Galea, J. (2019). *Xjenza Online*, 7:97–103.

Xjenza Online - Science Journal of the Malta Chamber of Scientists
www.xjenza.org
DOI: 10.7423/XJENZA.2019.2.02

Research Article

Environmental Effects on the Incidence of Spontaneous Pneumothorax

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Abstract. Spontaneous pneumothorax (SP) is a common occurrence especially in young male asthmatics and smokers. Several studies have shown that this condition occurs in clusters although other reports showed the contrary. There is evidence that clustering of cases occur as a result of severe changes in atmospheric pressure. The literature is however very limited with regards to the relationship between air pollution and spontaneous pneumothorax.
Methodology: Observational study on consecutive patients admitted with SP from January 2010 to December 2014. The data regarding dates of admissions, gender, age, residential address, smoking history, relevant medical history and sequential management of the pneumothorax were collected and tabulated. The admission dates were analysed to test for clustering of admissions of patients. The patients were identified by location to assess the incidence of SP in different locations or areas. The Environment and Resources Agency (ERA) of Malta supplied daily particulate data from 3 different sites in the archipelago for the years 2010-1014.
Results: There were 112 patients presenting with 134 episodes of SP. The mean age was 29 years and 86.6% were males. No admission date clustering occurred and therefore linkage to atmospheric pressure changes cannot be made. There was however a very significant increase in incidence in patients hailing from the harbour area ($p < 0.00001$). ERA data shows that there was a similarly significant increase in particulate material in the air of the harbour locality when compared to non-harbour areas.
Discussion and Conclusion: SP is commoner in men and smokers. There was no evidence of admission day clustering but areas with increased air particulate matter had an increased incidence of patients with SP. Increased air pollution seems to increase the incidence of SP either directly or indirectly.

Acknowledgements. We would like to thank Catherine Camilleri, senior administrative assistant at the Environment and Resources Authority and her colleagues who kindly supplied the air quality data.

1 Introduction

Pneumothorax is defined as air in the pleural cavity and spontaneous pneumothorax is the commonest presentation of this condition. Spontaneous pneumothorax is usually classified as primary (no obvious underlying lung disease) or secondary (in the presence of underlying lung condition). Spontaneous pneumothorax has been shown to be commoner in males (Bobbio et al., 2015) and smokers (Bense et al., 1987; Tschopp et al., 2015). Several studies have shown that this condition may occur in clusters (Smit et al., 1997) although others did not show this occurrence (Ayed et al., 2006). There is also some evidence that clustering occurs during moderate to severe changes in atmospheric pressure (Alifano et al., 2007; Schieman et al., 2009; Scott et al., 1989; Smit et al., 1999; Suarez-Varel et al., 2000). Bertolaccini showed that in Turin fluctuations of atmospheric pollutants increased the risk of SP (Bertolaccini et al., 2010). However there is no other research showing that increased air pollution predisposes to SP. Malta is a 30 by 10 km island state at the centre of the Mediterranean Sea (figure 1). Its terrain is flat with no substantial difference in altitude from sea level between different parts of the island. It is very densely populated with 1 350.28 persons per square kilometre and most of the population lives in the north-eastern part of the island. The most air-polluted area in Malta is the region around the main harbour because of the heavy traffic and machinery and

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Figure 1: The Geographic position of the Maltese Archipelago at the centre of the Mediterranean Sea (Wikipedia)

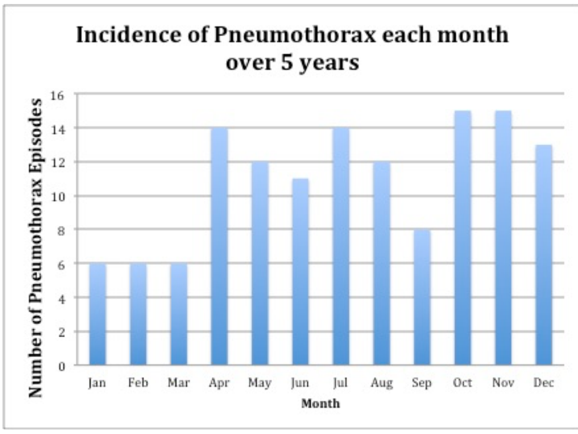

Figure 2: The Incidence of Pneumothorax per month over 5 years

the presence during the study of a heavy oil driven power station and the dockyards. In this study we attempt to address the issue of clustering of spontaneous pneumothorax and the possible association of air pollution with this condition.

2 Methodology

All patients admitted consecutively with primary spontaneous pneumothorax to the only public acute hospital on the island, Mater Dei Hospital, from January 2010 to December 2014 were included in the study. Patients with primary and secondary spontaneous pneumothoraces were studied but patients with iatrogenic pneumothorax and pneumothorax secondary to trauma were excluded from the study. This data was supplied by the Medical Records Department of the hospital. The data regarding dates of admissions, gender, age, smoking history, relevant medical history and sequential management of the pneumothorax were collected and tabulated. All the chest radiographs taken during these admissions were seen and the size of the pneumothorax assessed by the senior author (J. Galea). The size of the pneumothorax was labelled as small or large as described by British Thoracic Society (2010). If the pneumothorax was less than 2 cm (< 2 cm) at the hilum, it was described as small and if it was larger than 2 cm (> 2 cm) it was deemed large. The resident locality of the patients was identified from the hospital database and the number of inhabitants in each locality was derived from local council data for 2012. Persons who were not permanent residents on the island were excluded from the study. The harbour area has a concentration of heavy industry related to power generation and shipyards and other heavy machinery. The towns and villages in the proximity of this activity includes Valletta, Floriana, Cospicua, Senglea, Vittoriosa, Marsa, Pietà, Msida, Ta' Xbiex, Ħamrun, Paola, Fgura, Żabbar, Kalkara, Tarxien, Gudja, Għaxaq and Kirkop. All the other towns and villages of Malta were designated as the non-harbour area. People hailing from Gozo would have been managed at the Gozo General Hospital and they were excluded from the study. The year has been divided in two seasons; a wet winter season and a dry summer season. The winter months were from October to March and the summer months were from April to September. The occurrence of pneumothorax for each month was recorded from admission data. The Maltese Environmental and Resource Agency (ERA) supplied the data of daily concentration of particulate matter of less than 2.5 µm (PM 2.5) and less than 10 µm (PM 10) aerosols and the nitrogen oxide air concentration from 2 Malta sites; Msida (a harbour area site), Żejtun (outside harbour area sites) from January 2010 to December 2014. This data was captured using real time air monitoring stations.

3 Results

One hundred and twelve patients presented with 134 episodes of pneumothorax. The total mean age was 29 years (median 26) and 86.6% were male. Ninety six (85.7%) patients had a smoking history while 16 (14.3%) never smoked. 57.5% of patients with a first episode of pneumothorax and 79.2% of patients with a second pneumothorax were smokers. There was no statistical difference in the preponderance for sides for first or second episodes of pneumothorax although in both cases there were slightly more left than right pneumothoraces; (1st episode: right 44.3%, left 55.7%; 2nd episode: right 42.9%, left 57.1%).

4 Seasonal incidence

Figure 2 shows the number of pneumothoraces each month over the five-year period. Throughout the five years, the mean number of spontaneous pneumothorax

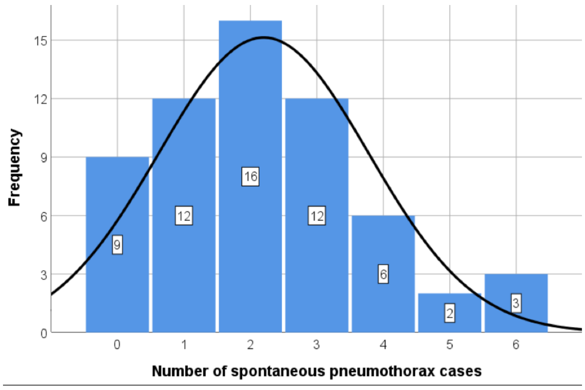

Figure 3: Frequency distribution curve of spontaneous pneumothorax patients

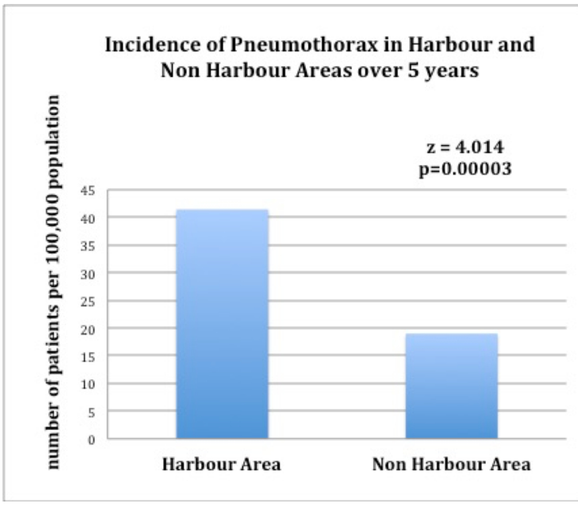

Figure 4: The incidence of pneumothorax in the harbour area and non harbour area in Malta

cases is highest in October and November (3.00) and lowest in January, February and March (1.20). Using the Kruskal Wallis test, the difference between the mean frequencies is not significant since the p-value (0.293) exceeds the 0.05 level of significance (table 1). Throughout the five years, the number of spontaneous pneumothorax cases per month ranged from 0 to 6. The mean, median and mode are respectively 2.2, 2.0 and 2.0 and the standard deviation is 1.582 (Figure 3). There is therefore no seasonal difference in incidence of spontaneous pneumothorax.

5 Clustering

The Chi square test reveals no association between the numbers of spontaneous pneumothorax monthly cases and the year in which these cases occurred since the p-value (0.123) exceeds the 0.05 level of significance. If we consider the larger frequencies (4, 5 and 6) of spontaneous pneumothorax monthly cases, these are occurring in all the months excluding February, March and September. If we consider the smaller frequencies (0 and 1) of spontaneous pneumothorax monthly cases, these are occurring in all the months except July (table 2). A method for testing the randomness of observed data is based on the theory of runs. A run is a succession of values which are all above or all below the mean. In other words, the runs test checks the randomness in which the observations vary around the mean. Too few runs indicate definite clustering (grouping), while too many runs indicates that the data alternates too often above and below the mean. The runs test displayed below indicates that the observations are random since the p-value (0.258) exceeds the 0.05 level of significance. This implies that there is no clustering of spontaneous pneumothorax cases (table 3).

6 Relationship of Pneumothorax to Air Pollution

The incidence of SP in the harbour area over the 5 years studied was 43 out of a population of 103,916 living in the harbour area (8.3 per year per 100,000 population in that area) and 56 out of a population living outside the harbour area of 295407 (3.8 per year per 100,000 population in the non harbour area). This difference is very statistically significant ($p = 0.00003$) (Figure 4). The mean ages for patients in harbour area and in non harbour area were of 28 and 32 years respectively and the difference was not statistically significant. The percentage of male patients and the prevalence of smoking and asthma did not differ significantly between the two regions (table 4).

During the same time period, there was a consistent significant increase in both PM 2.5 and PM 10 and the concentration of nitrogen dioxide (NO_2) in the harbour area as represented by Msida compared to non-harbour areas represented by Żejtun (figure 5 and table 5) over the five-year period studied.

7 Discussion

Spontaneous pneumothorax was commoner in males and in smokers. Although in several series of SP patients clustering of cases was observed and this was attributed to changes in atmospheric pressure, no clustering was recorded in this study. One explanation for this lack of clustering could be the rather small number of patients with SP. The lack of clustering and the wide distribution of cases compelled the authors to conclude that studying changes in atmospheric pressure during this time period was futile. Analysis of this distribution of cases shows an apparent decrease in incidence in the first 3 months

Month	Mean number of spontaneous pneumothorax cases per month	Std. deviation	p-value
January	1.20	2.168	
February	1.20	0.837	
March	1.20	1.095	
April	2.80	1.304	
May	2.40	1.817	
June	2.20	0.837	0.293
July	2.80	1.789	
August	2.40	2.302	
September	1.60	0.894	
October	3.00	2.121	
November	3.00	1.581	
December	2.60	1.140	

Table 1: Mean number of spontaneous pneumothorax for each month per year

	Year				
Month	2010	2011	2012	2013	2014
January	1	0	0	5	0
February	1	1	0	2	2
March	2	0	2	2	0
April	2	4	4	3	1
May	1	4	4	0	3
June	2	2	3	3	1
July	2	2	2	2	6
August	6	2	0	1	3
September	2	1	1	3	1
October	6	3	3	3	0
November	3	2	4	5	1
December	3	4	1	2	3

$\chi^2(44) = 55.055,\ p = 0.123$

Table 2: The occurrence of spontaneous pneumothorax per month for each year

	Frequency
Test value	0.072
Cases < test value	1705
Cases ⩾ test value	121
Total cases	1826
Number of runs	221
Z	−1.130
p-value	0.256

Table 3: Statistical analysis to determine whether clustering of cases occurred

	Harbour Area ($n = 43$)	Non-Harbour Area ($n = 56$)	z-value	p-value
Gender (Male)	37 (86.0%)	47 (83.9%)	0.2913	0.772
Smokers	27 (62.8%)	30 (53.5%)	0.9200	0.358
History of Asthma	4 (9.3%)	7 (12.5%)	0.5018	0.617

Table 4: Comparison in the incidence of known risk factors for spontaneous pneumothorax in the harbour and non-harbour area

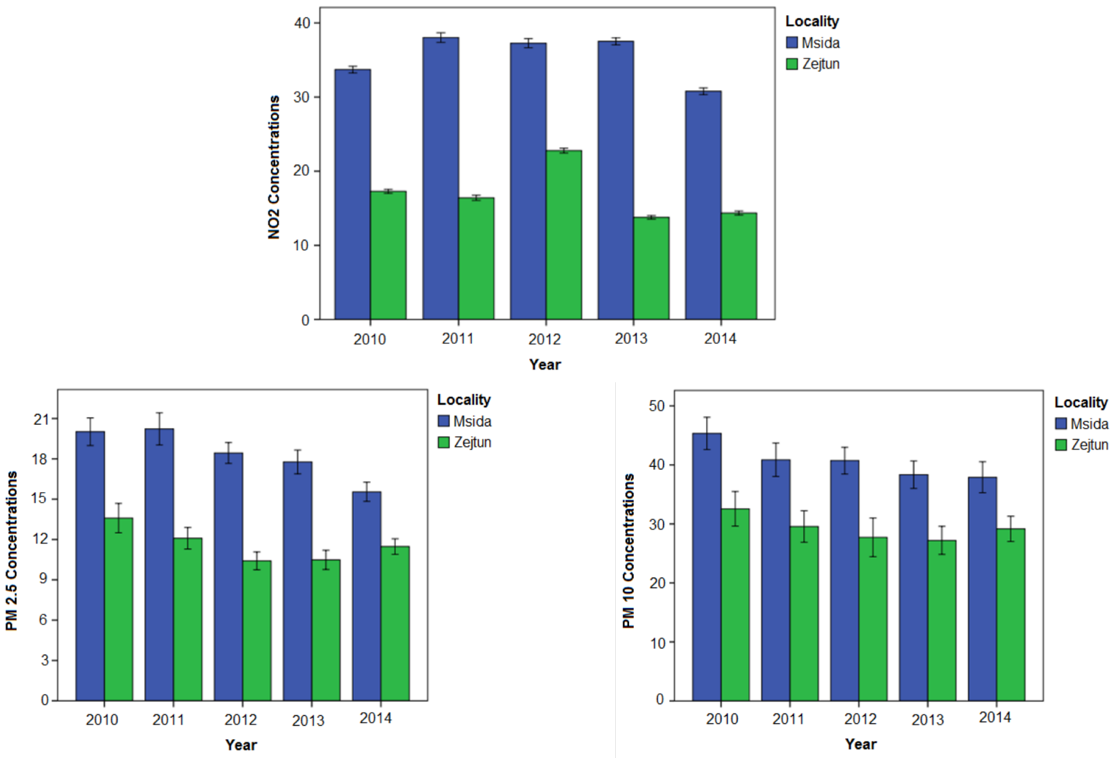

Figure 5: Comparison of PM 2.5 (A), PM 10 (B) and NO_2 concentration (C) between the harbour area (Msida) and non-harbour area (Zejtun) from 2010 to 2014

Pollutant	Harbour Area	Non-Harbour Area	p-value
Particulate matter 2.5 µm (µg/m^3)	18.3	11.8	< 0.001
Particulate matter 10 µm (µg/m^3)	40.6	27.5	< 0.001
Nitrogen dioxide (µg/m^3)	36.2	9.8	< 0.001

Table 5: Comparison of concentration of 2.5 µm and 10 µm particulate matter and Nitrogen dioxide between the harbour (Msida) and non harbour area (Żejtun)

of the year over the five-year period but the difference does not reach statistical significance and therefore not deemed important.

The harbour area in Malta is densely populated and has a very high traffic load. During the time of the investigation an oil-fuelled electricity generating power station was located in Marsa at the centre of the harbour area. This was present since 1953 and was decommissioned in 2015 after the end of this study. Data from the Maltese Environmental Resource Agency showed an increased PM levels and NO2 concentration in the monitoring site in Msida (harbour area) when compared to that in the rural Żejtun. This study shows that the difference in incidence of spontaneous pneumothorax between the densely populated, high density traffic and industrial harbour area and the more rural areas is very marked and highly significant. In Balzan et al. (2004), the authors showed that heavy traffic in the harbour area increased the incidence of asthma in Malta. In the current study there was no difference in the incidence of asthma and tobacco consumption in SP patients living in the harbour area when compared to the non-harbour area. Although there are possible unknown confounding factors there is a strong relationship between the quality of the air and the incidence of spontaneous pneumothorax. This association has not been studied before except for a study by Bertolaccini and colleagues who showed increased incidence of spontaneous pneumothorax in patients living in areas in Turin, Italy with a high atmospheric levels of NO_2 (Bertolaccini et al., 2010).

The limitations of the study include a small sample size and sampling data of PM10 and PM 2.5 was obtained retrospectively from a third party (ERA) thus making it difficult to ensure that the appropriate calibration and validation of sensors was performed by the testing agency. Some border locations between the two sites maybe problematic because of their equidistance from the monitoring stations (e.g. Gudja, Għaxaq and Kirkop).

In conclusion, the incidence of spontaneous pneumothorax in Malta is markedly higher in locations with higher atmospheric levels of particulate matter of $<$ 2.5 µm and $<$ 10 µm and NO_2. This has significant implications from a public health point of view since it provides further local data showing the urgent need to reduce such emissions. There was no clustering of cases in this study.

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