CORRELATION
BETWEEN CONCENTRATION OF AIR POLLUTANTS
AND OCCURRENCE OF CARDIAC ARRHYTHMIAS
IN A REGION WITH HUMID CONTINENTAL CLIMATE

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SUMMARY – In this study, we investigated the correlation of air temperature, pressure and con-
centration of air pollutants with the rate of admissions for cardiac arrhythmias at two clinical centers
in the area with a humid continental climate. This retrospective study included 3749 patients with
arrhythmias admitted to emergency department (ED). They were classified into four groups: supra-
ventricular tachycardia (SVT), ventricular tachycardia (VT), atrial fibrillation/undulation (Afib/
Aund), and palpitations (with no ECG changes, or with sinus tachycardia and extrasystoles). The
number of patients, values of meteorological parameters (average daily values of air temperature,
pressure and relative humidity) and concentrations of air pollutants (particles of dimensions ~10
micrometers or less (PM_{10}), ozone (O_3) and nitrogen dioxide (NO_2)) were collected during a two-year
period (July 2008-June 2010). There were 1650 (44.0%), 1525 (40.7%), 451 (12.0%) and 123 (3.3%)
patients with palpitations, Afib/Aund, SVT and VT, respectively. Spearman's correlation yielded
positive correlation between the occurrence of arrhythmias and air humidity on the day (r=0.07), and
1 (r=0.08), 2 (r=0.09) and 3 days before (r=0.09), and NO_2 particles on the day (r=0.08) of ED admis-
sion; palpitations and air humidity on the day (r=0.11), and 1 (r=0.09), 2 (r=0.07) and 3 days before
(r=0.10), and PM_{10} (r=0.11) and NO_2 (r=0.08) particles on the day of ED admission; and Afib/Aund
and air humidity 2 days before (r=0.08) ED admission (p<0.05 all). In conclusion, there was a very
weak positive correlation of the occurrence of cardiac arrhythmias with air humidity and concentra-
tion of air pollutants in the region with a humid continental climate.

Key words: *Air pollution – adverse effects; Arrhythmias, cardiac; Climate – adverse effects; Emergency
service, hospital*

Introduction

Air pollutants are a heterogeneous and complex
mixture of gases, liquids and particulate matter, which

are related to an increased risk of adverse cardiovascu-
lar (CV) events[1-3]. Furthermore, air pollution poses a
great health risk even in developed countries with le-
gally defined thresholds of air pollution[4-6]. Air pollu-
tion is associated with an increased risk of various
types of cardiac arrhythmias[7-11], as a consequence of
changes in the automation or conduction of impulses
that can occur in all parts and systems of the heart[12].

They are common in clinical practice. An arrhythmia may in some people lead to significant symptoms and hemodynamic effects (palpitations, hypotension, dizziness, syncope, heart failure, angina attacks, etc.), and sometimes sudden death. Other patients may be asymptomatic or have minimal symptoms. The arrhythmias that occur in a diseased heart have a prognostic importance[12].

Zagreb is the capital and the largest city of the Republic of Croatia, which is located in south-eastern Europe[13]. The wider Zagreb metropolitan area has a total population of up to 1.2 million (20% of the total Croatia's population). The climate of Zagreb is classified as a humid continental. The average daily mean temperature in winter is around +1 °C (from December to February) and the average temperature in summer is 22.0 °C.

In this study, we investigated the correlation between air temperature, pressure, concentration of air pollutants and the rate of admissions for cardiac arrhythmias in two clinical centers in the area with a humid continental climate.

Patients and Methods

This two-center retrospective study included 3749 consecutive patients admitted to emergency department (ED; Sestre milosrdnice University Hospital Center and Sveti Duh University Hospital) during a two-year period (June 2008-July 2010). All patients with arrhythmia as a primary diagnosis and living in Zagreb were included. Information on daily ED visits were collected retrospectively from the two hospital information systems. The study was approved by Ethics Committees of the two hospitals. All patient data were used without personal identifiers. Arrhythmias were diagnosed by using electrocardiography (ECG) and classified into four groups: supraventricular tachycardia (SVT), ventricular tachycardia (VT), atrial fibrillation/undulation (Afib/Aund), and palpitations (with no ECG changes, or with sinus tachycardia and extrasystoles). The concentrations of nitrogen dioxide (NO_2), ozone (O_3) and particles of dimensions ~10 micrometers or less (PM_{10}) were collected by the National Monitoring Station Zagreb 1 (Enviromental Protection Agency). The mean daily values of air temperature (°C), pressure (kPa) and relative humidity (%) were collected by the Meteorological and Hydrological Service of Croatia.

Statistical analysis

Qualitative data were presented as absolute number and percentage. We used χ^2-test with Yates correction for analysis. Quantitative data were presented as median and range. Differences between two groups and among three or more groups were tested by Mann-Whitney U-test and Kruskal-Wallis ANOVA test, respectively. The correlation between the number of patients with arrhythmias, values of meteorological parameters and concentrations of air pollutants was assessed by nonparametric Spearman's correlation test. It was classified by Spearman's r values as very weak (0-0.19), weak (0.20-0.39), moderate (0.40-0.59), strong (0.60-0.79) and very strong (0.80-1.0) correlation. The level of statistical significance was set at $\alpha=0.05$. Processing was done using the STATISTICA 6.0 for Windows software (Dell Software, StatSoft Inc., Tulsa, USA).
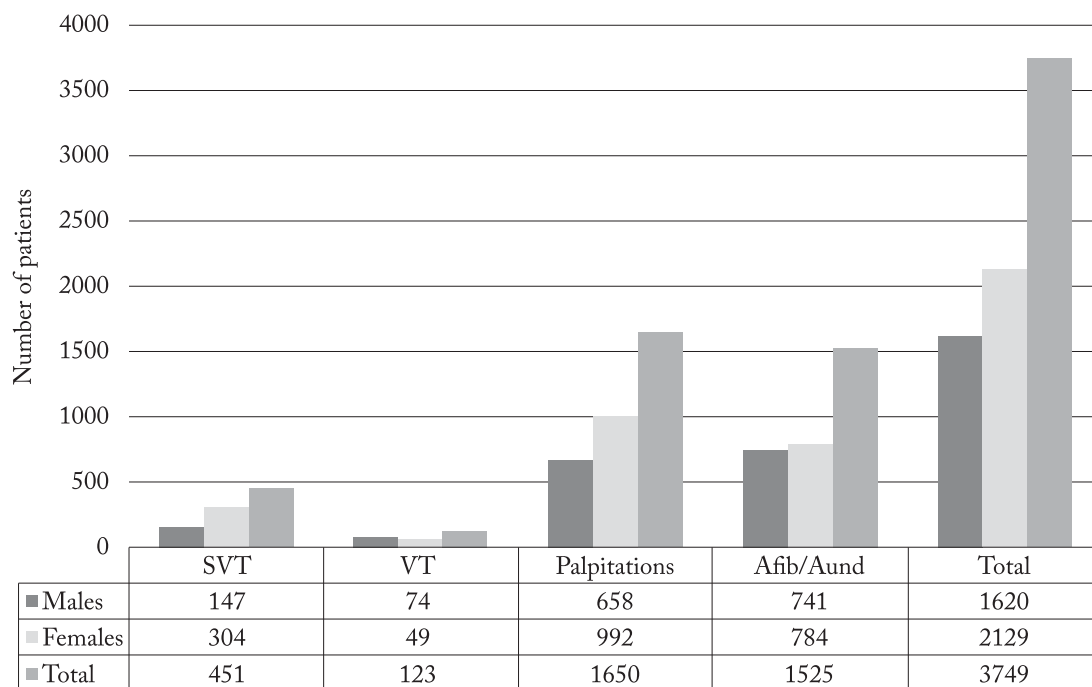
Results

Of the total of 3749 patients, there were 1650 (44.0%), 1525 (40.7%), 451 (12.0%) and 123 (3.3%) patients with palpitations, Afib/Aund, SVT and VT, respectively (Fig. 1). The occurrence of palpitations, Afib/Aund and SVT was higher in females, and of VT in males (Fig. 1). Age differences between males and females according to type of arrhythmia are shown in Table 1. Females with Afib/Aund were significantly older (median age 73 *vs.* 66 years, p<0.001).

During the study period, the mean daily values of NO_2 (25.9 (1.7-89.7) µg/m³), O_3 (47.1 (4.7-135.4) µg/

Table 1. Age differences between males and females according to type of arrhythmia

Diagnosis	Males[†]	Females[†]	Mann-Whitney U test[‡]
SVT	56 (16-89)	58 (19-89)	p=0.066
VT	69 (23-89)	69 (28-91)	p=0.967
Palpitations	47 (15-88)	46 (13-100)	p=0.568
Afib/Aund	66 (24-92)	73 (14-92)	p=0.000
Kruskal-Wallis ANOVA[‡]	p=0.000	p=0.000	

Afib/Aund = atrial fibrillation/atrial undulation; SVT = supraventricular tachycardia; VT = ventricular tachycardia; [†]data are presented as median and range; [‡]statistical significance at p<0.05

	SVT	VT	Palpitations	Afib/Aund	Total
■ Males	147	74	658	741	1620
■ Females	304	49	992	784	2129
■ Total	451	123	1650	1525	3749

SVT = supraventricular tachycardia; VT = ventricular tachycardia; Afib/Aund = atrial fibrillation/atrial undulation

Fig. 1. Number of patients with different arrhythmias admitted to emergency department during a two-year period (July 2008-June 2010).

Table 2. Correlation between meteorological parameters and occurrence of all arrhythmias (July 2008-June 2010)

Parameter	Days	Arrhythmias (total) (r)	p[†]	Arrhythmias (males) (r)	p	Arrhythmias (females) (r)	p
Temperature (Day 0)	730	-0.01	0.834	-0.01	0.879	-0.01	0.831
Temperature (Day 1)	730	-0.01	0.749	0.00	0.999	-0.02	0.617
Temperature (Day 2)	730	-0.02	0.566	-0.01	0.871	-0.03	0.456
Temperature (Day 3)	730	-0.03	0.412	-0.02	0.663	-0.04	0.341
Pressure (Day 0)	730	-0.03	0.360	-0.03	0.361	-0.04	0.304
Pressure (Day 1)	730	-0.04	0.265	-0.04	0.245	-0.03	0.391
Pressure (Day 2)	730	-0.01	0.765	0.01	0.805	-0.03	0.405
Pressure (Day 3)	730	-0.03	0.384	-0.01	0.748	-0.04	0.273
Humidity (Day 0)	730	0.07	**0.046**	0.04	0.236	0.06	0.105
Humidity (Day 1)	730	0.08	**0.028**	0.04	0.339	0.09	**0.021**
Humidity (Day 2)	730	0.09	**0.012**	-0.00	0.919	0.13	**0.001**
Humidity (Day 3)	730	0.09	**0.010**	0.01	0.763	0.11	**0.003**

Day 0 = day of hospital admission; days 1-3 = days before hospital admission; r = Spearman's rank order correlation coefficient; [†]statistical significance at $p<0.05$

m³) and PM_{10} (25.7 (4.6-146.6) μg/m³) were below the legally defined thresholds. Considering the humid continental climate characteristics, the given mean daily values of air temperature (13.4 (-7.9-28.5) °C), relative humidity (68.9 (37.7-95.3) %) and air pressure (996 (966-1020) kPa) were as expected.

Table 3. Correlation between meteorological parameters and occurrence of particular arrhythmias (July 2008-June 2010)

Parameter	Days	SVT (r)	p[†]	VT (r)	p	Palpitations (r)	P	Afib/ Aund (r)	p
Temperature (Day 0)	730	-0.02	0.522	0.01	0.880	-0.00	0.963	-0.02	0.503
Temperature (Day 1)	730	-0.03	0.355	0.01	0.759	-0.01	0.865	-0.02	0.606
Temperature (Day 2)	730	-0.04	0.288	0.01	0.737	-0.01	0.876	-0.03	0.386
Temperature (Day 3)	730	-0.04	0.319	0.01	0.878	-0.02	0.518	-0.03	0.477
Pressure (Day 0)	730	-0.04	0.327	-0.01	0.864	0.01	0.797	-0.06	0.084
Pressure (Day 1)	730	-0.05	0.141	-0.04	0.236	0.01	0.756	-0.05	0.174
Pressure (Day 2)	730	-0.03	0.447	-0.04	0.331	0.01	0.668	-0.02	0.641
Pressure (Day 3)	730	-0.01	0.749	0.01	0.762	-0.00	0.897	-0.04	0.269
Humidity (Day 0)	730	0.00	0.908	-0.04	0.283	0.11	**0.004**	0.05	0.162
Humidity (Day 1)	730	0.02	0.619	-0.00	0.921	0.09	**0.013**	0.05	0.169
Humidity (Day 2)	730	0.04	0.332	-0.02	0.683	0.07	**0.047**	0.08	**0.032**
Humidity (Day 3)	730	0.02	0.680	-0.01	0.693	0.10	**0.009**	0.06	0.093

Day 0 = day of hospital admission; Days 1-3 = days before hospital admission; Afib/Aund = atrial fibrillation/atrial undulation; SVT = supraventricular tachycardia; VT = ventricular tachycardia; r = Spearman's rank order correlation coefficient; [†]statistical significance at p<0.05

We found no correlation between the occurrence of arrhythmias and air temperature and pressure, but there was positive correlation with air humidity on the day (r=0.07), and 1 (r=0.08), 2 (r=0.09) and 3 days (r=0.09) before ED admission, especially in females (p<0.05 all) (Table 2). The occurrence of palpitations showed positive correlation with air humidity on the day (r=0.11), and 1 (r=0.09), 2 (r=0.07) and 3 (r=0.10) days before ED admission; and the occurrence of Afib/ Aund showed positive correlation with air humidity 2 days (r=0.08) before ED admission (p<0.05 all) (Table 3). On the day of ED admission, the occurrence of arrhythmias yielded positive correlation with the concentration of NO_2 particles (r=0.08) and the occurrence of palpitations with the concentration of PM_{10} (r=0.11) and NO_2 (r=0.08) particles (p<0.05 all) (Tables 4 and 5).

Discussion

This study investigated the correlation of air temperature, pressure, concentration of air pollutants with the rate of admissions for cardiac arrhythmias at two clinical centers in the area with a humid continental climate. There was a very weak positive correlation of

the number of cases with arrhythmias with air humidity and concentration of NO_2 and PM_{10} particles. It should be noted that daily concentrations of air pollutants were below the permissible exposure limits during the study period. Nguyen *et al.* found negative association between air temperature and occurrence of Afib[14]. Gluszak *et al.* report no association between air temperature, pressure, or relative humidity, and occurrence of Afib[15]. Other authors found positive association between relative humidity, air pressure and occurrence of arrhythmias, SVT and ventricular extrasytoles[16-19].

In our study, the appearance of arrhythmias showed a very weak positive correlation with air humidity, especially in females. The possible explanation may be impaired perspiration and overall thermoregulation during the period of raising moisture, and it may gradually burden the less capable cardiovascular system beyond its adaptive ability. It is possible that women have less efficient thermoregulatory and sweating mechanisms[20]. The absence of correlation with air temperature and pressure may be explained by the characteristics of our climate, as well as cooperation of hydrometeorology services and media, which has strong influence on informing the population about weather conditions; citizens are informed on daily basis how to

Table 4. Correlation between air pollution and occurrence of all arrhythmias (July 2008-June 2010)

Parameter	Days	Arrhythmias (r)	p†	Arrhythmias (males) (r)	p	Arrhythmias (females) (r)	p
PM_{10} (Day 0)	720	0.06	0.117	0.02	0.514	0.05	0.202
PM_{10} (Day 1)	719	0.02	0.526	0.06	0.097	-0.02	0.591
PM_{10} (Day 2)	718	-0.00	0.959	0.04	0.302	-0.02	0.610
PM_{10} (Day 3)	717	-0.00	0.930	-0.01	0.862	0.00	0.901
NO_2 (Day 0)	692	0.08	**0.032**	0.04	0.297	0.07	0.065
NO_2 (Day 1)	692	0.07	0.075	0.06	0.098	0.04	0.248
NO_2 (Day 2)	692	0.02	0.520	0.03	0.370	0.02	0.555
NO_2 (Day 3)	692	0.00	0.950	-0.00	0.918	0.02	0.670
O_3 (Day 0)	646	-0.03	0.417	0.01	0.807	-0.05	0.247
O_3 (Day 1)	646	-0.04	0.266	-0.03	0.510	-0.04	0.297
O_3 (Day 2)	646	-0.04	0.297	-0.01	0.864	-0.07	0.083
O_3 (Day 3)	646	-0.00	0.902	0.02	0.536	-0.03	0.469

Day 0 = day of hospital admission; Days 1-3 = days before hospital admission; PM_{10} = particles of dimensions ~10 micrometers or less; O_3 = ozone; NO_2 = nitrogen dioxide; r = Spearman's rank order correlation coefficient; †statistical significance at p<0.05

Table 5. Correlation between air pollution and occurrence of particular arrhythmias (July 2008-June 2010)

Parameter	Days	SVT (r)	p†	VT (r)	p	Palpitations (r)	p	Afib/ Aund (r)	p
PM_{10} (Day 0)	730	0.03	0.454	-0.02	0.574	0.11	**0.003**	-0.03	0.373
PM_{10} (Day 1)	730	-0.00	0.983	-0.01	0.875	0.07	0.053	-0.02	0.506
PM_{10} (Day 2)	730	0.02	0.543	0.02	0.630	0.03	0.881	-0.02	0.593
PM_{10} (Day 3)	730	0.03	0.377	0.02	0.674	0.03	0.356	-0.04	0.325
NO_2 (Day 0)	730	0.01	0.831	0.01	0.847	0.08	**0.038**	0.03	0.476
NO_2 (Day 1)	730	0.00	0.989	0.04	0.279	0.07	0.060	0.04	0.328
NO_2 (Day 2)	730	0.04	0.250	0.03	0.497	0.05	0.200	-0.02	0.678
NO_2 (Day 3)	730	0.01	0.701	0.00	0.908	0.06	0.090	-0.06	0.146
O_3 (Day 0)	730	-0.00	0.997	0.02	0.687	-0.05	0.176	-0.03	0.505
O_3 (Day 1)	730	-0.00	0.966	-0.00	0.936	-0.04	0.365	-0.06	0.138
O_3 (Day 2)	730	0.01	0.844	0.02	0.652	-0.05	0.179	-0.07	0.082
O_3 (Day 3)	730	0.02	0.656	0.03	0.504	-0.05	0.179	-0.01	0.833

Day 0 = day of hospital admission; Days 1-3 = days before hospital admission; Afib/Aund = atrial fibrillation/atrial undulation; SVT = supraventricular tachycardia; VT = ventricular tachycardia; PM_{10} = particles of dimensions ~10 micrometers or less; O_3 = ozone; NO_2 = nitrogen dioxide; r = Spearman's rank order correlation coefficient; †statistical significance at p<0.05

prevent the impact of undesirable weather changes on their health.

Ozone is a secondary pollutant created indirectly from combustion engines; it is related to hospital admissions for cardiovascular and respiratory diseases[21-24]. Several authors have reported positive associa-tion, whereas others found no association between ar-rhythmias and O_3 particles[25,26]. These opposite findings may reflect individual susceptibility to arrhythmia be-cause of the underlying heart disease. The same con-clusion was made by the authors of a systematic review and meta-analysis of global association of air pollut-

ants and heart failure[27]. Nitrogen dioxide is a primary pollutant and strong respiratory irritant mainly from outdoor sources including motor vehicles and fossil-fuel power plants, whereas the most important indoor sources are gas heaters, stoves and tobacco smoke[28]. The number of patients admitted to ED correlates with the concentration of NO_2 and PM_{10} particles[8,10,24,29-31], which have strong influence on cardiovascular morbidity and mortality. In this study, the number of patients with arrhythmias was in positive correlation with the concentration of NO_2 and PM_{10} particles on the day of ED admission.

The results of the study should be viewed in the light of some limitations. The study period was rather short. Data on O_3 were obtained from only one monitoring station, which may have led to misclassification of the exposure level. Moreover, there was the lack of precise exposure estimates at the individual level due to different daily activity patterns and local mobility of each patient. There are many factors that may influence the rate of admissions for cardiac arrhythmias that were not taken into account.

In conclusion, the occurrence of arrhythmias showed very weak positive correlation with air humidity and concentration of air pollutants in the area with a humid continental climate. However, the upper lawful limits of air pollutants should be additionally restricted. It is of utmost importance because the currently permissible air pollution level increases the number of patients presenting to ED.

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Sažetak

KORELACIJA IZMEĐU KONCENTRACIJE ONEČIŠĆIVAČA ZRAKA
I POJAVNOSTI SRČANIH ARITMIJA U PODRUČJU S VLAŽNOM KONTINENTALNOM KLIMOM

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U ovoj studiji istraživali smo korelaciju temperature zraka, tlaka zraka, koncentracije onečišćivača zraka i učestalosti srčanih aritmija u dva klinička centra u području s vlažnom kontinentalnom klimom. Retrospektivna studija je uključivala 3749 bolesnika s aritmijama primljenih u hitnu službu (HS). Oni su klasificirani u četiri skupine: supraventrikulska tahikardija (SVT), ventrikulska tahikardija (VT), atrijska fibrilacija/undulacija (Afib/Aund) i palpitacije (bez EKG promjena ili sa sinusnom tahikardijom i ekstrasistolama). Broj bolesnika, vrijednosti meteoroloških parametara (prosječne dnevne vrijednosti temperature zraka, tlaka i relativne vlage) i koncentracije onečišćujućih tvari u zraku (čestice dimenzija ~10 mikrometara ili manje (PM_{10}), ozon (O_3) i dušikov dioksid (NO_2)) prikupljene su tijekom dvije godine (srpanj 2008.-lipanj 2010.). Bilo je 1650 (44,0%), 1525 (40,7%), 451 (12,0%) i 123 (3,3%) bolesnika s palpitacijama, Afib/Aund-om, SVT-om odnosno VT-om. Primjenom Spearmanove analize našli smo pozitivnu korelaciju između pojave aritmije i vlažnosti zraka na dan (r=0,07), 1 (r=0,08), 2 (r=0,09) i 3 dana prije (r=0,09) te NO_2 čestica na dan (r=0,08) prijma u HS; palpitacija i vlažnosti zraka na dan (r=0,11), 1 (r=0,09), 2 (r=0,07) i 3 dana prije (r=0,10) te PM_{10} (r=0,11) i NO_2 (r=0,08) čestica na dan prijma u HS; Afib/Aund i vlažnosti zraka 2 dana prije (r=0,08) prijma u HS (za sve p<0,05). U zaključku, utvrđena je vrlo slaba pozitivna korelacija između pojavnosti srčanih aritmija i vlage u zraku te koncentracije onečišćivača zraka u području s vlažnom kontinentalnom klimom.

Ključne riječi: *Onečišćenost zraka – štetna djelovanja; Aritmije, srčane; Klima – štetna djelovanja; Hitna služba, bolnička*