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***Original Article** / Özgün Makale*

The association between pneumothorax onset and meteorological parameters and air pollution

Pnömotoraks başlangıcı ile meteorolojik parametreler ve hava kirliliği arasındaki ilişki

Osman Yakşi[1], Alp Özel[2], Mehmet Ünal[1], Fatma Öztürk[3], Ali Kılıçgün[1]

Institution where the research was done:
Bolu Abant İzzet Baysal University Faculty of Medicine, Bolu, Turkey

Author Affiliations:
[1]Department of Thoracic Surgery, Bolu Abant İzzet Baysal University Faculty of Medicine, Bolu, Turkey
[2]Department of Physiotherapy and Rehabilitation, Bolu Abant İzzet Baysal University Faculty of Health Sciences, Bolu, Turkey
[3]Department of Environmental Engineering, Bolu Abant İzzet Baysal University, Bolu, Turkey

ABSTRACT

Background: The aim of this study was to investigate the possible relation of meteorological parameters and air pollutant particle concentrations with the incidence of spontaneous pneumothorax in the Bolu region of Turkey.

Methods: Between January 2015 and February 2019, a total of 200 patients (175 males, 25 females; mean age 42.5±19.9 years, range, 10 to 88 years) with spontaneous pneumothorax were retrospectively analyzed. For each day, standard weather parameters including daily average temperature, relative humidity, wind speed, actual pressure, and daily total precipitation and concentration of air pollutants (PM_{10} and SO_2) were recorded.

Results: During the study period, there were 200 cases with spontaneous pneumothorax within 178 days. The number of days with spontaneous pneumothorax represented 11.8% of the total number of days (1,504 days). In the study, 76.9% of the days with spontaneous pneumothorax were clustered. All meteorological (temperature, humidity, pressure, wind speed, and precipitation) and air pollution parameters (PM_{10} and SO_2) were available for 1,438 days (95.61%) and 853 days (56.71%), respectively. There was a significant relationship between spontaneous pneumothorax and air temperature (r=-0.094, p=0.001), and air pollution (PM_{10}, r=-0.080, p=0.020; SO_2, r=-0.067, p=0.045).

Conclusion: Our study results show a relationship between spontaneous pneumothorax and air temperature, and air pollution. Preventing air pollution, which is a public health problem, can lead to a reduction in spontaneous pneumothorax.

Keywords: Air pollution; meteorology; pneumothorax; thoracic surgery.

ÖZ

Amaç: Bu çalışmada Türkiye'nin Bolu bölgesindeki meteorolojik parametreler ve hava kirletici partikül konsantrasyonlarının spontan pnömotoraks insidansı ile olan muhtemel ilişkisi araştırıldı.

Çalışma planı: Ocak 2015 - Şubat 2019 tarihleri arasında spontan pnömotorakslı toplam 200 hasta (175 erkek, 25 kadın; ort. yaş 42.5±19.9 yıl; dağılım, 10-88 yıl) retrospektif olarak incelendi. Her gün için günlük ortalama sıcaklık, bağıl nem, rüzgar hızı, gerçek basınç ve günlük toplam yağış dahil olmak üzere standart hava parametreleri ve hava kirleticilerinin konsantrasyonu (PM_{10} ve SO_2) kaydedildi.

Bulgular: Çalışma süresince 178 günde spontan pnömotorakslı 200 olgu vardı. Spontan pnömotoraks olgularında gün sayısı, toplam gün sayısının %11.8'ini (1504 gün) temsil ediyordu. Çalışmada, spontan pnömotoraks olgusu olan günlerin %76.9'u kümelendirildi. Tüm meteorolojik (sıcaklık, nem, basınç, rüzgar hızı ve yağış) ve hava kirliliği parametreleri (PM_{10} ve SO_2) sırasıyla 1438 gün (%95.61) ve 853 gün (%56.71) için mevcuttu. Spontan pnömotoraks ile hava sıcaklığı (r=-0.094, p=0.001) ve hava kirliliği arasında anlamlı bir ilişki vardı (PM_{10}, r=-0.080, p=0.020; SO_2, r=-0.067, p=0.045).

Sonuç: Çalışma sonuçlarımız spontan pnömotoraks ile hava sıcaklığı ve hava kirliliği arasında bir ilişki olduğunu göstermektedir. Bir halk sağlığı sorunu olan hava kirliliğinin önlenmesi, spontan pnömotoraksta azalmaya yol açabilir.

Anahtar sözcükler: Hava kirliliği, meteoroloji, pnömotoraks, göğüs cerrahisi.

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Correspondence: Ali Kılıçgün, MD. Bolu Abant İzzet Baysal Üniversitesi Tıp Fakültesi Göğüs Cerrahisi Anabilim Dalı, 14030 Bolu, Türkiye.
Tel: +90 374 - 253 46 56 / 3237 e-mail: kilicgun@gmail.com

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Pneumothorax is the accumulation of air in the pleural space.[1] Spontaneous pneumothorax (SP) is classified into two main categories as primary and secondary. It is usually caused by rupture of the apical localized subpleural blebs, while secondary SP is caused by a variety of underlying lung diseases.[2,3] Although the factors responsible for the onset and how often this pathology is responsible for the leakage of air from the alveolar into the pleural space are still unclear, it is believed that rupture may occur, when there is a significant pressure gradient exists. Under these conditions, the pressure balance between air trapped in blebs, bullae, or diseased alveoli cannot be adjusted, resulting in rupture rapid change in environmental pressure: i.e., exposure to scuba diving or flying may result in pneumothorax in healthy individuals.[4] The possible effect of changes in atmospheric pressure on SP formation has been studied in several studies, but the results are largely controversial.[5-7]

Although air pollution levels are regularly monitored and tackled, they remain above the accepted limits, particularly in major metropolises around the world. In 2015, about nine million people died from air pollution worldwide. This number corresponds to 16% of all deaths and approximately 15 times those killed in wars.[8] Air pollution is mainly caused by industrial plants, heating fuel consumption in residential buildings, and motor vehicle exhausts. Although there is a relative decline in air pollution in large cities with the use of natural gas in Turkey, air pollution still exists as a serious problem. Table 1 shows 24-h threshold limits of Turkey, European Union countries, and the World Health Organization.

A variety of environmental factors may be responsible for the occurrence of SP cases. Common triggering factors for SP are infection, air pollution, and pollen-induced cough.[9] Regarding other environmental factors, previous studies have investigated the relationship between the occurrence of SP and meteorological events.[5-7,10] In the present study, we aimed to evaluate the possible relation of the occurrence of SP and meteorological conditions with air pollution in Bursa region of Turkey and to gain a better understanding of pathophysiological mechanisms involved in the occurrence of SP.

Table 1. 24-h threshold limits of PM_{10} and SO_2 in Turkey, EU, and WHO

	Turkey†	EU‡	WHO§
PM_{10} (µg/m^3)	50*	50*	50
SO_2 (µg/m^3)	125**	125**	20

EU: European Union; WHO: World Health Organization; * Permitted exceedances each year is 35; ** Permitted exceedances each year is 3 † Turkish Air Quality Assessment and Management Regulation, Official Gazette No:26898, 06/06/2008 ‡ ec.europa.eu/environment/air/quality/standards.htm, last access date:19/05/2019 § WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide, Global update 2005, Summary of risk assessment, WHO/SDE/PHE/OEH/06.02

PATIENTS AND METHODS

This study was designed as a single-center, retrospective study using data from patients admitted to our hospital and diagnosed with SP between January 2015 and February 2019. In our province (Turkey, Bolu; population; 312,000 individuals), all SP cases are being treated in a single thoracic surgery center. Medical and demographic data of the cases with SP were obtained from the electronic database of all hospitalized patients. Patients were diagnosed with SP based on their medical history, physical examination, and chest X-ray findings. Although rare, in suspected cases, thoracic computed tomography was used. All SP cases were included in the study regardless of their size. As previously reported, we defined the cluster as the admission of at least two different SP cases within three consecutive days.[11] Clusters of more than four consecutive days were divided into two or more clusters to sustain the relationship of the SP cases with the meteorological events. A written informed consent was obtained from each patient. The study protocol was approved by the Bolu Abant Izzet Baysal University, Ethics Committee for Clinical Research and Trials (Date and no: 2019/172). The study was conducted in accordance with the principles of the Declaration of Helsinki.

Meteorological data

There is a ground-based meteorological station operated by the Turkish State Meteorological Service, which is responsible for the Republic of Turkey, Ministry of Agriculture and Forestry, at the Bolu city center (40.73°N-31.60°E and 741 m asl). The meteorological sensor was placed at 10 meters above the ground level. Daily mean temperature, wind speed, precipitation, pressure, and relative humidity values interpreted in this study were obtained from this station between January 2015 and February 2018. In addition, manually collected daily precipitation data were evaluated in this study for the same period for the site.

Air quality data

The Republic of Turkey, Ministry of Environment and Urbanization monitors the particles less than 10 µm in aerodynamic diameter (PM_{10}) and sulfur dioxide

Table 2. Distribution of clusters of the study

	n	%
Total study period (days)	1,504	100.0
Number of days with PSP cases	178	11.8
PSP cases	200	
Clusters	51	
Number of cases in clusters	128	
Clusters with 2 cases	33	64.7
Clusters with 3 cases	12	23.5
Clusters with 4 cases	4	7.8
Clusters with 5 cases	2	3.9
Clusters per year		
2015	24	47.05
2016	8	15.68
2017	3	5.88
2018	16	31.37
Clusters by season		
Spring	14	27.45
Summer	17	33.33
Fall	13	25.49
Winter	7	13.72

PSP: Primary spontaneous pneumothorax.

(SO_2) parameters continuously in the same region through the Air Quality Monitoring Network. The validated daily data corresponding to these parameters was acquired from this network for the study period.

Statistical analysis

Statistical analysis was performed using the IBM SPSS version 24.0 software (IBM Corp., Armonk, NY, USA). Descriptive data were expressed in mean ± standard deviation (SD), median (min-max) or number and frequency. The chi-square test was used for the analysis of the relationship between the days of pneumothorax and clusters (first day of clusters) and the relationship between meteorological and air pollution parameters. The Student's t-test was used for the analysis of quantitative variables. The Pearson correlation analysis was performed to analyze significant correlations between variables. A *p* value of <0.05 was considered statistically significant.

RESULTS

There were 200 new cases (175 males, 25 females; mean age 42.5±19.9 years, 10 to 88 years) of SP that occurred within 178 days during the study period. The number of days with SP were 11.8% of the total number of days (1,504 days). A total of 76.9% of the days with SP cases were clustered. A total of 51 clusters were identified with a maximum of five cases on four consecutive days. Totally, 64% of SP cases were in clusters. The mean number of SP cases per cluster was 2.51±0.809. Clusters tended to be grouped between 2015 and 2018. The winter season had the lowest number of clusters, while clusters had approximately the same frequency in other seasons (Table 2). All meteorological values (temperature, humidity, pressure, wind speed, and precipitation) and air pollution parameters (PM_{10} and SO_2) were

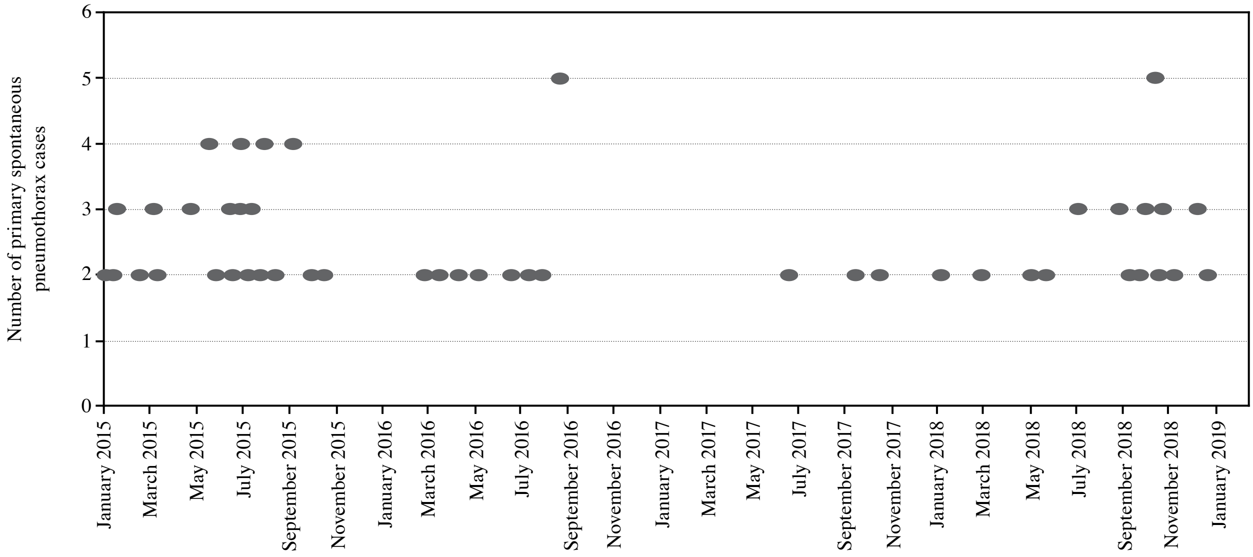

Figure 1. Number of primary spontaneous pneumothorax in clusters.

Table 3. Distribution of PM_{10} and SO_2 limits between the years of 2015 and 2018

2015			2016			2017		
μg/m³	Day	%	μg/m³	Day	%	μg/m³	Day	%
PM_{10} >50	121	33.15	PM_{10} >50	41	11.21	PM_{10} >50	31	8.49
PM_{10} <50	244	66.85	PM_{10} <50	325	88.79	PM_{10} <50	334	91.51
SO_2 >125	9	2.47	SO_2 >125	0	-	SO_2 >125	0	-
SO_2 <125	356	97.53	SO_2 <125	366	100.00	SO_2 <125	365	100.00

PM_{10}: Particles less than 10 μm in aerodynamic diameter; SO_2: Sulfur dioxide.

available for 1,438 days (95.61%) and 853 days (56.71%), respectively.

Figure 1 illustrates the number of SP cases occurred in clusters during the study period and the mean temperature change during the study. The number of days exceeding the threshold values for air pollution during the study period is given in Table 3.

Statistically significant differences were found between the mean temperature (p=0.001), the mean PM_{10} (p=0.027), and the mean SO_2 (p=0.001) values of the days with SP cases and the days without SP cases (Table 4). Except for SO_2 values (p=0.009), no significant difference was found in meteorological parameters on the days, when clusters were seen or not

Table 4. Meteorological parameter analysis by primary spontaneous pneumothorax occurrence

	Group 1			Group 2			
	n	Mean±SD	Min-Max	n	Mean±SD	Min-Max	*p*
Temperature (°C)	190	13.2±7.6	-7.3-24.8	1248	11.1±7.7	-8.7-26.4	0.001*
Humidity (%)	190	74.7±11.8	37.6-98.5	1248	73.4±11.8	36.3-99.5	0.161
Pressure (hPa)	75	930.5±6.0	912.2-943.6	622	930.0±4.8	915.0-943.9	0.351
Wind speed (m/s)	190	1.4±0.4	0.7-2.8	1247	1.4±0.4	0.6-3.4	0.691
PM_{10} (μg/m³)	91	60.6±74.1	2.3-464.9	762	46.0±54.1	2.1-469.2	0.027*
SO_2 (μg/m³)	108	22.4±68.9	0.6-494.7	799	14.8±30.2	0.3-496.2	0.001*
Precipitation (mm) (Manuel)	33	4.9±6.3	0.0-25.6	249	3.9±5.3	0.0-36.2	0.392
Precipitation (mm) (AMOS)	75	1.9±4.6	0.0-32.7	622	1.1±2.6	0.0-19.6	0.246

Group 1: With pneumothorax Group 2: Without pneumothorax; SD: Standard deviation; Min: Minimum; Max: Maximum; SO_2: Sulfur dioxide; * p<0.05
AMOS: Automatic Meteorological Observation Station.

Table 5. Comparison of meteorological data based on cluster analysis

	Group 1			Group 2			
	n	Mean±SD	Min-Max	n	Mean±SD	Min-Max	*p*
Temperature (°C)	49	13.6±7.5	-3.0-24.8	1389	11.3±7.7	-8.7-26.4	0.055
Humidity (%)	49	76.5±10.9	53.6-98.1	1389	73.4±11.9	36.3-99.5	0.060
Pressure (hPa)	17	929.6±5.9	920.0-943.6	680	930.1±4.9	912.2-943.9	0.575
Wind speed (m/s)	49	1.37±0.4	0.7-2.5	1388	1.4±0.4	0.6-3.4	0.790
PM_{10} (μg/m³)	21	78.8±109.0	2.3-464.9	832	46.7±54.7	2.1-469.2	0.240
SO_2 (μg/m³)	24	35.8±107.5	1.9-494.7	883	15.1±33.1	0.3-496.2	0.009*
Precipitation (mm) (Manuel)	9	4.4±4.6	0.0-12.9	273	4.0±5.4	0.0-36.2	0.140
Precipitation (mm) (AMOS)	17	1.8±2.8	0.0-7.6	680	1.2±2.9	0.0-32.7	0.555

Group 1: With pneumothorax Group 2: Without pneumothorax; SD: Standard deviation; Min: Minimum; Max: Maximum; SO_2: Sulfur dioxide; * p<0.05
AMOS: Automatic Meteorological Observation Station.

Table 6. Analysis of primary spontaneous pneumothorax occurrence according to environment parameters

		PM_{10}	SO_2	Temperature	Humidity	Wind speed	Current pressure	PSP existence
PM_{10}	r	1	0.724*	-0.273*	0.180*	-0.400*	0.240*	-0.080*
	p		0.000	0.000	0.000	0.000	0.000	0.020
SO_2	r		1	-0.294*	0.171*	-0.279*	0.255*	-0.067*
	p			0.000	0.000	0.000	0.000	0.045
Temperature	r			1	-0.456*	0.244*	-0.334*	-0.094*
	p				0.000	0.000	0.000	0.001
Humidity	r				1	-0.228*	0.085*	-0.038
	p					0.000	0.025	0.149
Wind speed	r					1	-0.442*	-0.006
	p						0.000	0.830
Current pressure	r						1	-0.030
	p							0.429
PSP case (Yes-No)	r							1
	p							

PM_{10}: Particles less than 10 µm in aerodynamic diameter; SO_2: Sulfur dioxide; * $p<0.05$ Pearson correlation analysis, statistical significance; PSP: Primary spontaneous pneumothorax.

($p>0.05$) (Table 4). Finally, a significant correlation was found between the days with SP and daily average air temperature and air pollution parameters (Table 5). The sequence of SP cases was not random. There was a significant relationship between SP and air temperature ($r=-0.094$, $p=0.001$), and air pollution (PM_{10}, $r=-0.080$, $p=0.020$; SO_2, $r=-0.067$, $p=0.045$).

DISCUSSION

This comprehensive study confirms that the pattern of SP clusters is associated with an increase in daily average temperature and air pollution. The previous study reported that 73% of SP cases were in clusters.[7] In a similar study, 60% of SP cases were reported to be in clusters.[9] In this study, 64% of SP cases were found in the cluster and this trend was confirmed in this study. An average number of 2.51 SP cases per cluster is consistent with the literature.[9] In our study, no relationship was found between SP and daily mean pressure values. Yet, we may consider that the following sequential series of environmental factors and events may responsible for bubble rupture: airway pressure shift due to atmospheric pressure change, and the burst of the bubbles due to atmospheric change.

The previous study reported a significant increase in the number of SP admissions over a two-day period following a 10 hPa or more decrease in atmospheric pressure over a 24-h period.[12] Differently from the previous studies of Bertolaccini et al.[5] and Chen et al.,[13] in our study, we found that neither humidity nor precipitation parameters were related to SP. We consider that regional climate variations between our study and the study of Chen et al.[13] where performed in Taiwan characterized by heavily raining climate is responsible for this difference. In the same study, it was reported that SP did not show a significant seasonal variation.[13] Bulajich et al.[14] reported that there was no significant correlation of SP pattern with certain months or seasons of the year. However, Bertolaccini et al.[5] reported a higher rate of SP cases in the spring. In this study, SP was proportionally at least in winter.

Stimuli from environmental factors are known to affect our immune system. Inflammation of small airways is assumed to be the main reason for isolating blisters. Some recent studies have shown that exposure to certain pollutants in small airways, as well as some fluid imbalances, can lead to airway obstruction with a segmental increase in airway resistance and increased distal pressure.[15] There are studies showing the relationship between air pollution and SP.[5,16,17] Similarly, this relationship was confirmed in our study.

Nonetheless, there are some limitations to this study. Firstly, it is a retrospective, single-center study with a relatively small sample size; therefore, there may be selection bias. Secondly, previously reported risk factors such as smoking status, height or body mass index were not considered. Thirdly, although multiple meteorological variables have been included, we may exclude the possibility of other potential contributing factors. Finally, it is not possible for every patient to seek medical care immediately after the onset of pneumothorax. Altogether, generalization of the results should be made with caution.

In conclusion, our study results show a relationship between spontaneous pneumothorax and air temperature, and air pollution. Preventing air pollution, which is a public health problem, can lead to a reduction in spontaneous pneumothorax. However, further large-scale studies are needed to confirm these results.

Declaration of conflicting interests

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