP differences do not seem to influence the chance of developing SP. SP occurs in clusters, and more often 1 to 2 days after thunderstorms. Whether the identified temperature rise prior to the SP is a causative factor is unlikely; coexisting weather phenomena might explain this unexpected finding and should be studied in the future.

Key words: atmospheric pressure; clustering; spontaneous pneumothorax; temperature; thunderstorm

Abbreviations: AP = atmospheric pressure; CI = confidence interval; RR = rate ratio; SP = spontaneous pneumothorax

Idiopathic spontaneous pneumothorax (SP) is defined as “air present in the pleural cavity, without any known underlying disease.” It is thought to result from rupture of the alveolar structure with an air leak into the pleural space through the visceral pleura. We hypothesize that trapped air related to peripheral airway inflammation is an important clue to the pathogenesis of SP. This hypothesis is supported by the fact that emphysema-like changes are seen on CT in 63% of SP patients and during video-assisted thoracoscopy in 74% of SP patients, while only 30% of the age-matched normal individuals show emphysema-like changes. Rupture can occur when a substantial transpulmonary pressure gradient is present. Air trapping coexists with pressure differences that may occur with scuba diving or flying, two examples of risk factors. Trapped air in the alveoli will expand when the out-of-body pressure falls. In our hypothesis, intrapulmonary air pressure differences may increase in the case of a check valve phenomenon, which may occur in cases of mucus retention or bronchiolitis. Smoking cigarettes can increase the chance of developing blebs and bullae, as well as cause bronchiolitis. The hypothesis mentioned for the pathogenesis of SP is supported by the fact that ± 80% of the SP patients developed these changes.
patients are smokers, whereas ±30% of the age-matched normal individuals in Europe are smokers.

When air is trapped in the (weakened) alveolar structure, pressure differences may influence the chances of developing SP, because an equilibrium may not reached immediately.

Clinicians have the idea that SP patients are admitted in clusters, as was recently confirmed in *Lancet*. This has some similarity with epidemic and nonepidemic asthma outbreaks: asthma is another disease of bronchial inflammation that has been reported to be related to thunderstorms, lightning, pollen counts, sulfur dioxide concentrations, and a fall in air temperature. Weather changes, such as atmospheric pressure (AP) changes, may influence the incidence of SP, as has been reported before. Temperature has an influence on pressure (Boyle’s law), and therefore both should be measured simultaneously. Temperature itself has not been reported to be a risk factor for developing SP.

The aim of this study was to define the influence of weather changes, such as AP and temperature, on the incidence of SP.

**Materials and Methods**

**Patients**

One hundred fifteen consecutive SP events that occurred between December 1, 1991, and November 30, 1993 were retrospectively analyzed; all cases were drawn from two hospitals in Amsterdam, the Free University Hospital and the Onze Lieve Vrouwe Gasthuis. The initial onset of SP was defined as the onset of patient-reported complaints. Only patients who contracted SP at least 1 day before, were included. Seventy-nine percent were men, the mean age was 33.4 ± 1.4 years old. At hospital admission, patients had no previous lung disease, such as pneumonia, tuberculosis, asthma, or COPD.

SP cases in all Amsterdam hospitals were routinely registered anonymously. Our data were compared with data for the Amsterdam SP population as a whole to judge the reliability of our selected cases.

**Environmental Data**

The Royal Dutch Meteorological Institute, or Koninklijk Nederlands Meteorologisch Instituut, in de Bilt, the Netherlands, provided AP and temperature measurements, which were obtained hourly at Schiphol Amsterdam airport. Daily minimum, mean, and maximum AP and minimum, mean, and maximum temperatures were calculated and compared. Because of the retrospective character of the patient history study, the exact hour that SP developed was not considered to be reliable enough to define. Therefore, we decided to compare the measured values of the particular day that each patient developed SP to the values of the previous day (−1 = previous 24 h). The respective values were compared between days with and without SP occurrences. This was done for the minimum, mean, and maximum values on day 0 and day −1.

Lightning measured at > 5,000 A was considered to be part of a thunderstorm, and was seen as a moment of most extreme weather conditions and changes. The reported days with lightning were recorded for the Amsterdam/Schiphol airport region.

Groups of SPs were called clusters when ≤3 days without SP were present in between days with SP. The meteorologic significance or relevance of the AP differences over 1 day is approximately 0.08 mm Hg. Temperature differences of < 0.4°C measured during 1 day are considered to be irrelevant (Koninklijk Nederlands Meteorologisch Instituut). The relationship between AP and temperature is according to Boyle Gay-Lusac’s law.

**Data Analysis**

Because time-related phenomena mostly show autocorrelation-like dependencies, we have to consider whether this is true also for our dependent variable, namely days with SP and days without SP. There are two possible reasons for autocorrelation: (1) Causal, i.e., the occurrence of a SP on a day before induces higher probability of a SP the day considered; or (2) autocorrelation is induced by the autocorrelated structure of the prognostic variables, i.e., the atmospheric state of the days before both influences the occurrence of a SP on the day before and on the day under consideration.

In our view, there is no reason to suppose a causal relation for the occurrence of a SP, so we may use a straightforward regression analysis for the days with SP if we take into account the autocorrelation structure of the independent variable by using a lagged variable.

Mean values are ± SEM. Differences in AP, temperature, and lightning as determinants for SP were analyzed in a univariate and multivariate way by Poisson regression. Regression coefficients were transformed into rate ratios (RRs) by taking the exponent of the coefficients. An RR of >1 means that the determinant increases the incidence rate on the days with SP compared with the rate on days without SP. A risk ratio is statistically significant when the 95% confidence interval (CI) does not include 1. The proportion of days with SP in different seasons, as well as differences in proportion of days with temperature rises or falls, were tested by the Z-test. The tests used were two-sided at α = 0.05.

**Results**

SP occurred on 14.7% of the 731 days recorded (115 cases in all; 8 days, two SP cases were reported).

Amsterdam, a relatively small but highly populated area, had 724,000 inhabitants in 1993 and nine hospitals. During the study period, 409 SP cases were seen in all nine hospitals. During the 2-year study, 28.9% of the SP patients in Amsterdam were treated in the two study hospitals. No seasonal differences were found between our incidence data and the complete Amsterdam group, which suggests that our population is a representative selection (28.9%) of the complete Amsterdam SP population for these 2 years.
Amsterdam has a sea climate. The average temperature recorded was 10.5 ± 2.2°C (range, −8.8 to 30.4°C). The mean AP was 762.6 ± 0.3 mm Hg (range, 733.1 to 784.0 mm Hg) in the 2-year period.

There was no significant relation of AP differences between the days with and without SP, either in univariate Poisson regression analysis or in the analysis corrected for the temperature (Table 1). Table 1 also shows the statistical analysis of temperature differences between days without SP vs the day of SP occurrence and the day prior to SP. For days with SP, a mean rise of 0.57 ± 0.2°C was recorded from the previous day, compared with a 1-day fall of 0.08 ± 0.05°C for days without SP. The differences in mean temperature between day −1 and day 0, corrected for the mean pressure difference between day −1 and day 0, remained significant (p < 0.01). The maximum temperature rise, corrected for the maximum pressure differences, also remained significant (p < 0.01).

The statistically significant temperature change differences (maximum temperature differences) found between the days with and without SP were consistent throughout all four seasons (Table 2) and both years. The maximum rise in temperature on the days prior to SP is statistically more pronounced in autumn than in spring, as is seen in Table 2. This difference is not statistically significant, possibly because of lack of power in these season subgroups. Table 2 also shows the SP incidence over the different seasons. In winter, a season with fewer thunderstorms, SP cases occurred on 8.8% of the days, whereas in the other three seasons, SP occurred on 16.5% of the days (Z-test: 95% CI, 5 to 13; p = 0.041). However, a relationship was found between the days with SP and 1 day after lightning (RR, 1.640; 95% CI, 1.009 to 2.665; p = 0.046), as well as 2 days after lightning (RR, 1.673; 95% CI, 1.039 to 2.694; p = 0.034).

### Clustering

Seventy-three percent of the SP cases occurred in clusters with ≤ 3 days without SP in between the events. Using other time intervals, the clustering is still present: 61% of the SP occurred in clusters with ≤ 2 days without SP in between, and 83% in clusters with ≤ 4 days without SP. When compared with the theoretical expectancy that 50% of the SP would occur in clusters (which is very optimistic), a significant clustering (73%) occurred in our data (95% CI, 65 to 81%; p < 0.0001). The randomly expected number of days between SP events is also significantly different from the recorded number of days between SP events (0.05 > p > 0.02).

Clusters with SP (with ≤ 3 days without SP in between days with SP) were correlated with the differences in mean temperature between the day of the SP and the day prior to it (Poisson regression: RR, 1.014; 95% CI, 1.002 to 1.026; p = 0.026).

We appreciated the comments by Knox in our discussion in *Lancet*.

Table 1—Comparison of AP and Temperature Changes For Days With SP vs SP Days Without SP

<table>
<thead>
<tr>
<th></th>
<th>SP Days, Mean Change (SEM)</th>
<th>Non-SP Days, Mean Change (SEM)</th>
<th>RR (CI), Univariate Poisson Regression</th>
<th>RR (CI), Multivariate Poisson Regression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δ AP from day before, mm Hg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ Mean AP</td>
<td>−0.513 (0.4)</td>
<td>0.044 (0.2)</td>
<td>1.000 (.995–1.001)</td>
<td>.999 (.996–1.003)</td>
</tr>
<tr>
<td>Δ Min AP max AP day −1</td>
<td>−4.94 (0.4)</td>
<td>−4.79 (0.2)</td>
<td>1.000 (.997–1.003)</td>
<td>1.000 (.997–1.003)</td>
</tr>
<tr>
<td>Δ Max AP min AP day −1</td>
<td>3.89 (0.4)</td>
<td>48.8 (0.2)</td>
<td>1.000 (.994–1.000)</td>
<td>.998 (.995–1.002)</td>
</tr>
<tr>
<td>Δ Temp with day before, °C</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δ Mean temp</td>
<td>0.57 (0.2)</td>
<td>−0.08 (0.08)</td>
<td>1.014 (1.004–1.024)</td>
<td>1.014 (1.004–1.025)</td>
</tr>
<tr>
<td>Δ Min temp max day −1</td>
<td>−6.87 (0.4)</td>
<td>−6.87 (0.4)</td>
<td>.999 (.994–1.005)</td>
<td>.999 (.993–1.005)</td>
</tr>
<tr>
<td>Δ Max temp min day −1</td>
<td>8.0 (0.4)</td>
<td>6.7 (0.2)</td>
<td>1.006 (1.002–1.011)</td>
<td>1.006 (1.001–1.011)</td>
</tr>
</tbody>
</table>

*Δ mean AP (temp) = difference in mean from day before SP to day of SP; Δ min AP (temp) max AP (temp) day −1 = difference between minimal AP (temp) on day of SP and maximal AP (temp) on day before SP; Δ max AP (temp) min AP (temp) day −1 = difference between maximal AP (temp) on day of SP and minimal AP (temp) on day before SP; temp = temperature.

†p < 0.01.
less than t days (where t = 4) of each other in a period of D days (where D = 731) is $1 - [(D - t)/(D - 0.5)] \Delta 2$. This gives a random expectation of 62.66 pairs\(^2\); in the present study, 78 such pairs were observed. A substantial observed excess of t < 4 pairs (eg, 79 pairs of SP cases) would offer evidence of an epidemic pattern. For “within 2 days,” the expected number is 44.78; the actual observed number was 58. For “within 4 days,” it is 80.5; the actual observed number was 102. The results show a significant clustering using this approach as well, as is seen in Figure 1.

When days with lightning were correlated with clusters of SP (with ≤ 2 days in between the SP cases), a trend toward a significant relationship was found (RR, 1.448; 95% CI, 0.975 to 2.149; p = 0.066).

Using the univariate Poisson regression analysis, there is a clear relationship between the SP clusters within 2 days and (1) lightning occurring 1 day (RR, 2.100; p = 0.014) and 2 days (RR, 2.02; p = 0.02) before the SP clusters; (2) the mean temperature (RR, 1.006; p = 0.017); (3) the mean temperature rise (RR, 1.015; p = 0.023 vs the day before SP); and (4) the seasons (RR, 0.689; p = 0.002; the relationship gets smaller from spring to winter).

In the multivariate regression analysis, only the seasons (RR, 0.689; 95% CI, 0.5427 to 0.8753; p = 0.002) and the mean temperature rise (RR, 1.015; 95% CI, 1.001 to 1.028; p = 0.03) remain in the model.

Looking univariately at the association with clusters (with ≤ 2 days in between SP cases) within each of the four seasons, the RRs remained constant for the mean temperature rise (spring RR, 1.241; 95% CI, 0.3700 to 4.159; p = 0.73; summer RR, 1.027; winter RR, 1.018); there were no statistically significant differences, probably because of the smaller power. In summer and autumn, there are strong relationships between the SP clusters and lightning occurring the day before (spring: RR, 1.241; 95% CI, 0.3700 to 4.159; p = 0.73; summer: RR, 2.056; 95% CI, 0.7715 to 5.477; p = 0.15; autumn: RR, 2.880; 95% CI, 1.015 to 8.176; p = 0.047; winter: regression not possible).

### Table 2—Differences in Temperature on SP Days vs Non-SP Days in All Seasons*

<table>
<thead>
<tr>
<th>Data</th>
<th>Spring</th>
<th>Summer</th>
<th>Autumn</th>
<th>Winter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Days with SP (SEM)</td>
<td>8.8 (0.7)</td>
<td>8.8 (0.8)</td>
<td>7.3 (0.6)</td>
<td>5.7 (0.9)</td>
</tr>
<tr>
<td>Days without SP (SEM)</td>
<td>8.1 (0.3)</td>
<td>8.2 (0.3)</td>
<td>6.1 (0.3)</td>
<td>4.5 (0.2)</td>
</tr>
<tr>
<td>RR</td>
<td>1002</td>
<td>1004</td>
<td>1009</td>
<td>1012</td>
</tr>
<tr>
<td>(CI)</td>
<td>(0.994–1.010)</td>
<td>(0.994–1.013)</td>
<td>(0.997–1.022)</td>
<td>(0.998–1.027)</td>
</tr>
<tr>
<td>% of days with SP†</td>
<td>18.5</td>
<td>14.6</td>
<td>16.5</td>
<td>8.8</td>
</tr>
</tbody>
</table>

*Difference between the maximum temperature on the day with or without SP and the minimum temperature on the day before, in degrees Celsius. Univariate Poisson regression analysis.
†Difference between the winter (8.8% SP days) and the other seasons (mean, 16.5% SP days) is significant (95% CI, 5 to 13; p = 0.0014). Seasons are based on meteorologic dates.

![Figure 1](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21931/ on 06/25/2017)
Days following days with lightning showed twice as many SP clusters (≤ 2 days in between SP) as the days that did not follow lightning (lightning 1 day before, 16.3% vs 7.8%; p = 0.009; lightning 2 days before, 15.7% vs 7.8%; p = 0.013). This holds true for spring, summer, and autumn.

Days with SP clusters (≤ 2 days in between SP cases) had higher mean temperatures than the other days in that particular season, except for autumn.

**Discussion**

The confirmation of the feeling of clinicians, that SP patients are admitted in clusters, strongly supports the hypothesis that weather changes (or related conditions) play a role in the mechanism responsible for development of SP. Our findings of SP clustering were later supported by a retrospective analysis of Boulay et al. The first question we had was whether pressure differences in the atmosphere exert an influence on the chance of contracting a pneumothorax. Because AP and temperature are related (Boyle Gay-Lusac’s law), we calculated and compared the changes in AP, as well as changes in the temperature, from the day before SP developed and the day of SP.

Bense and Scott et al described an influence of AP changes on SP risk. To compare the slowly occurring AP differences with other pressure differences, we mention here some examples: diving 10 m deep results in a pressure rise of 750 mm Hg; riding an elevator to the 20th floor in a building results in a decrease of 0.094 mm Hg/m (or a total of about 7.5 mm Hg) in seconds; transatlantic flights result in pressure differences of ± 190 mm Hg. Daily AP differences in the Netherlands are 7.5 mm Hg over several hours in the most extreme circumstances (around thunderstorms).

Our results did not show AP to have an influence on SP. We found no significance nor trend in the statistical models pointing toward the confirmation of the theory of Bense and Scott et al. Because no trend was found, the absence of influence of AP on SP is not likely to be due to a lack of statistical power. We realize that our study took into account only 1 day prior to the start of the complaints of the SP event, instead of several days; however, for rupture of an alveolar structure, this seems to be a fair approach.

To judge the influence of AP, we also calculated temperature differences (Boyle Gay-Lusac’s law). When corrected for temperature, AP influence remained absent. The temperature changes, however, were correlated with SP. A clearly significant, but small, mean difference was found. On the days prior to the SP, the temperature rose an average of 0.57°C, whereas on the other days, the temperature dropped an average of 0.08°C (p < 0.01; Table 1). The temperature drop of 0.08°C on the other days was not considered relevant.

We believe that the temperature rise itself cannot explain the higher chance of contracting the SP. Temperature differences of much > 0.5°C are experienced daily by people from day to night, and especially in winter, by going in and out of heated buildings. There was no trend toward more SP in the winter; rather, the reverse was true. The noted temperature differences between days before SP development and days before non-SP days are consistently present in all separate analyses from the different seasons throughout both years studied.

Air temperature is equilibrated to body temperature by passing through the mouth or nose and the bronchial tract to the alveolar region under normal conditions. Because air temperature differences associated with SP days are highly significant and consistently present, they cannot be ignored. The temperature rise before SP development is even more clearly present in autumn, the season in which the mean temperature normally drops over time, while proceeding toward winter. Therefore, other possible explanations must be considered.

We found a relationship between the days after lightning (as a way of defining extreme weather changes) and SP. Asthma exacerbations have also been reported in association with thunderstorms. Because asthma is also characterized by bronchial inflammation with peripheral obstruction and air trapping, similarities in the pathogenesis of asthma and SP are possible. The weather conditions associated with thunderstorms are quite extreme, and changes occur over a relatively short time. In our climate, the air temperature and humidity usually rise during the days prior to a thunderstorm. Other changes occur as well, such as enhanced pollen concentrations in the air, air pollution, AP changes, electrostatical power, and physical stress because of warmth, wind, or humidity. Whether these factors influence the pathogenesis of SP is, of course, speculative at this time. The fact that SP is more likely to occur 1 to 2 days after a thunderstorm cannot be explained clearly without more knowledge of the relationship of SP with these other coexisting factors. The relationship between lightning and SP is also confirmed by the fact that fewer instances of SP occur in winter, when fewer thunderstorms occur.

Although we could not confirm that AP is related to the development of SP, we did find circumstantial hints that some weather conditions are involved in the pathogenesis of SP. Therefore, we hypothesize that a weather-related phenomenon might enhance
bronchial inflammation and thereby enhance the chances of contracting SP (see introduction). In this model, temperature rise is a cofactor with another weather phenomenon during the days prior to SP.

We believe that further study is necessary to explain the unexpected finding that temperature rise is related to development of SP. The clustering of SP and its relationship to lightning also strongly suggest that environmental conditions do play a role in the pathogenesis of SP.

Conclusions

A small but highly significant average temperature increase is found on the day prior to development of SP, whereas a small temperature drop is found on the other normal, non-SP days, suggesting the influence of weather on the pathogenesis of SP. AP differences were not associated with the development of SP in this study. SP develops in clusters, and this clustering is related to thunderstorms.

ACKNOWLEDGMENT: We thank P.J. Kuik and P.D. Bezemer for their critical review of the paper, especially the statistical portion.

References