Climatic Conditions and the Onset of Primary Spontaneous Pneumothorax: An Investigation of the Influence of Solar Terms

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Key Words

Atmospheric pressure • Climate • Seasonal variation • Spontaneous pneumothorax • Temperature

End of Heat were found to be closely related with PSP development, which shed light on a new way for PSP incidence evaluation.

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Abstract

Objective: To study the correlation between climatic changes and the development of primary spontaneous pneumothorax (PSP). **Subjects and Methods:** We retrospectively studied the relationship between 337 patients with conservatively treated PSP and meteorological conditions during a 3-year period in the urban area of Xi'an, China. The comparison was made depending on solar terms and on different aspects of atmospheric pressure, outdoor temperature, relative humidity, and wind speed. **Results:** Significant differences were found between PSP and non-PSP days depending on daily mean values of outdoor temperature and atmospheric pressure ($p = 0.001$ and $p < 0.001$, respectively). However, no obvious differences of meteorological factor variations between the 'PSP day' and the 'pre-PSP day' on days with and without PSP were found. The occurrence of PSP was associated with the solar terms Spring Equinox ($p < 0.05$) and End of Heat ($p < 0.01$). **Conclusion:** Among the factors examined in our study, daily mean outdoor temperature and atmospheric pressure showed a strong correlation with the occurrence of PSP. The solar terms Spring Equinox and

Introduction

Primary spontaneous pneumothorax (PSP) is a global concern due to its increasing incidence and potentially life-threatening complications [1, 2]. Although the morphology and ultrastructure of causative lesions in PSP are well known, the reason for rupture of air-containing cysts is not clear. Studies suggest that meteorological factors may possibly influence the incidence of PSP, while broad consensus does not exist [3–5]. Up to now quite a few studies have been conducted to evaluate the possible impact of seasonal changes on PSP development. However, the outcomes are quite controversial, indicating that 'seasons' may not be an accurate parameter for this issue [6–11].

The 24 solar terms in the traditional Chinese calendar are a special divisional method created in ancient China to reflect the specific changes of weather, climate and natural phenomena [12]. The division summarizes the influence of several meteorological factors and indicates the

dynamics of their changes, and it is believed to directly correlate with possible host response mechanisms [13]. Hence we raise the hypothesis that the solar terms might be a more appropriate divisional method for evaluation of PSP incidence. The aim of this study, apart from the analysis of the influence of routine meteorological factor changes on the occurrence of PSP, was to assess the relationship between PSP and the solar terms in a semihumid continental monsoon climate.

Subjects and Methods

Study Population

A total number of 337 consecutive PSP episodes that occurred between January 1, 2007 and December 31, 2009 were retrospectively analyzed. All cases were from the First Affiliated Hospital, Xi'an Jiao Tong University, China and the study was approved by the Ethics Committee of the hospital. The day of the onset of symptoms reported by a patient was recorded as the day of PSP onset. Only patients with exact onset dates were included in the study. Also, only patients who developed PSP in Xi'an and who had been in Xi'an for at least 1 day before they developed PSP were included. Patients with previous lung diseases such as pneumonia, tuberculosis, asthma, or COPD were excluded.

Meteorological Data

For each of the 1,096 days of the study period, meteorological data were obtained from the local meteorological institute (Xi'an Meteorological Bureau), which is located at the same altitude as the participating hospital, within a 12-km-wide area. Daily mean atmospheric pressure and outdoor temperature, relative humidity and wind speed were calculated and compared. The difference of the mean values of the meteorological factors of each day relative to the previous day was calculated (Δ = mean values of one day – mean values of the previous day). The obtained data were categorized into two groups: those of the days with PSP onset and those of the days without PSP onset. Moreover, the daily mean values were compared between days with and without PSP occurrences (PSP days vs. non-PSP days).

The 24 solar terms are widely used along the Yellow River Drainage Area, where Xi'an is located. They are spaced 15° apart along the ecliptic and stay synchronized with the seasons. Each day in the analyzed period corresponds to one of the 24 solar terms. Names and main characteristics of the solar terms analyzed in this study are listed in table 1. The frequency of PSP occurrence was also evaluated in all seasons of the year, and in 12 months simultaneously.

Statistical Analysis

Quantitative data were expressed as mean $\pm$ SD. The software package SPSS 13.0 was used for statistical analysis. The days with PSP were compared with all those days without pneumothorax during the analyzed period. Statistical analyses including distribution of frequencies, χ^2 test, Wilcoxon-Mann-Whitney U test, and Kruskal-Wallis one-way analysis of variance (Dunn's method) were conducted. A p value of <0.05 was considered to be significant.

Results

Of the 337 patients, 266 (78.93%) were males and 71 (21.07%) females, among whom 201 (59.64%) were aged from 21 to 40 years, whilst only 59 (17.51%) patients were younger than 20 and 77 (22.85%) were older than 41. The mean age was 30.53 ± 2.41 years.

Comparison of Difference of Δ Mean Values of Meteorological Factors between PSP Days and Non-PSP Days

Δ temperature of days with PSP onset varied from -6 to 11°C with a mean value of $0.03 \pm 2.47^\circ\text{C}$. Although a slight temperature rise was registered, compared to Δ temperature of days without PSP onset, no significant difference was found between the two groups ($p = 0.93$). Δ atmospheric pressure of days with PSP onset varied from -23 to 35 hPa with a mean value of -0.35 ± 7.54 hPa, while the mean value of Δ atmospheric pressure of non-PSP days was 0.16 ± 7.83 hPa. There was no significant difference between them ($p = 0.85$). Similarly, differences of Δ relative humidity and Δ wind speed between the two groups of data were not statistically significant ($p = 0.91$ and 0.31 , table 2). Altogether, no remarkable difference was found between the changes of meteorological factors on PSP days relative to previous days and those of non-PSP days relative to previous days.

Comparison of Daily Mean Values of Meteorological Factors between PSP Days and Non-PSP Days

The comparison of daily mean temperature and atmospheric pressure between days with and without PSP is given in table 2. Compared with the mean temperature of non-PSP days, a higher mean temperature was recorded from PSP days ($15.24 \pm 9.42^\circ\text{C}$ vs. $12.81 \pm 10.24^\circ\text{C}$), suggesting a tendency for PSP to occur in a warm climate. The differences in mean ambient temperature between the two groups of days, corrected for the mean pressure difference, remained significant ($p = 0.001$). The mean difference in atmospheric pressure was also significant ($p < 0.001$). However, no significant difference was found in mean humidity and wind speed (table 2).

Seasons, Solar Terms and the Occurrence of PSP

Although we discovered a PSP peak in autumn, most patients were admitted in April (data not shown). The distribution of PSP occurrence across the four seasons of the study period is shown in figure 1.

The detailed meteorological characteristics of 24 solar terms are summarized in table 1, including mean daily

Table 1. Differences in climatic factors of the 24 solar terms (mean $\pm$ SD)

Longitude ^a	Solar terms	Beginning ^b	T, °C	AP, hPa	H, %	WS, m/s
270°	Winter Solstice	Jan 5th	-2.00 $\pm$ 2.48 ^c	1,028.27 $\pm$ 6.65 ^c	69.47 $\pm$ 13.68 ^c	5.93 $\pm$ 3.89 ^c
285°	Lesser Cold	Jan 20th	-2.83 $\pm$ 4.22 ^c	1,027.63 $\pm$ 6.48 ^c	65.43 $\pm$ 16.40 ^c	6.07 $\pm$ 4.86
300°	Greater Cold	Feb 4th	1.93 $\pm$ 4.62 ^c	1,024.80 $\pm$ 9.83 ^c	68.67 $\pm$ 13.49 ^c	5.77 $\pm$ 3.92 ^c
315°	The Beginning of Spring	Feb 19th	4.25 $\pm$ 2.67 ^c	1,023.61 $\pm$ 6.88 ^c	62.00 $\pm$ 18.53 ^c	7.39 $\pm$ 5.92
330°	Rain Water	Mar 5th	9.18 $\pm$ 3.46 ^c	1,017.34 $\pm$ 6.08	58.52 $\pm$ 8.42 ^c	8.73 $\pm$ 7.10
345°	The Waking of Insects	Mar 21st	10.30 $\pm$ 1.99 ^c	1,017.70 $\pm$ 4.44	63.63 $\pm$ 13.85 ^c	9.17 $\pm$ 6.29
0°	The Spring Equinox	Apr 5th	15.23 $\pm$ 2.78 ^c	1,011.20 $\pm$ 4.63	72.83 $\pm$ 11.13 ^c	9.17 $\pm$ 7.47
15°	Pure Brightness	Apr 20th	16.17 $\pm$ 3.35	1,014.17 $\pm$ 6.55	62.23 $\pm$ 14.27 ^c	8.60 $\pm$ 6.95
30°	Grain Rain	May 5th	18.19 $\pm$ 2.96	1,010.97 $\pm$ 5.12 ^c	71.57 $\pm$ 15.46 ^c	8.00 $\pm$ 4.21
45°	The Beginning of Summer	May 21st	20.84 $\pm$ 2.77	1,009.16 $\pm$ 5.24 ^c	59.63 $\pm$ 14.53 ^c	7.60 $\pm$ 6.99
60°	Lesser Fullness of Grain	Jun 6th	23.70 $\pm$ 2.46 ^c	1,006.37 $\pm$ 2.95 ^c	63.80 $\pm$ 15.30 ^c	10.93 $\pm$ 6.23
75°	Grain in Beard	Jun 21st	25.87 $\pm$ 2.57 ^c	1,003.84 $\pm$ 1.69 ^c	59.58 $\pm$ 13.99 ^c	5.44 $\pm$ 3.37 ^c
90°	The Summer Solstice	Jul 7th	25.95 $\pm$ 2.47 ^c	1,004.60 $\pm$ 2.04	69.65 $\pm$ 10.32 ^c	10.81 $\pm$ 6.61
105°	Lesser Heat	Jul 23rd	25.08 $\pm$ 3.11 ^c	1,006.45 $\pm$ 2.06 ^c	75.66 $\pm$ 10.22 ^c	10.23 $\pm$ 5.99
120°	Greater Heat	Aug 8th	24.32 $\pm$ 2.43 ^c	1,008.14 $\pm$ 1.90 ^c	76.79 $\pm$ 8.56 ^c	8.29 $\pm$ 5.06
135°	The Beginning of Autumn	Aug 23rd	21.67 $\pm$ 2.30	1,011.41 $\pm$ 2.73	78.70 $\pm$ 8.99 ^c	8.38 $\pm$ 6.10
150°	The End of Heat	Sep 8th	18.80 $\pm$ 2.46	1,014.67 $\pm$ 3.33	83.40 $\pm$ 9.59	8.37 $\pm$ 7.36
165°	White Dew	Sep 23rd	17.73 $\pm$ 3.11	1,017.63 $\pm$ 3.19	80.27 $\pm$ 9.95	7.73 $\pm$ 6.80
180°	The Autumn Equinox	Oct 8th	14.27 $\pm$ 1.38 ^c	1,020.33 $\pm$ 3.24 ^c	80.87 $\pm$ 13.85	5.57 $\pm$ 4.78 ^c
195°	Cold Dew	Oct 23rd	11.33 $\pm$ 3.36 ^c	1,021.97 $\pm$ 5.70 ^c	74.03 $\pm$ 11.83 ^c	5.03 $\pm$ 2.97 ^c
210°	Frost's Descent	Nov 7th	4.43 $\pm$ 5.28 ^c	1,025.67 $\pm$ 4.43 ^c	82.43 $\pm$ 14.13	7.10 $\pm$ 5.48
225°	The Beginning of Winter	Nov 22nd	2.90 $\pm$ 2.31 ^c	1,026.13 $\pm$ 2.90 ^c	68.70 $\pm$ 17.95 ^c	7.63 $\pm$ 4.59
240°	Lesser Snow	Dec 7th	1.50 $\pm$ 2.89 ^c	1,024.93 $\pm$ 1.50 ^c	70.90 $\pm$ 15.16 ^c	6.20 $\pm$ 3.19
255°	Greater Snow	Dec 22nd	-1.41 $\pm$ 2.03 ^c	1,028.27 $\pm$ 1.41 ^c	53.03 $\pm$ 10.80 ^c	7.21 $\pm$ 4.73

Meteorological factors in this table refer to mean daily values. T = Outdoor temperature; AP = atmospheric pressure; H = relative humidity; WS = wind speed.

^a Longitude along the ecliptic. ^b Since the beginning day of each solar term varies slightly every year, the dates given here are just indicative. ^c $p < 0.05$ by Kruskal-Wallis one-way analysis of variance on ranks, with reference to the data of the term End of Heat in which PSP occurrence peaked.

Table 2. Correlation between general meteorological factors and PSP occurrences (mean $\pm$ SD)

Mean values	Days with PSP	Days without PSP	p ^b
Δ T, °C	0.03 $\pm$ 2.47	-0.05 $\pm$ 2.34	0.93
Daily T, °C ^a	15.24 $\pm$ 9.42	12.81 $\pm$ 10.24	0.001
Δ AP, hPa	-0.35 $\pm$ 7.54	0.16 $\pm$ 7.83	0.85
Daily AP, hPa ^a	1,014.01 $\pm$ 8.58	1,016.69 $\pm$ 9.47	<0.001
Δ H, %	-0.12 $\pm$ 9.05	0.06 $\pm$ 9.21	0.91
Daily H, % ^a	69.57 $\pm$ 15.19	67.59 $\pm$ 16.05	0.12
Δ WS, m/s	0.70 $\pm$ 7.24	-0.25 $\pm$ 6.49	0.31
Daily WS, m/s ^a	9.03 $\pm$ 6.41	8.02 $\pm$ 5.38	0.08

Δ = The mean values of one day – the mean values of the previous day. T = Outdoor temperature; AP = atmospheric pressure; H = relative humidity; WS = wind speed.

^a Refers to mean daily values. ^b Statistical analysis included Wilcoxon-Mann-Whitney U test and χ^2 test.

Fig. 1. Admitted cases for PSP per season from 2007 to 2009 in Xi'an, China.

Fig. 2. **a, b** Daily atmospheric pressure (**a**) and mean temperature (**b**) for the 24 solar terms during the study period. **c** Total PSP occurrence for each solar term of the 3-year period (2007–2009).

atmospheric pressure, temperature, relative humidity, and wind speed. As shown in figure 2, the mean outdoor temperature and atmospheric pressure varied simultaneously and reached their absolute maximum values in the middle of the year, which is the period of the Summer Solstice. It was also observed that PSP occurrence peaked during the solar term End of Heat, when 29 (8.61%) PSP cases developed. The term with the lowest PSP occurrence was the Great Snow, associated with 6 (1.78%) cases admitted during that period (fig. 2). Interestingly, another PSP peak with 27 cases (8.01%) was observed in the

solar term Spring Equinox. This might offer an explanation for the contradiction we discovered between seasons and months.

Discussion

Our research data demonstrated only a slight change in all the meteorological factors including atmospheric pressure, temperature, relative humidity and wind speed relative to the previous day, and a correlation between the Δ values of the factors with PSP onset was not established. The link between PSP and weather changes has been disputed. Some studies identified a correlation between them [3, 8, 14], while others provided opposite results [9, 11, 15]. It is possible that a small meteorological change alone may not fully account for an increased occurrence of PSP.

However, when comparing the mean daily atmospheric pressure between days with PSP onset and days without, we observed that the mean atmospheric pressure of PSP days was obviously lower than that of non-PSP days. Though explanations have been proposed in some studies, the exact mechanism by which lower atmospheric pressure may cause PSP remains unclear. With regard to the association between PSP and daily temperature, controversial understandings exist [10, 15, 16]. Among those studies with different or even opposite results, it is hard to decide which one is more reliable due to their different designs, populations, climatic conditions, and number of patients included.

A seasonal or monthly correlation of the incidence of PSP has been identified in our study, similar to the study of Ayed et al. [17]. However, we discovered in our study that although the PSP occurrence peaked in autumn, the maximum monthly occurrence was in April, as reported by Accard et al. [18]. The above contradiction indicates a need for a more appropriate divisional system to evaluate the influence of meteorological factors on PSP incidence [19]. As reported, the 24 solar terms are closely related with meteorological changes, and some preliminary studies have suggested the relationship between solar terms and pathogenesis of diseases such as asthma, upper gastrointestinal bleeding, strokes, etc., indicating that this division might be a better way for evaluating the connection between climatic factors and disease occurrence [20, 21]. The results of our study suggest that there might be an association between solar terms and PSP.

Xi'an has a climate which is typical of the Yellow River Drainage Area, where the solar terms have been ap-

plied for ages because of their sensitivity and comprehensiveness in explaining climatic conditions. According to a similar study, in which the influence of solar terms on the development of upper gastrointestinal bleeding was analyzed, the solar terms Waking of Insects and Cold Dew were used for this serious condition [22]. Our study showed that PSP occurred most frequently in the term End of Heat, and the frequency difference between this term and others is significant. The lowest PSP occurrence terms are Great Snow and Winter Solstice (table 1, fig. 2). The PSP incidence is found to be most closely related to the solar terms Spring Equinox and End of Heat. The common features of these two terms might be fast changes of several meteorological factors, because they are both at seasonal turning points. Subsequent prompt adaptations to a new situation might lead to frequent changes of lung cyst volume. It is likely that not the changes in vol-

ume of the air-containing lung cysts but the repeated changes weaken the cyst wall and increase the incidence of cyst rupture. Further studies are needed to test our hypothesis.

Conclusion

This study demonstrated a significant relationship of PSP occurrence with daily mean temperature and atmospheric pressure. PSP development was closely related to the solar terms Spring Equinox and End of Heat, which is supposedly caused by frequent change of meteorological factors. Further studies with a larger sample size in this geographical area focusing on different combinations of weather factors and other potential triggering factors are required.

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