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Ambient air pollution and emergency department visits and hospitalisation for cardiac arrest: a population-based case-crossover study

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Abstract

Objectives To assess the association between traffic-related ambient air pollution and emergency hospital visits for cardiac arrest.

Design A bidirectional time-stratified case-crossover design was used with a lag time to 4 days.

Setting The Reykjavik capital area and the study population were the inhabitants 18 years and older identified by encrypted personal identification number and zip codes.

Participants and exposure Cases were those who had made emergency visits to Landspitali University Hospital during the period 2006 to 2017 and who were given the primary discharge diagnosis of cardiac arrest according to The International Classification of Diseases 10th edition (ICD-10), code I46. The pollutants were NO_2, PM_{10}, $PM_{2.5}$, and SO_2 with adjustment for H_2S, temperature and relative humidity.

Main outcome measure Odds ratio (OR) and 95% confidence intervals (CI) per 10 µg/m^3 increase in concentration of pollutants.

Results: The 24-h mean NO_2 was 20.7 µg/m^3, mean PM_{10} was 20.5 µg/m^3, mean $PM_{2.5}$ was 12.5 µg/m^3, and mean SO_2 was 2.5 µg/m^3. PM_{10} level was positively associated with the number of emergency hospital visits (n=453) for cardiac arrest. Each 10 µg/m^3 increase in PM_{10} was associated with increased risk of cardiac arrest (ICD-10: I46), odds ratio (OR) 1.093 (95%CI 1.033-1.162) on lag 2, OR 1.118 (95%CI 1.031-1.212) on lag 0-2, OR 1.150 (95% CI 1.050-1.261) on lag 0-3, and OR 1.168 (95% CI 1.054-1.295) on lag 0-4. Significant associations were shown between exposure to PM_{10} on lag 2 and on lag 0-2 and increased risk of cardiac arrest in the age, gender, and season strata.

Conclusions: A new endpoint was used for the first time in this study: cardiac arrest (ICD-10 code I46). Short-term increase in PM_{10} concentrations was associated with cardiac arrest. Future ecological studies of this type and their related discussions should perhaps concentrate more on precisely defined endpoints.

Key words Cardiac arrest, urgent hospital visits, successful resuscitation, multivariate models, cardiovascular diseases

Strength and limitations of this study

- The study is population-based, relies on comprehensive population registries, and include information of daily concentrations of the pollutants which cover more than 75% of the days in the study period.
- The methodology allows within-subject comparison while adjusting for various time trends such as seasonality, and day of week.
- The concentration of the pollutants derived from one monitoring station, and not from individual exposure measurements.
- The population is small, and therefore the total number of cases were few, resulting in low statistical power.

Introduction

Epidemiological studies have found increased risk of cardiovascular morbidity and mortality in association with particulate matter (PM) in air pollution (1,2), and the overall evidence is considered to support the existence of a causal relationship between PM exposure and cardiovascular morbidity, primarily due to fine particles (2). Both short-term and long-term PM air pollution contribute to cardiovascular morbidity and mortality (1,2). Urban ambient air pollution is a complex mixture of gases, particles and liquid, and in an attempt to monitor air quality, certain pollutants are traditionally measured. However, adverse cardiovascular health impacts of exposure to a combination of air pollutants are not completely understood at present. A recent multilocation analysis found that a short term increase in NO_2 on the previous day was associated with an increased risk of daily total, cardiovascular, and respiratory mortality (3). In a systemic review and meta-analysis of short-term exposure to NO_2 and ischemic heart diseases, the authors concluded that the relationship was likely causal (4), but uncertainties remained due to possible confounding in the epidemiological studies and lack of evidence from mechanistic studies. Several epidemiological studies have found that NO_2 and PM are associated with cardiovascular diseases (CVD), and the endpoints studied have included not only mortality from CVD (3), but also discharge diagnosis at hospitals and emergency departments for a wide range of CVD, ischemic heart disease, myocardial infraction, and different cardiac dysrhythmias (5-10). In a large US study (9), acute myocardial infarction, and multiple other cardiovascular outcomes, like cardiac dysrhythmia and heart failure were found to be associated with particulate air pollution; however, in that analysis it was only possible to consider potential confounding by ozone, not by other pollutants. In a case-crossover study in China, an association was found between particulate matter, NO_2, and carbon monoxide, and number of hospital admissions for cardiac arrhythmia (10). In another case-crossover study in the UK (8), the risk of emergency hospital admissions for CVD, arrhythmias, atrial fibrillation, and heart failure was associated with an increased concentration of NO_2; however, cardiac arrest was not included as an outcome in the study. Cardiac arrest was mentioned in the aforementioned Chinese study (10) but was not analysed separately.

The comprehensive population and health registries in Iceland make this an optimal setting to study the association between relatively low daily exposure to air pollution, and different heart related conditions (7,11,12). The aim of the present study was to explore the association between traffic-related pollutants, NO_2,

PM_{10}, $PM_{2.5}$, and SO_2 in the Reykjavik capital area and urgent hospital and emergency department visits for cardiac arrest as the primary discharge diagnosis, and to simultaneously adjust for meteorological variables and geothermal-originated pollutants.

Methods

Study base

The Reykjavik capital area is in the southwestern part of Iceland. Traffic emission is the main source of air pollution in the city. Other sources of air pollution include two geothermal power plants: Hellisheidi, located 26 km east-southeast of the city, and Nesjavellir, located 33 km east of the city. Ambient H_2S emission originates from the plants. Reykjavik's capital area spreads over 247.5 km^2 and in 2017 the inhabitants numbered 217,000, equivalent to approximately two-thirds of the total Icelandic population (13). The study base included the residents of the Reykjavik capital area, which consists of seven municipalities (Gardabaer, Hafnarfjordur, Kjosarhreppur, Kopavogur, Mosfellsbaer, Reykjavik, and Seltjarnarnes) identified by 24 zip codes.

Health data

Hospital discharge data were obtained from January 1 2006 to December 31 2017 from computerised records in SAGA (Register of hospital-treated patients in Iceland) for certain heart diseases; the procedures have been described in a previous publication (7). The study included adult inhabitants (≥18 years) of the Reykjavik capital area, identified by zip code. We analysed data on urgent visits to the emergency department and urgent admissions to in-patient wards of Landspitali University Hospital (LUH). The study was confined to new admissions, meaning that no visits by appointment were included. LUH is operated by the Icelandic government and is the only acute care hospital serving the population of the Reykjavik capital area, making this study population-based. In Iceland, the national health insurance scheme is covered by taxes and is available to all residents. For ambulatory visits, patients pay a small fee that amounts to approximately 10 to 15 US dollars, but seniors are exempt from payment. Admission to the hospital ward is free of charge. Every inhabitant of Iceland receives a personal identification number at birth (or at immigration), and the identification numbers are widely used in Icelandic society and population registries, including the SAGA register. We received the identification numbers in encrypted form, which enabled us to identify repeated visits to LUH. Readmissions to LUH within 10 days with the same ICD-10 primary discharge diagnosis were excluded. From the SAGA register we received the following details: admission date, encrypted identification number, unique number of the admission, age, gender, primary discharge diagnosis for certain codes according to the International Classification of Diseases 10th edition (ICD-10). In this study, both admission to the emergency department and formal admission to the hospital are included, so there is no requirement that a patient stayed overnight. The diagnoses are registered at discharge from the hospital, transfer to another hospital, and death in the hospital. In a previous study (7), the outcomes were heart diseases ICD-10 codes: I20-I25, I44-I50, ischemic heart diseases ICD-10 codes: I20-I25, cardiac arrhythmias and heart failure ICD-10 codes: I44-I50, and atrial fibrillation ICD-10 I48 (7). In the present study, the outcome analysed was cardiac arrest ICD-10 code I46. Emergency department visits and urgent hospital admissions were combined and are called emergency hospital visits.

Air pollutants and meteorological data

Information on pollution was obtained from Grensas monitor station (GRE), operated by the governmental institution Environment Agency of Iceland. GRE is in the centre of the Reykjavik capital area near one of the busiest road intersections in the city. Other stations in the city were not permanently located or were not continuously monitoring throughout the study period and were therefore not used in the study. However, to test whether GRE was reflective of the total capital area, Pearson's correlation was calculated for GRE measurements and measurements from another station located in Dalsmari, Kopavogur municipality, for the period 2014-2017. Results of Pearson's correlation coefficients between these two measurement stations were for PM_{10} 0.44, for NO_2 0.78, for SO_2 0.98, and for H_2S 0.84. PM2.5 was not measured in Dalsmari.

Pollutants measured at GRE were NO_2, particulate matter with aerodynamic diameter less than 10 µm (PM_{10}), particulate matter with aerodynamic diameter less than 2.5 µm ($PM_{2.5}$), sulphur dioxide (SO_2), and hydrogen sulphide (H_2S), all measured in µg/m^3. The meteorological data was obtained from the governmental institution Icelandic Meteorological Office and included temperature (°C) and relative humidity (RH). PM_{10} and $PM_{2.5}$ were measured with an Andersen EMS IR Thermo (model FH62 I-R), NO_2 with Horiba device (model APNA 360E), and SO_2 and H_2S with the Horiba model APOA 360E. Every 6-12 months the devices are calibrated. Exposure data included 12 years or 4,383 days. Daily averages (midnight to midnight the following day) were calculated from hourly concentrations if at least 75% of one-hour data existed. Missing daily averages for NO_2, PM_{10}, $PM_{2.5}$, SO_2, and H_2S were 383 days (8.7%), 165 days (3.8%), 923 days (21.1%), 200 days (4.6%), and 284 days (6.5%), respectively. Data gaps were seen and can be attributed to inactive measurement devices due to unknown causes, with the exception of 52 days of missing H_2S measurements at the beginning of the study period, as H_2S measurements at GRE started at the end of February 2006. For temperature and RH, 6 days (0.1%) and 6 days (0.1%) were missing, respectively. Minor gaps in the curves were fitted by linear interpolation.

Descriptive statistics were calculated and showed as daily concentration levels in µg/m³ of the pollutants, as well as Spearman's correlation coefficient between pollutants and meteorological factors.

Analysis

Short-term associations between daily exposure to air pollutants and emergent hospital visits for cardiac arrest (ICD-10 code I46) were assessed using bidirectional time-stratified case-crossover design. The study period was divided into monthly strata, and exposure during case periods (24h) was compared to exposure during control periods, which were matched as the same weekdays within the same month (3-4 control periods per case period) (14,15). We did several calculations: single pollutant models were calculated in conditional logistic regression, multivariate models containing all traffic-related pollutants, H_2S, and the meteorological variables. Separate analyses were done for subgroups according to gender, age (≥71 and < 71 years), gender, and age combined, winter (November 1st to April 30th), and summer (May 1st to October 31st). It was possible to divide the diagnostic category I46 according to decimals into cardiac arrest with successful resuscitation (I46.0) and other categories without indication of successful resuscitation (I46, I46.1, and I46.9). These two subcategories were also analysed separately as there are indication that the latter category concern mortality. The risk estimates were expressed as odds ratio (OR), and 95% confidence intervals (CI) were calculated for every 10 µg/m³ increase of pollutants (24h concentrations).

Different lag structures were applied. Single-day lag structure (lag 0 to lag 4), and multiple-day lag structure (lag 0-1, lag 0-2, lag 0-3, and lag 0-4, moving average of pollutants concentration) were employed in the analyses to explore the temporal association between pollutants and cardiac arrest. The results of the multivariate models with all lag structures are presented in the article, and other results are shown as Supplementary data.

Although readmissions within 10 days with the same primary discharge diagnosis were excluded, it is still possible that some patients first went to the emergency department and were subsequently admitted that same day to in-hospital wards where they might have received a different diagnosis than they were given at the emergency department. To test whether this could distort the main result of the association between increased pollutant concentration and the emergency hospital visits, a sensitivity analysis was done, in which data was restricted to emergency department visits only.

Statistical analysis was done with R version 4.0.3 (https://www.r-project.org/). Statistical tests used in this study were all two-tailed and we considered results statistically significant for $p < 0.05$.

The study was approved by the National Bioethics Committee (ref. no. VSNb2018120011/03.01), the Data Protection Authority (ref. no. 10-050), and the Scientific Committee of LUH.

Patient and public involvement

None.

Results

The basic characteristics of cardiac arrest according to subcategories are shown in Table 1.

Table 1. Descriptive statistics of emergency hospital visits for cardiac arrest (ICD-10: I46) to Landspitali University Hospital, according to subgroups, January 1st, 2006 to December 31st, 2017.

Discharge diagnosis (ICD-10)	No. of visits (%)	No. of patients
Cardiac arrest (I46)	453 (100)	447
Females	125 (28)	123
Males	328 (72)	324
Older (≥71yr)	192 (42)	190
Younger (<71yr)	261 (58)	257
Older females	57	56
Younger females	68	67
Older males	135	134
Younger males	193	190
Winter	236 (52)	236
Summer	217 (48)	214
Cardiac arrest (I46)	5	5
Cardiac arrest with successful resuscitation (I46.0)	194	192
Sudden cardiac death, so described (I46.1)	23	23
Cardiac arrest, unspecified (I46.9)	231	229
Emergency department visits, only	313	312

Winter: November 1st to April 30th.
Summer: May 1st to October 31st.

The total number of visits with primary discharge diagnosis cardiac arrest (ICD-10 code I46) was 453, and repeated visits were extremely rare. The distribution of the 453 visits was even over the 4383-day study period. One visit per day was most common, but there were several days with up to two visits, which was the higest number of visits per day; thus, most days were without visits with cardiac arrest. The median age at the time of visits was 71 years. Descriptive statistics and Spearman's correlation coefficients of traffic-related pollutants, H_2S, and meteorological variables are presented in Table 2.

Table 2. Descriptive statistics of 24-hour concentration levels (μg/m³) of pollutants and meteorological data in the Reykjavík capital area during the study period, 2006-2017, and Spearman's correlation between daily concentrations of pollutants

	PM_{10}	$PM_{2,5}$	NO_2	SO_2	H_2S	TEMP (°C)	RH (%)
24-h availability n (%)	4218 (96.2)	3460 (78.9)	4000 (91.3)	4183 (95.4)	4099 (93.5)	4377 (99.9)	4377 (99.9)
Mean (SD)	20.5 (19.7)	12.5 (21.8)	20.7 (15.0)	2.51 (13.8)	2.98 (5.2)	5.5 (4.9)	74.9 (10.6)
Summer* mean (SD)	17.4 (14.9)	10.8 (16.2)	16.2 (9.9)	2.48 (14.1)	2.08 (3.1)	9.1 (3.2)	74.6 (9.8)
Winter** mean (SD)	23.6 (23.2)	14.2 (26.1)	25.3 (17.6)	2.54 (13.5)	3.90 (6.6)	1.9 (3.4)	75.1 (11.3)
Range	2.4-381	0-423	0-119	0-409	0-96	-10.5-17.7	37-97
Median	15.1	7.0	16.6	1.1	1.2	5.6	77.0
Interquartile range	11.6	8.2	15.8	1.2	2.7	7.9	15.0
Spearman's correlation							
PM_{10}	1.00						

$PM_{2,5}$	0.76	1.00					
NO_2	0.09	0.00	1.00				
SO_2	0.08	0.08	0.50	1.00			
H_2S	-0.08	-0.11	0.31	0.39	1.00		
TEMP (°C)	-0.16	-0.08	-0.44	-0.17	-0.23	1.00	
RH (%)	-0.30	-0.56	0.09	-0.03	0.04	0.12	1.00

* May 1st to October 31st.
** November 1st to April 30th.
SD: standard deviation; H_2S: hydrogen sulphide; NO_2: nitrogen dioxide; PM_{10}: particulate matter ≤10μm in diameter; $PM_{2.5}$: particulate matter ≤2.5μm in diameter; RH: relative humidity; SO_2: sulphur dioxide; TEMP: temperature.

Missing daily average was highest for PM_{10} but did not exceed 25% of the days of the study period. The concentrations of PM_{10} and $PM_{2.5}$ were correlated, particulate matter did not correlate with the gaseous pollutants, and correlations among gaseous pollutants were moderate.

In the single pollutant analyses, positive associations were observed for exposure to PM_{10} at lag 2 and lag 0-2, and unstratified emergency hospital visits for cardiac arrest (ICD-10 codes: I46); the increased risks of cardiac arrest were OR 1.096 (95% CI 1.033-1.162) and OR 1.118 (95% CI 1.031-1.212), respectively, per 10 μg/m³ increase of PM_{10}, as shown in Table A, Supplementary data. A positive association was observed between exposure to NO_2 at lag 4 and the increased risk of cardiac arrest; the increased risk was OR 1.081 (95% CI 1.002-1.166) per 10 μg/m³ increase of NO_2, as shown in Table A, Supplementary data.

In examining the daily lag exposure to PM_{10} and unstratified emergency hospital visits for cardiac arrest, positive associations were observed in the multivariate model; the increased risks of cardiac arrest were OR 1.096 (95% CI 1.033-1.162) for lag 2, OR 1.118 (95% CI 1.031-1.212) for lag 0-2, OR 1.150 (95% CI 1.050-1.261) for lag 0-3, and OR 1.168 (95% CI 1.054-1.295) for lag 0-4 per 10 μg/m³ increase of PM_{10} (Table 3). Significant associations were shown for exposure to NO_2 at lag 4 and for SO_2 at lag 0, and unstratified emergency hospital visits for cardiac arrest; the increased risks were OR 1.096 (95% CI 1.008-1.192) and OR 1.084 (95% CI 1.002-1.173) per 10 μg/m³ increase of NO_2 and SO_2, respectively (Table 3).

When applying the multivariate model in the stratified analyses of daily pollutants exposure and the association of emergency hospital visits for cardiac arrest (ICD-10 code I46), a discernible pattern emerges. Significant associations were shown between exposure to PM_{10} at lag 2 and/or exposure to PM_{10} at lag 0-2, lag 0-3, and lag 0-4, and increased risks of cardiac arrest, in the age, gender, age and gender combined, and season strata, i.e., in all the strata except in the stratum of young females (Table 3).

Table 3 Number of visits (n), odds ratios (OR) and 95% confidence intervals (CI) for the daily emergency hospital visits for cardiac arrest (ICD-10 code: I46) in Reykjavik capital area associated with 10 μg/m³ increase in NO_2, PM_{10}, $PM_{2.5}$, SO_2 and H_2S, adjusted for each pollutant, temperature and relative humidity, unstratified and stratified by gender, age, and season, at lag 0 to lag 4, lag 0-1, lag 0-2, lag 0-3, and lag 0-4.

		NO_2		PM_{10}		$PM_{2.5}$		SO_2		H_2S	
Categories/Visits (n)	**Lag**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
All (453)	0	0.989	0.904-1.083	1.017	0.957-1.082	0.990	0.930-1.053	1.084	1.002-1.173	1.187	0.972-1.449
	1	1.003	0.916-1.099	1.041	0.987-1.097	0.994	0.936-1.055	0.983	0.873-1.107	1.056	0.829-1.344
	2	0.972	0.885-1.068	1.096	1.033-1.162	0.993	0.935-1.054	0.999	0.935-1.067	1.118	0.892-1.402
	3	1.052	0.963-1.150	1.038	0.988-1.090	1.022	0.968-1.079	0.991	0.916-1.074	1.191	0.980-1.449
	4	1.096	1.008-1.192	1.029	0.963-1.099	1.054	0.992-1.020	1.003	0.940-1.070	0.915	0.714-1.171
	0-1	0.982	0.876-1.101	1.049	0.978-1.124	0.988	0.922-1.059	1.084	0.971-1.211	1.214	0.923-1.597
	0-2	0.957	0.838-1.093	1.118	1.031-1.212	0.989	0.918-1.066	1.070	0.945-1.212	1.301	0.936-1.810
	0-3	0.981	0.846-1.137	1.150	1.050-1.261	0.998	0.921-1.081	1.061	0.922-1.221	1.423	1.007-2.011
	0-4	1.039	0.889-1.215	1.168	1.054-1.295	1.019	0.934-1.112	1.057	0.588-1.928	1.313	0.897-1.921
Females (125)	0	1.223	1.011-1.481	0.982	0.857-1.126	0.900	0.763-1.063	0.256	0.039-1.665	1.270	0.797-2.024
	1	1.029	0.860-1.231	1.006	0.928-1.091	0.895	0.764-1.049	0.740	0.237-2.316	1.036	0.688-1.561
	2	1.009	0.839-1.212	1.193	1.059-1.344	0.958	0.843-1.089	0.284	0.051-1.582	0.902	0.531-1.532
	3	1.029	0.860-1.232	1.040	0.959-1.129	0.983	0.857-1.127	0.286	0.064-1.287	1.156	0.759-1.760
	4	1.175	0.997-1.384	0.927	0.806-1.068	1.036	0.909-1.181	0.495	0.154-1.591	1.006	0.639-1.583
	0-1	1.214	0.948-1.555	1.016	0.893-1.157	0.867	0.724-1.038	0.404	0.076-2.132	1.184	0.698-2.008
	0-2	1.174	0.893-1.543	1.110	0.958-1.287	0.889	0.740-1.068	0.236	0.034-1.664	1.172	0.605-2.273
	0-3	1.177	0.867-1.597	1.162	0.982-1.374	0.901	0.748-1.085	0.134	0.015-1.166	1.350	0.665-2.740
	0-4	1.278	0.939-1.740	1.133	0.935-1.372	0.914	0.754-1.108	0.118	0.012-1.125	1.276	0.593-2.743
Males (328)	0	0.935	0.841-1.041	1.036	0.966-1.112	1.012	0.946-1.083	1.093	1.009-1.184	1.218	0.972-1.526
	1	0.989	0.888-1.101	1.067	0.993-1.147	1.013	0.951-1.079	0.992	0.882-1.116	1.094	0.805-1.486
	2	0.982	0.878-1.098	1.058	0.992-1.128	0.997	0.932-1.067	1.000	0.937-1.067	1.242	0.962-1.604
	3	1.087	0.978-1.208	1.028	0.966-1.094	1.031	0.972-1.094	0.996	0.921-1.077	1.238	0.988-1.550
	4	1.079	0.975-1.194	1.070	0.988-1.158	1.066	0.995-1.142	1.007	0.944-1.073	0.895	0.666-1.203
	0-1	0.924	0.808-1.057	1.077	0.989-1.174	1.015	0.943-1.092	1.102	0.984-1.233	1.302	0.936-1.810
	0-2	0.902	0.771-1.055	1.120	1.015-1.237	1.012	0.933-1.099	1.088	0.958-1.235	1.503	1.013-2.229
	0-3	0.942	0.793-1.120	1.139	1.020-1.273	1.022	0.935-1.117	1.086	0.940-1.255	1.628	1.078-2.457
	0-4	0.985	0.818-1.186	1.174	1.037-1.328	1.047	0.949-1.154	1.087	0.937-1.260	1.499	0.955-2.351
Older ≥71 (192)	0	1.035	0.901-1.188	0.995	0.898-1.102	1.038	0.940-1.147	1.089	0.967-1.226	1.096	0.815-1.475
	1	0.985	0.853-1.137	1.000	0.891-1.122	1.001	0.910-1.101	0.974	0.833-1.140	1.065	0.763-1.485
	2	1.099	0.953-1.267	1.186	1.066-1.320	1.034	0.942-1.135	0.989	0.901-1.085	1.210	0.883-1.659
	3	1.030	0.894-1.188	1.054	0.981-1.134	1.032	0.931-1.144	0.823	0.513-1.318	1.315	0.992-1.744
	4	1.071	0.943-1.216	1.057	0.969-1.152	1.024	0.938-1.117	1.000	0.895-1.117	0.887	0.618-1.272
	0-1	0.999	0.839-1.190	0.997	0.872-1.141	1.019	0.912-1.138	1.065	0.917-1.236	1.154	0.776-1.717
	0-2	1.055	0.862-1.291	1.151	1.005-1.319	1.036	0.921-1.164	1.045	0.891-1.226	1.266	0.796-2.014
	0-3	1.060	0.848-1.325	1.197	1.033-1.386	1.038	0.910-1.185	0.993	0.824-1.197	1.460	0.906-2.354
	0-4	1.087	0.860-1.374	1.243	1.056-1.463	1.056	0.915-1.218	0.998	0.824-1.208	1.371	0.808-2.324
Younger <71 (261)	0	0.961	0.853-1.083	1.037	0.958-1.122	0.962	0.885-1.045	1.083	0.975-1.204	1.242	0.941-1.640
	1	1.019	0.905-1.148	1.055	0.993-1.122	0.989	0.916-1.068	0.998	0.833-1.195	1.031	0.724-1.469
	2	0.892	0.784-1.014	1.059	0.978-1.147	0.965	0.889-1.048	1.005	0.914-1.105	1.019	0.723-1.438
	3	1.076	0.957-1.209	1.025	0.958-1.097	1.020	0.956-1.088	1.069	0.941-1.214	1.094	0.814-1.470
	4	1.123	1.002-1.259	0.992	0.893-1.101	1.083	0.991-1.183	1.007	0.930-1.091	0.926	0.653-1.312
	0-1	0.973	0.837-1.132	1.075	0.990-1.166	0.970	0.887-1.060	1.108	0.941-1.306	1.236	0.840-1.818
	0-2	0.890	0.744-1.065	1.117	1.007-1.238	0.959	0.869-1.058	1.108	0.907-1.353	1.286	0.799-2.069
	0-3	0.930	0.761-1.136	1.136	1.009-1.279	0.975	0.881-1.080	1.149	0.915-1.445	1.349	0.808-2.253
	0-4	1.162	0.720-1.874	1.133	0.856-1.499	0.951	0.708-1.277	0.047	0.002-1.342	2.088	0.734-5.942

Table 3 Continued

Older females (57)	0	1.394	1.036-1.876	0.926	0.750-1.142	0.772	0.523-1.140	0.420	0.024-7.404	0.847	0.418-1.713
	1	0.970	0.717-1.312	1.020	0.840-1.238	0.927	0.767-1.119	0.454	0.045-4.562	1.168	0.676-2.019
	2	1.228	0.926-1.628	1.177	1.010-1.371	0.983	0.840-1.151	0.150	0.005-4.657	0.534	0.182-1.565
	3	1.002	0.778-1.291	1.039	0.945-1.144	0.966	0.781-1.194	0.630	0.101-3.918	1.074	0.633-1.823
	4	1.128	0.908-1.401	0.925	0.772-1.108	0.935	0.761-1.148	3.684	0.414-32.751	0.736	0.351-1.545
	0-1	1.330	0.907-1.950	0.967	0.753-1.242	0.861	0.653-1.136	0.470	0.028-7.870	0.994	0.472-2.093
	0-2	1.435	0.941-2.189	1.105	0.869-1.404	0.933	0.732-1.189	0.195	0.006-6.790	0.777	0.270-2.242
	0-3	1.364	0.879-2.115	1.167	0.916-1.486	0.931	0.726-1.194	0.174	0.006-5.284	0.951	0.338-2.669
	0-4	1.401	0.924-2.124	1.116	0.847-1.469	0.918	0.701-1.201	0.421	0.017-10.137	0.727	0.217-2.434
Younger females (68)	0	1.131	0.873-1.465	1.052	0.864-1.281	0.930	0.776-1.113	0.184	0.017-2.013	2.148	1.038-4.446
	1	1.074	0.853-1.350	1.013	0.926-1.109	0.857	0.649-1.130	0.896	0.250-3.212	0.958	0.509-1.800
	2	0.853	0.661-1.100	1.186	0.976-1.440	0.901	0.714-1.137	0.481	0.072-3.209	1.194	0.638-2.232
	3	1.062	0.815-1.384	1.037	0.879-1.224	0.999	0.834-1.197	0.097	0.007-1.338	1.248	0.608-2.560
	4	1.186	0.910-1.546	0.880	0.693-1.118	1.197	0.964-1.486	0.187	0.023-1.544	1.137	0.603-2.146
	0-1	1.149	0.828-1.595	1.044	0.900-1.211	0.892	0.696-1.142	0.363	0.045-2.893	1.624	0.711-3.711
	0-2	1.001	0.687-1.459	1.124	0.921-1.371	0.866	0.653-1.150	0.277	0.027-2.883	1.763	0.701-4.434
	0-3	1.013	0.652-1.573	1.167	0.910-1.496	0.896	0.674-1.192	0.105	0.006-1.872	2.165	0.764-6.133
	0-4	1.162	0.720-1.874	1.133	0.856-1.499	0.951	0.708-1.277	0.047	0.002-1.342	2.088	0.734-5.942
Older males (135)	0	0.940	0.795-1.111	1.021	0.907-1.150	1.079	0.969-1.202	1.097	0.971-1.240	1.222	0.877-1.703
	1	1.000	0.846-1.183	0.985	0.846-1.145	1.032	0.925-1.151	0.996	0.851-1.164	1.116	0.722-1.725
	2	1.095	0.919-1.305	1.167	1.001-1.362	1.039	0.920-1.172	0.984	0.897-1.079	1.483	1.019-2.159
	3	1.053	0.881-1.258	1.058	0.947-1.182	1.059	0.940-1.192	0.831	0.518-1.334	1.457	1.000-2.121
	4	1.006	0.850-1.191	1.126	1.005-1.262	1.051	0.952-1.161	1.003	0.895-1.123	0.938	0.910-1.440
	0-1	0.920	0.748-1.132	1.010	0.856-1.191	1.067	0.943-1.207	1.090	0.938-1.268	1.381	0.848-2.248
	0-2	0.948	0.745-1.208	1.138	0.959-1.350	1.078	0.937-1.240	1.062	0.906-1.245	1.738	1.000-3.021
	0-3	0.966	0.739-1.263	1.177	0.972-1.424	1.092	0.924-1.289	1.020	0.846-1.230	1.963	1.062-3.628
	0-4	0.949	0.709-1.272	1.280	1.037-1.579	1.125	0.942-1.344	1.033	0.851-1.254	1.907	0.990-3.673
Younger males (193)	0	0.941	0.818-1.081	1.050	0.960-1.147	0.971	0.883-1.067	1.093	0.981-1.217	1.194	0.871-1.637
	1	0.984	0.855-1.134	1.097	1.009-1.193	1.005	0.929-1.087	1.001	0.834-1.203	1.076	0.694-1.668
	2	0.922	0.792-1.074	1.018	0.926-1.118	0.976	0.894-1.066	1.011	0.919-1.113	0.974	0.640-1.484
	3	1.111	0.970-1.272	1.017	0.942-1.099	1.025	0.956-1.098	1.082	0.945-1.238	1.108	0.798-1.538
	4	1.134	0.997-1.291	1.017	0.905-1.143	1.076	0.975-1.188	1.013	0.936-1.096	0.850	0.559-1.292
	0-1	0.932	0.781-1.113	1.110	1.003-1.229	0.989	0.899-1.087	1.123	0.948-1.329	1.208	0.767-1.902
	0-2	0.868	0.704-1.071	1.127	0.995-1.276	0.979	0.882-1.086	1.134	0.919-1.400	1.244	0.697-2.222
	0-3	0.929	0.738-1.169	1.125	0.979-1.293	0.993	0.891-1.107	1.186	0.924-1.522	1.318	0.716-2.426
	0-4	1.020	0.801-1.300	1.123	0.961-1.312	1.017	0.902-1.146	1.185	0.903-1.556	1.173	0.596-2.306
Winter (236)	0	1.003	0.906-1.111	1.064	0.992-1.141	0.958	0.884-1.039	1.119	0.990-1.265	1.224	0.980-1.529
	1	1.030	0.927-1.145	1.047	0.984-1.115	0.982	0.905-1.065	0.957	0.781-1.172	0.988	0.741-1.319
	2	1.021	0.919-1.133	1.071	1.003-1.143	0.988	0.908-1.076	0.972	0.886-1.067	1.129	0.878-1.451
	3	1.082	0.979-1.195	1.038	0.980-1.100	0.995	0.926-1.069	0.990	0.912-1.074	1.207	0.976-1.493
	4	1.087	0.988-1.195	1.085	0.993-1.187	1.089	0.995-1.191	0.979	0.900-1.064	0.951	0.722-1.252
	0-1	1.013	0.889-1.154	1.089	1.003-1.182	0.961	0.877-1.054	1.104	0.953-1.279	1.200	0.876-1.645
	0-2	1.016	0.873-1.183	1.148	1.041-1.266	0.965	0.872-1.068	1.037	0.874-1.230	1.301	0.889-1.904
	0-3	1.056	0.892-1.249	1.187	1.061-1.328	0.965	0.866-1.075	1.016	0.848-1.218	1.451	0.980-2.149
	0-4	1.109	0.927-1.326	1.240	1.089-1.412	0.989	0.881-1.111	0.996	0.833-1.191	1.362	0.882-2.104
Summer (217)	0	0.914	0.743-1.126	0.864	0.736-1.014	1.036	0.934-1.148	1.083	0.967-1.214	1.043	0.633-1.717
	1	0.993	0.814-1.211	0.997	0.889-1.118	1.008	0.920-1.105	0.984	0.852-1.136	1.441	0.888-2.340
	2	0.821	0.658-1.023	1.175	1.046-1.320	0.992	0.912-1.079	1.175	0.915-1.509	1.009	0.583-1.744
	3	0.927	0.753-1.142	1.047	0.951-1.152	1.073	0.982-1.172	1.041	0.723-1.499	0.964	0.540-1.720
	4	1.036	0.841-1.275	0.951	0.844-1.072	1.022	0.938-1.114	1.373	0.863-2.187	0.759	0.416-1.384
	0-1	0.903	0.703-1.160	0.910	0.773-1.071	1.027	0.920-1.147	1.073	0.917-1.257	1.363	0.763-2.435
	0-2	0.800	0.594-1.076	1.033	0.878-1.216	1.014	0.907-1.135	1.132	0.920-1.393	1.360	0.684-2.703
	0-3	0.764	0.546-1.070	1.061	0.891-1.263	1.039	0.921-1.172	1.176	0.902-1.534	1.354	0.617-2.970
	0-4	0.802	0.556-1.156	1.021	0.843-1.236	1.056	0.924-1.207	1.257	0.925-1.708	1.133	0.479-2.679

In Figure 1, OR and 95% CI of cardiac arrest per 10 μg/m³ increase of PM_{10} concentrations in multi-pollutant models are shown at lag 0 to lag 4 for different strata and unstratified.

In the single pollutant analyses, positive associations were observed for exposure to PM_{10} at lag 0-3, and lag 0-4, and emergency hospital visits for cardiac arrest with successful resuscitation (ICD-10 codes: I46.0); the increased risks of cardiac arrest were OR 1.161 (95% CI 1.014-1.329), and OR 1.177 (95% CI 1.013-1.368), respectively, per 10 μg/m³ increase of PM_{10}, as shown in Table B, Supplementary data. A positive association was observed for exposure to $PM_{2.5}$ at lag 3, and lag 4, and the increased risk of cardiac arrest with successful resuscitation; the increased risk was OR 1.090 (95% CI 1.008-1.178), and OR 1.101 (95% CI 1.006-1.204), per 10 μg/m³ increase of $PM_{2.5}$, respectively, as shown in Table B, Supplementary data. A positive association was observed for exposure to PM_{10} at lag 2, and the increased risk of cardiac arrest without indication of successful resuscitation (ICD-10 codes: I46, I46.1, and I46.9); the increased risk was OR 1.079 (95% CI 1.008-1.155), as shown in Table B, Supplementary data.

When we applied the multivariate model to the stratification of whether the cardiac arrests were indicated with successful resuscitation (ICD-10 code I46.0) or not (ICD-10 code I46, I46.1, and I46.9) and the association with daily pollutant exposure, a similar pattern emerges to that of the single pollutants analyses, shown in Table 4; however, the OR were somewhat higher and were observed at more lags and pollutants. A positive association was observed between exposure to PM_{10} and emergency hospital visits for cardiac arrest with successful resuscitation (ICD-10 codes: I46.0); the increased risks of cardiac arrest were OR 1.104 (95% CI 1.002-1.216) at lag 2, OR 1.153 (95% CI 1.021-1.301) at lag 0-2, OR 1.202 (95% CI 1.039-1.392) at lag 0-3, and OR 1.209 (95% CI 1.027-1.422) at lag 0-4, per 10 μg/m³ increase of PM_{10}, as shown in Table 4.

Table 4 Number of visits (n), odds ratios (OR) and 95% confidence intervals (CI) for the daily emergency hospital visits for cardiac arrest with successful resuscitation(ICD-10 code: I46.0) and other cardiac arrest categories grouped together (ICD-10 codes I46, I46.1 and I46.9) in Reykjavik capital area associated with 10 μg/m³ increase in NO_2, PM_{10}, $PM_{2.5}$, SO_2, and H_2S, adjusted for each pollutant, temperature and relative humidity, at lag 0 to lag 4, lag 0-1, lag 0-2, lag 0-3, and lag 0-4.

		NO_2		PM_{10}		$PM_{2,5}$		SO_2		H_2S	
Categories/Visits (n)	**Lag**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
I46.0 (194)	0	0.988	0.856-1.139	1.057	0.967-1.156	0.983	0.875-1.105	1.386	0.758-2.534	1.008	0.735-1.383
	1	1.012	0.881-1.163	1.053	0.982-1.129	0.999	0.894-1.115	0.845	0.471-1.515	1.055	0.707-1.577
	2	0.953	0.826-1.100	1.104	1.002-1.216	1.037	0.957-1.125	1.078	0.893-1.301	1.177	0.797-1.737
	3	1.072	0.937-1.227	1.035	0.941-1.138	1.088	1.001-1.182	0.995	0.910-1.089	1.141	0.794-1.642
	4	1.194	1.023-1.393	1.040	0.936-1.157	1.104	1.006-1.211	0.292	0.084-1.010	1.313	0.847-2.036
	0-1	0.992	0.832-1.183	1.083	0.985-1.190	0.987	0.870-1.121	1.167	0.932-1.462	1.050	0.663-1.664
	0-2	0.952	0.774-1.171	1.153	1.021-1.301	1.017	0.899-1.150	1.196	0.941-1.520	1.203	0.680-2.129
	0-3	0.986	0.781-1.246	1.202	1.039-1.392	1.058	0.936-1.197	1.120	0.879-1.426	1.323	0.693-2.527
	0-4	1.047	0.818-1.340	1.209	1.027-1.422	1.093	0.957-1.248	1.015	0.785-1.314	1.421	0.702-2.877
I46, I46.1, I46.9 (259)	0	0.983	0.875-1.105	0.991	0.909-1.081	0.992	0.921-1.068	1.055	0.964-1.155	1.327	1.012-1.739
	1	0.998	0.882-1.130	1.024	0.940-1.116	0.991	0.923-1.065	0.996	0.876-1.132	1.055	0.778-1.430
	2	0.985	0.869-1.116	1.090	1.013-1.173	0.945	0.861-1.036	0.987	0.914-1.067	1.123	0.843-1.497
	3	1.041	0.923-1.176	1.027	0.968-1.089	0.960	0.876-1.052	0.993	0.829-1.190	1.191	0.943-1.505
	4	1.082	0.975-1.201	1.030	0.945-1.121	1.012	0.929-1.102	1.056	0.968-1.152	0.781	0.564-1.082
	0-1	0.972	0.835-1.130	1.011	0.908-1.126	0.987	0.908-1.072	1.051	0.927-1.190	1.312	0.928-1.856
	0-2	0.958	0.803-1.142	1.093	0.976-1.223	0.968	0.879-1.066	1.030	0.895-1.185	1.386	0.922-2.084
	0-3	0.968	0.796-1.177	1.108	0.982-1.250	0.951	0.852-1.062	1.033	0.869-1.227	1.485	0.984-2.240
	0-4	1.019	0.830-1.252	1.126	0.983-1.290	0.963	0.852-1.087	1.079	0.905-1.286	1.283	0.813-2.027

A positive association was observed between exposure to $PM_{2.5}$ and the increased risk of cardiac arrest with successful resuscitation; the increased risk was OR 1.088 (95% CI 1.001-1.182) at lag 3, and OR 1.104 (95% CI 1.006-1.21) at lag 4, per 10 μg/m³ increase of $PM_{2.5}$, as shown in Table 4. A positive association was observed for exposure to NO_2 and the increased risk of cardiac arrest with successful resuscitation; the increased risk was OR 1.194 (95% CI 1.023-1.393) at lag 4, as shown in Table 4. A positive association was observed between exposure to PM_{10} and the increased risk of cardiac arrest without indication of successful resuscitation (ICD-10 codes: I46, I46.1, and I46.9); the increased risk was OR 1.090 (95% CI 1.013-1.173) at lag 2, as shown in Table 4. In Figure 2, OR and 95% CI of cardiac arrest per 10 μg/m³ increase of PM_{10} concentrations in multi-pollutant models are shown at lag 0 to lag 4 when stratified on season and whether there is an indication of successful resuscitation or not.

In the sensitive analysis of the association between daily exposure to PM_{10} and emergency hospital visits for cardiac arrest (ICD-10 code I46), when restricting the calculation to emergency department visits only (353 visits), the results did not change substantially: in the unstratified analysis, the increased risk of cardiac arrest was OR 1.099 (95% CI 1.028-1.175) at lag 2 per 10 μg/m³ increase of PM_{10}.

Discussion

Our study examined the association between ambient air pollution and emergency hospitalization and emergency department visits where the primary discharge diagnosis was cardiac arrest (ICD-10 code I46). To our knowledge, that single outcome has not been used in previous studies of a similar type. The main results of this study were the association between increased PM_{10} and cardiac arrest at lag 2, lag 0-2, lag 0-3, and lag 0-4. The effects seemed high in most subcategories, in both seasons, and among those who were successfully resuscitated.

Cardiac arrest is a life-threatening event. The decimal following the code I46 indicates whether the patients were successfully resuscitated or not. Patients categorised as I46 comprise those who have survived and those who have died, and in the present study these are in nearly equal proportion. The associations between pollutants and mortality and hospital admission are commonly analysed separately (8). The primary discharge diagnosis cardiac arrest (ICD-10 code I46) has in previous studies been included within all CVD, or large subgroups such as cardiac dysrhythmias, and the endpoint closest to this entity may be out-of-hospital cardiac arrest (OHCA). However, there is a substantial difference between patients with the diagnosis cardiac arrest (ICD-10 code I46) at hospitals and persons included in studies on OHCA. OHCA has often been the subject of studies on association with air pollutants. In a review of 67 studies on OHCA (16), OHCA was associated with high mortality, with a global average survival rate of 7%. The definition of OHCA is: 1) the cardiovascular collapse has occurred outside a hospital, and 2) the event has elicited a resuscitation attempt. Neither of these conditions is required for cardiac arrest according to ICD-10 code I46, when this diagnosis is used at hospitals or emergency departments. Some studies have shown that the risks of OHCA were associated with a short-term increase in exposure to particulate matter, sometimes $PM_{2.5}$, or ultrafine particulate matter (17-20), and sometimes PM_{10} (21), with various associations with O_3, other caseous pollutants, and high temperature. In these OHCA studies (17-21) no difference is made between those who survive the event and those who do not survive. In the previously mentioned UK study (8) on the association between air pollution and hospital admission for different cardiovascular events, exposure to NO_2 was significant, while in the same publication some of the mortality outcomes were associated with exposure to $PM_{2.5}$ but not to NO_2 (8), indicating the possibility of different pathogenetic pathways for the outcomes, as has been discussed briefly in the case of

NO_2 (4), and in the comprehensive review of the causal role of particulate material (2). The category cardiac arrest in the ICD-10 coding system represents a small group compared to other CVD diagnoses and seems to be concealed within the larger summary group of cardiac arrhythmias (10) or omitted from the analysis (8). In this respect, our recent study on the same dataset is not an exception: increased risk of cardiac arrhythmias (ICD-10 codes I44 to I50) was associated with an increase in NO_2 exposure (7), a finding that hides the association between cardiac arrest (ICD-10 code I46) and exposure to PM_{10} as demonstrated in the present study.

Among the strengths of this study is that it is population-based, as the hospital and emergency department data were obtained from the only emergency health care institution, the LUH, serving the population in the catchment area of the Reykjavik capital. The design of the study is also a strength, as the bidirectional time-stratified case-crossover approach virtually excludes confounding of individual characteristics and the matching adjusted for weekly pattern and time trends. Another strength of the study is its use of the encrypted identification number of each patient in the Register of hospital-treated patients, which ensures the correct counting and identification of the cases and their admissions. Furthermore, it is noteworthy that visits of the cases receiving the primary discharge diagnosis cardiac arrest (453 cases) were evenly distributed over the study period (4383 days), so the distribution diminished the risk of overlapping the sets of case and control days.

That said, there are few limitations. First, the concentration of the pollutants derived from one monitoring station in the Reykjavik capital area, and not from individual exposure measurements. The results from these measurements did, however, correlate well with measurements from another monitoring station located in the capital area during three years of the study period. Another limitation is that only the primary discharge diagnosis was included in the study, meaning that the cases may have underlying diseases that could modify the result.

Furthermore, the quality of the routine discharge diagnosis at the LUH has not been investigated in a separate study for accuracy or reliability, which is a weakness our study shares with the many studies based on hospital records. The primary discharge diagnosis of cardiac arrest (ICD-10 code I46) set at emergency admission to the hospital and emergency department does not indicate whether the causes were cardiac- or trauma related, and there may be doubt as to where the patient developed the cardiac arrest, i.e., whether the event initially occurred outside or inside the hospital. The study population consisted of patients aged 18 years and older, which limits the generalisability of the results to those under 18.

The present study concentrates on traffic related pollutants; however, emissions from the volcanic eruptions occurring in Iceland during the study period may have confounded the results. The Eyjafjallajökull eruption in 2010 was found to have minor health effect on the local population, but not the population in the Reykjavik capital area (22). The Holuhraun eruption in 2014 to 2015 emitted a massive amount of SO_2 and mature volcanic plume, and the exposure to these was associated with an increase in the dispensing of asthma medication and an increase in health care utilisation for respiratory diseases in the Reykjavik capital area during four months in the year 2014 (23,24). The present study was not designed to catch the possible effect of these emissions on the cardiovascular health of the population of the Reykjavik capital area, and its role remains unknown with that respect.

We made several stratifications to explore the possible association between air pollutants and emergency hospital visits for cardiac arrest in this study. Because of this, some concerns may emerge about multiple comparisons; however, this has been dealt with in the literature (25).

Conclusions

This study was, to our knowledge, the first to utilise the new endpoint of cardiac arrest (ICD-10 code I46). This outcome has in previous epidemiological studies been included in larger groups of CVDs, and its special status may have been overshadowed by the more common diagnosis of CVDs. Our results indicate a positive association between short-term increase in PM_{10} and emergency hospital visits for cardiac arrest in the Reykjavik capital area, known for having low levels of traffic-related pollution. The effects were found in most subgroups, and were highest among the elderly, and in the winter season, and among those who were successfully resuscitated. Future ecological studies of this type should perhaps concentrate more on precisely defined endpoints; however, doing so will not replace the obvious lack of exact individual exposure measurements for each of the cases.

List of abbreviations

µm	Micrometre
AF	Atrial fibrillation
CI	Confidence interval
CVD	Cardiovascular diseases
ED	Emergency department
GRE	Air quality measurement station located at Grensasvegur-Miklabraut intersection in Reykjavik
H_2S	Hydrogen sulphide
ICD-10	International Classification of Diseases 10th edition
IHD	Ischemic heart disease
km	Kilometre
LUH	Landspitali University Hospital
NO_2	Nitrogen dioxide
OR	Odds ratio
PM_{10}	Particulate matter less than 10 µm in aerodynamic diameter
$PM_{2.5}$	Particulate matter less than 2.5 µm in aerodynamic diameter
RH	Relative humidity
SAGA	Register of Hospital-treated Patients in Iceland
SO_2	Sulphur dioxide
yr	Year

Ethical approval and consent to participate

The study was approved by the National Bioethics Committee (ref. no. VSNb2018120011/03.01), the Data Protection Authority (ref. no. 10-050), and the Scientific Committee of LUH.

Availability of data and materials

The hospital data contain sensitive individual-level information which is not publicly available. It can be made available to researchers after obtaining approval of a formal application to the National Bioethics Committee and the Scientific Committee of LUH. The dataset of air pollution used and analysed during the current study are available from the corresponding author on reasonable request.

Competing interest

The authors declare that they have no competing interests.

Funding

The study had no external funding.

Authors' contribution

SH, RGF, VR designed the study; SH, RGF, BTE, VR planned the analysis; SH, GG, VR collected the data; SH, RGF, BTE analysed the data; VR wrote the first draft; SH, RGF, BTE, OSG, GG, VR read the manuscript, interpreted the conclusion, and agreed on the final version.

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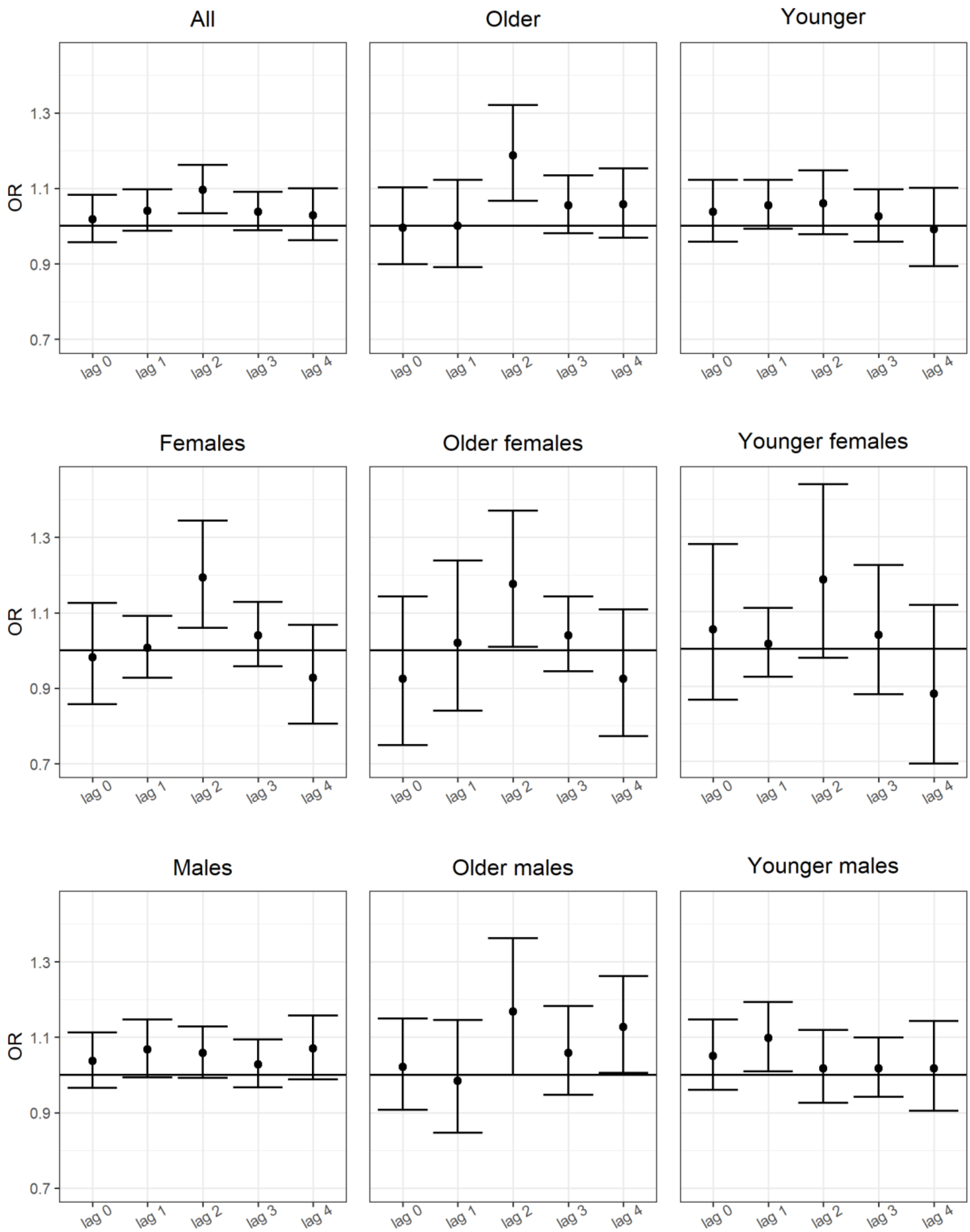

Figure 1. The odds ratio (OR) and bars showing 95% confidence intervals of cardiac arrest (ICD-10 code I46) per 10 µg/m^3 increase in PM_{10} concentrations in multiple-pollutant models at lag 0 to lag 4 for unstratified material and different strata.

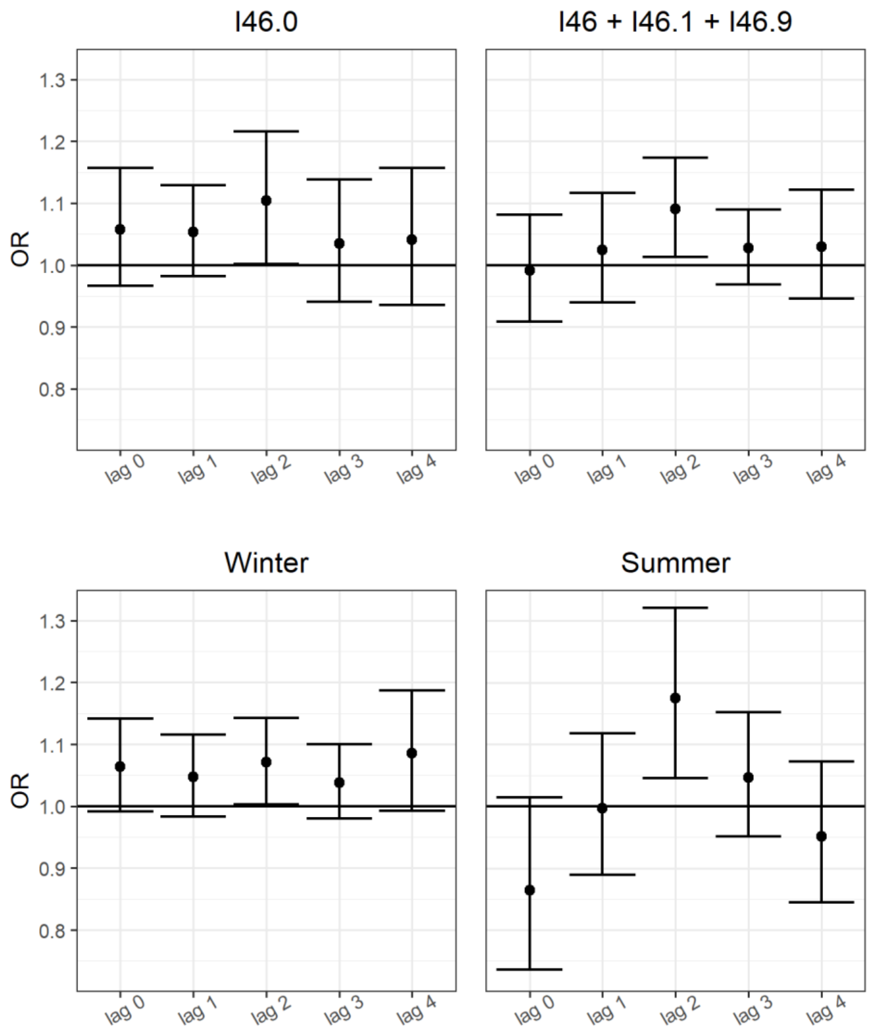

Figure 2. The odds ratio (OR) and bars showing 95% confidence intervals of cardiac arrest with successful resuscitation (ICD-10 code: I46.0) and other cardiac arrest categories grouped together (ICD-10 codes I46, I46.1 and I46.9), as well as cardiac arrest (ICD-10 code: I46) stratified to winter and summer, per 10 µg/m^3 increase in PM_{10} concentrations in multiple-pollutant models at lag 0 to lag 4.

Table A Number of visits (n), odds ratios (OR) and 95% confidence intervals (CI) for the daily emergency hospital visits for cardiac arrest (ICD-10 code: I46) in Reykjavik capital area associated with 10 µg/m³ increase in NO_2, PM_{10}, $PM_{2.5}$, SO_2, and H_2S, in single pollutant models, unstratified and stratified by gender, age, and season, at lag 0 to lag 4, lag 0-1, and lag 0-2.

		NO_2		PM_{10}		$PM_{2.5}$		SO_2		H_2S	
Categories/Visits (n)	**Lag**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
All (453)	0	1.028	0.948-1.115	1.020	0.961-1.081	0.994	0.934-1.058	1.085	1.003-1.173	1.199	0.990-1.451
	1	1.012	0.933-1.098	1.037	0.985-1.091	0.993	0.936-1.054	0.985	0.876-1.107	1.044	0.827-1.317
	2	0.986	0.907-1.071	1.077	1.020-1.137	0.997	0.940-1.058	1.005	0.941-1.073	1.047	0.848-1.294
	3	1.062	0.981-1.151	1.032	0.984-1.081	1.024	0.970-1.081	1.001	0.925-1.082	1.195	0.993-1.439
	4	1.081	1.002-1.166	1.036	0.974-1.103	1.051	0.989-1.116	1.007	0.947-1.072	0.969	0.764-1.228
	0-1	1.030	0.933-1.137	1.045	0.977-1.116	0.992	0.926-1.062	1.082	0.970-1.207	1.207	0.934-1.560
	0-2	1.017	0.908-1.139	1.097	1.016-1.184	0.992	0.921-1.069	1.076	0.950-1.219	1.228	0.907-1.663
Females (125)	0	1.215	1.033-1.429	1.002	0.891-1.126	0.906	0.765-1.073	0.683	0.166-2.800	1.341	0.874-2.058
	1	1.052	0.902-1.228	1.028	0.953-1.109	0.905	0.772-1.060	0.782	0.276-2.211	1.052	0.719-1.540
	2	1.002	0.858-1.171	1.175	1.058-1.304	0.972	0.856-1.104	0.292	0.066-1.287	0.769	0.470-1.260
	3	1.042	0.893-1.215	1.042	0.963-1.128	0.992	0.867-1.134	0.387	0.105-1.431	1.094	0.733-1.631
	4	1.153	1.002-1.327	0.955	0.843-1.081	1.027	0.901-1.171	0.689	0.254-1.870	1.072	0.695-1.653
	0-1	1.222	0.993-1.503	1.033	0.921-1.160	0.875	0.726-1.056	0.655	0.158-2.710	1.243	0.774-1.996
	0-2	1.175	0.937-1.474	1.130	0.990-1.289	0.898	0.748-1.078	0.375	0.073-1.923	1.064	0.603-1.880
Males (328)	0	0.974	0.886-1.071	1.026	0.958-1.098	1.015	0.949-1.086	1.086	1.004-1.176	1.167	0.943-1.444
	1	0.997	0.906-1.098	1.044	0.975-1.118	1.013	0.951-1.079	0.988	0.879-1.110	1.039	0.775-1.393
	2	0.979	0.887-1.081	1.043	0.981-1.108	1.005	0.940-1.074	1.008	0.945-1.075	1.144	0.902-1.450
	3	1.070	0.975-1.175	1.026	0.967-1.088	1.031	0.972-1.093	1.005	0.931-1.084	1.226	0.991-1.516
	4	1.053	0.962-1.152	1.075	0.998-1.157	1.057	0.988-1.132	1.009	0.949-1.073	0.930	0.700-1.236
	0-1	0.979	0.873-1.098	1.050	0.968-1.140	1.017	0.946-1.094	1.085	0.972-1.212	1.192	0.878-1.618
	0-2	0.969	0.849-1.106	1.080	0.983-1.188	1.016	0.937-1.102	1.084	0.955-1.230	1.304	0.910-1.867
Older ≥71 (192)	0	1.063	0.938-1.204	0.988	0.898-1.087	1.039	0.941-1.148	1.091	0.970-1.228	1.162	0.880-1.534
	1	1.005	0.884-1.142	0.997	0.894-1.113	1.000	0.910-1.100	0.973	0.834-1.135	1.078	0.784-1.483
	2	1.094	0.963-1.241	1.149	1.043-1.266	1.026	0.939-1.121	1.009	0.924-1.103	1.153	0.870-1.528
	3	1.042	0.919-1.182	1.044	0.973-1.120	1.026	0.928-1.135	0.886	0.621-1.264	1.263	0.974-1.638
	4	1.048	0.934-1.175	1.053	0.971-1.143	1.020	0.935-1.112	0.999	0.898-1.112	0.898	0.634-1.271
	0-1	1.047	0.902-1.216	0.988	0.870-1.121	1.024	0.917-1.142	1.062	0.918-1.229	1.190	0.829-1.707
	0-2	1.100	0.927-1.306	1.111	0.979-1.261	1.032	0.920-1.158	1.060	0.904-1.244	1.293	0.853-1.959
Younger <71 (261)	0	1.005	0.903-1.117	1.041	0.966-1.121	0.969	0.893-1.051	1.079	0.973-1.198	1.234	0.948-1.605
	1	1.018	0.915-1.131	1.049	0.989-1.112	0.989	0.916-1.067	1.002	0.841-1.196	1.007	0.718-1.414
	2	0.911	0.814-1.021	1.033	0.959-1.112	0.976	0.900-1.059	1.000	0.906-1.103	0.932	0.674-1.289
	3	1.077	0.971-1.194	1.022	0.958-1.089	1.023	0.960-1.091	1.072	0.943-1.219	1.120	0.847-1.481
	4	1.108	1.002-1.226	1.014	0.921-1.117	1.085	0.995-1.183	1.012	0.938-1.092	1.042	0.751-1.447
	0-1	1.017	0.892-1.160	1.068	0.988-1.155	0.974	0.892-1.063	1.106	0.939-1.302	1.225	0.849-1.766
	0-2	0.958	0.824-1.115	1.089	0.988-1.199	0.967	0.878-1.066	1.100	0.901-1.344	1.161	0.746-1.806
Older females (57)	0	1.312	1.025-1.678	0.973	0.811-1.167	0.740	0.494-1.110	0.980	0.126-7.599	0.987	0.523-1.863
	1	0.963	0.749-1.238	1.073	0.907-1.270	0.934	0.775-1.126	0.599	0.073-4.883	1.054	0.632-1.757
	2	1.126	0.887-1.429	1.195	1.039-1.375	0.999	0.858-1.162	0.149	0.010-2.192	0.453	0.181-1.136
	3	1.013	0.810-1.267	1.042	0.949-1.143	0.968	0.780-1.202	0.777	0.151-4.010	1.071	0.651-1.759
	4	1.157	0.960-1.394	0.975	0.842-1.128	0.937	0.765-1.148	4.023	0.561-28.834	0.871	0.449-1.688
	0-1	1.211	0.890-1.648	1.036	0.833-1.288	0.852	0.636-1.141	0.701	0.064-7.649	1.035	0.539-1.989
	0-2	1.256	0.898-1.755	1.178	0.956-1.451	0.919	0.722-1.171	0.302	0.019-4.803	0.758	0.323-1.778

Table A Continued

Younger females (68)	0	1.141	0.914-1.424	1.024	0.879-1.194	0.956	0.808-1.130	0.521	0.077-3.537	1.909	0.996-3.659
	1	1.114	0.915-1.355	1.018	0.934-1.109	0.855	0.652-1.123	0.855	0.265-2.751	1.050	0.593-1.858
	2	0.916	0.740-1.134	1.149	0.981-1.345	0.926	0.744-1.153	0.428	0.075-2.441	1.045	0.599-1.825
	3	1.069	0.864-1.323	1.042	0.897-1.211	1.008	0.847-1.199	0.168	0.019-1.457	1.139	0.579-2.240
	4	1.149	0.928-1.422	0.916	0.736-1.141	1.167	0.937-1.455	0.323	0.066-1.582	1.296	0.720-2.334
	0-1	1.231	0.930-1.629	1.032	0.901-1.183	0.894	0.700-1.141	0.632	0.107-3.717	1.593	0.767-3.308
	0-2	1.110	0.815-1.511	1.098	0.924-1.304	0.875	0.668-1.146	0.424	0.056-3.220	1.485	0.677-3.254
Older males (135)	0	0.982	0.844-1.142	0.994	0.888-1.112	1.079	0.972-1.199	1.092	0.970-1.229	1.212	0.888-1.654
	1	1.020	0.879-1.183	0.952	0.823-1.100	1.031	0.925-1.149	0.976	0.837-1.137	1.094	0.727-1.646
	2	1.081	0.931-1.256	1.109	0.981-1.254	1.041	0.933-1.163	1.013	0.928-1.105	1.380	0.995-1.913
	3	1.056	0.907-1.230	1.047	0.942-1.165	1.046	0.932-1.173	0.891	0.629-1.264	1.360	0.971-1.903
	4	0.984	0.847-1.144	1.105	0.994-1.229	1.045	0.949-1.152	0.995	0.892-1.110	0.908	0.604-1.366
	0-1	1.001	0.841-1.191	0.965	0.825-1.128	1.073	0.951-1.210	1.064	0.919-1.232	1.272	0.822-1.968
	0-2	1.049	0.857-1.282	1.073	0.914-1.260	1.083	0.946-1.241	1.066	0.907-1.251	1.590	0.972-2.600
Younger males (193)	0	0.969	0.858-1.094	1.046	0.961-1.139	0.973	0.886-1.069	1.082	0.974-1.202	1.129	0.841-1.514
	1	0.982	0.865-1.114	1.078	0.996-1.166	1.004	0.929-1.085	1.006	0.844-1.200	0.986	0.648-1.500
	2	0.910	0.796-1.039	0.999	0.913-1.093	0.985	0.904-1.074	1.003	0.912-1.104	0.884	0.595-1.314
	3	1.079	0.958-1.215	1.017	0.947-1.092	1.026	0.958-1.098	1.084	0.948-1.239	1.116	0.821-1.517
	4	1.097	0.978-1.230	1.045	0.938-1.163	1.070	0.972-1.177	1.016	0.944-1.094	0.952	0.640-1.417
	0-1	0.963	0.827-1.121	1.088	0.989-1.197	0.989	0.901-1.085	1.112	0.942-1.312	1.123	0.734-1.718
	0-2	0.915	0.768-1.091	1.084	0.965-1.219	0.984	0.888-1.091	1.113	0.907-1.365	1.041	0.610-1.778
Winter (236)	0	1.059	0.968-1.157	1.060	0.994-1.131	0.973	0.898-1.053	1.103	0.980-1.240	1.237	1.002-1.527
	1	1.008	0.921-1.104	1.055	0.994-1.119	0.979	0.904-1.060	0.981	0.806-1.195	0.962	0.732-1.264
	2	1.010	0.922-1.106	1.056	0.995-1.120	0.984	0.905-1.071	0.979	0.892-1.073	1.052	0.833-1.327
	3	1.094	1.003-1.193	1.028	0.974-1.085	0.996	0.926-1.070	1.000	0.923-1.084	1.230	1.009-1.500
	4	1.090	1.004-1.184	1.084	1.002-1.174	1.082	0.991-1.181	0.986	0.911-1.066	1.006	0.777-1.301
	0-1	1.049	0.941-1.170	1.088	1.009-1.173	0.970	0.887-1.060	1.098	0.951-1.268	1.191	0.891-1.593
	0-2	1.049	0.926-1.187	1.126	1.030-1.231	0.968	0.877-1.068	1.048	0.888-1.238	1.221	0.866-1.723
Summer (217)	0	0.910	0.754-1.098	0.873	0.748-1.018	1.038	0.936-1.150	1.067	0.958-1.189	1.038	0.654-1.649
	1	1.031	0.854-1.244	0.980	0.875-1.098	1.014	0.925-1.110	0.987	0.853-1.141	1.361	0.849-2.182
	2	0.873	0.711-1.073	1.154	1.032-1.292	1.010	0.930-1.098	1.144	0.927-1.412	1.028	0.620-1.704
	3	0.920	0.756-1.120	1.043	0.950-1.146	1.074	0.984-1.172	1.006	0.705-1.436	0.951	0.538-1.679
	4	1.033	0.853-1.251	0.962	0.859-1.078	1.024	0.940-1.115	1.322	0.892-1.959	0.815	0.460-1.442
	0-1	0.953	0.759-1.196	0.906	0.773-1.062	1.031	0.924-1.149	1.061	0.905-1.244	1.265	0.730-2.192
	0-2	0.883	0.673-1.158	1.013	0.864-1.187	1.028	0.919-1.151	1.114	0.911-1.363	1.253	0.661-2.376

Table B Number of visits (n), odds ratios (OR) and 95% confidence intervals (CI) for the daily emergency hospital visits for cardiac arrest with successful resuscitation(ICD-10 code: I46.0) and other cardiac arrest categories grouped together (ICD-10 codes I46, I46.1, and I46.9) in Reykjavik capital area associated with 10 µg/m³ increase in NO_2, PM_{10}, $PM_{2.5}$, SO_2, and H_2S, in single pollutant models, at lag 0 to lag 4, lag 0-1, lag 0-2, lag 0-3, and lag 0-4.

		NO_2		PM_{10}		$PM_{2.5}$		SO_2		H_2S	
Categories/Visits (n)	**Lag**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
I46.0 (194)	0	1.037	0.913-1.177	1.056	0.970-1.149	0.984	0.877-1.104	1.374	0.762-2.477	1.043	0.773-1.406
	1	1.043	0.923-1.178	1.045	0.978-1.117	0.998	0.895-1.114	0.865	0.534-1.401	1.070	0.729-1.571
	2	0.995	0.874-1.132	1.073	0.980-1.176	1.043	0.963-1.129	1.053	0.878-1.264	1.098	0.754-1.601
	3	1.085	0.967-1.218	1.052	0.967-1.144	1.090	1.008-1.178	0.999	0.914-1.092	1.193	0.890-1.655
	4	1.108	0.978-1.256	1.036	0.938-1.144	1.101	1.006-1.204	0.570	0.222-1.460	1.372	0.916-2.053
	0-1	1.060	0.911-1.234	1.076	0.983-1.177	0.990	0.875-1.119	1.153	0.924-1.439	1.087	0.711-1.661
	0-2	1.049	0.881-1.249	1.118	0.998-1.252	1.023	0.909-1.152	1.157	0.911-1.471	1.158	0.684-1.960
	0-3	0.102	0.911-1.335	1.161	1.014-1.329	1.071	0.952-1.204	1.110	0.866-1.423	1.313	0.736-2.342
	0-4	1.147	0.940-1.401	1.177	1.013-1.368	1.103	0.973-1.250	1.013	0.788-1.302	1.504	0.801-2.825
I46, I46.1, I46.9 (259)	0	1.023	0.921-1.136	0.990	0.912-1.074	0.999	0.928-1.075	1.061	0.971-1.160	1.338	1.034-1.730
	1	0.989	0.885-1.104	1.025	0.945-1.111	0.991	0.923-1.064	1.003	0.886-1.135	1.029	0.768-1.379
	2	0.979	0.878-1.092	1.079	1.008-1.155	0.952	0.870-1.042	0.997	0.925-1.075	1.025	0.793-1.326
	3	1.042	0.933-1.164	1.023	0.967-1.083	0.957	0.874-1.048	1.007	0.851-1.191	1.196	0.954-1.498
	4	1.066	0.969-1.172	1.037	0.957-1.122	1.012	0.930-1.101	1.061	0.973-1.156	0.813	0.595-1.112
	0-1	1.009	0.886-1.150	1.010	0.914-1.116	0.993	0.915-1.078	1.058	0.936-1.197	1.285	0.931-1.773
	0-2	0.995	0.858-1.154	1.079	0.972-1.198	0.974	0.885-1.072	1.047	0.910-1.206	1.265	0.874-1.832
	0-3	1.018	0.865-1.199	1.089	0.975-1.218	0.958	0.859-1.069	1.054	0.888-1.251	1.350	0.931-1.957
	0-4	1.058	0.892-1.254	1.110	0.979-1.259	0.962	0.853-1.086	1.090	0.919-1.294	1.225	0.817-1.836

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *case-control studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	2, 6-9
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls	6-7
		(*b*) For matched studies, give matching criteria and the number of controls per case	9
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*6, 7 ,9*
Bias	9	Describe any efforts to address potential sources of bias	9-10
Study size	10	Explain how the study size was arrived at	7-9
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	9
		(*c*) Explain how missing data were addressed	8
		(*d*) If applicable, explain how matching of cases and controls was addressed	9
		(*e*) Describe any sensitivity analyses	9-10
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10, table 1
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10, tables 1, 2
		(b) Indicate number of participants with missing data for each variable of interest	NA
Outcome data	15*	Report numbers in each exposure category, or summary measures of exposure	tables 3 , 4
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11-13
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	11-13
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	13
Discussion			
Key results	18	Summarise key results with reference to study objectives	14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14-15, 16-17
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	19

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Ambient air pollution and emergency department visits and hospitalisation for cardiac arrest: a population-based case-crossover study in Reykjavik, Iceland

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Abstract

Objectives To assess the association between traffic-related ambient air pollution and emergency hospital visits for cardiac arrest.

Design Case-crossover design was used with a lag time to 4 days.

Setting The Reykjavik capital area and the study population were the inhabitants 18 years and older identified by encrypted personal identification number and zip codes.

Participants and exposure Cases were those with emergency visits to Landspitali University Hospital during the period 2006 to 2017 and who were given the primary discharge diagnosis of cardiac arrest according to The International Classification of Diseases 10th edition (ICD-10), code I46. The pollutants were NO_2, PM_{10}, $PM_{2.5}$, and SO_2 with adjustment for H_2S, temperature and relative humidity.

Main outcome measure Odds ratio (OR) and 95% confidence intervals (CI) per 10 $\mu g/m^3$ increase in concentration of pollutants.

Results: The 24-h mean NO_2 was 20.7 $\mu g/m^3$, mean PM_{10} was 20.5 $\mu g/m^3$, mean $PM_{2.5}$ was 12.5 $\mu g/m^3$, and mean SO_2 was 2.5 $\mu g/m^3$. PM_{10} level was positively associated with the number of emergency hospital visits (n=453) for cardiac arrest. Each 10 $\mu g/m^3$ increase in PM_{10} was associated with increased risk of cardiac arrest (ICD-10: I46), odds ratio (OR) 1.093 (95%CI 1.033-1.162) on lag 2, OR 1.118 (95%CI 1.031-1.212) on lag 0-2, OR 1.150 (95% CI 1.050-1.261) on lag 0-3, and OR 1.168 (95% CI 1.054-1.295) on lag 0-4. Significant associations were shown between exposure to PM_{10} on lag 2 and on lag 0-2 and increased risk of cardiac arrest in the age, gender, and season strata.

Conclusions: A new endpoint was used for the first time in this study: cardiac arrest (ICD-10 code I46) according to hospital discharge registry. Short-term increase in PM_{10} concentrations

was associated with cardiac arrest. Future ecological studies of this type and their related discussions should perhaps concentrate more on precisely defined endpoints.

Key words Cardiac arrest, urgent hospital visits, successful resuscitation, multivariate models, cardiovascular diseases

Strength and limitations of this study

- The study is population-based, relies on comprehensive population registries, and include information of daily concentrations of the pollutants which cover more than 75% of the days in the study period.
- The methodology allows within-subject comparison while adjusting for various time trends such as seasonality, and day of week.
- The concentration of the pollutants derived from one monitoring station, and not from individual exposure measurements.
- The population is small, and therefore the total number of cases were few, resulting in low statistical power.

Introduction

Epidemiological studies have found increased risk of cardiovascular morbidity and mortality in association with particulate matter (PM) in air pollution (1,2), and the overall evidence is considered to support the existence of a causal relationship between PM exposure and cardiovascular morbidity, primarily due to fine particles (2). Both short-term and long-term PM air pollution contribute to cardiovascular morbidity and mortality (1,2). Urban ambient air pollution is a complex mixture of gases, particles and liquid, and in an attempt to monitor air quality, certain pollutants are traditionally measured. However, adverse cardiovascular health impacts of exposure to a combination of air pollutants are not completely understood at present. A recent multilocation analysis found that a short term increase in NO_2 on the previous day was associated with an increased risk of daily total, cardiovascular, and respiratory mortality (3). In a systemic review and meta-analysis of short-term exposure to NO_2 and ischemic heart diseases, the authors concluded that the relationship was likely causal (4), but uncertainties remained due to possible confounding in the epidemiological studies and lack of evidence from mechanistic studies. Several epidemiological studies have found that NO_2 and PM are associated with cardiovascular diseases (CVD), and the endpoints studied have included not only mortality from CVD (3), but also discharge diagnosis at hospitals and emergency departments for a wide range of CVD, ischemic heart disease, myocardial infraction, and different cardiac dysrhythmias (5-10). In a large US study (9), acute myocardial infarction, and multiple other cardiovascular outcomes, like cardiac dysrhythmia and heart failure were found to be associated with particulate air pollution; however, in that analysis it was only possible to consider potential confounding by ozone, not by other pollutants. In a case-crossover study in China, an association was found between particulate matter, NO_2, and carbon monoxide, and number of hospital admissions for cardiac arrhythmia (10). In another case-crossover study in the UK (8), the risk of emergency hospital admissions for CVD, arrhythmias, atrial fibrillation, and heart failure was associated with an increased concentration of NO_2; however, cardiac arrest was not included as an outcome in the study. Cardiac arrest was mentioned in the aforementioned Chinese study (10) but was not analysed separately.

There are several studies on the association of air pollution and out of hospital cardiac arrest (OHCA) (11-15). The risk of OHCA were associated with a short-term increase in exposure to particulate matter, sometimes $PM_{2.5}$, or ultrafine particulate matter (11-14), and sometimes PM_{10} (15), with various associations with O_3, other caseous pollutants, and high temperature. The collection of cases in the OHCA studies use special registers as a source, regarding Utstein definition (16,17) with the original purpose to provide a structured framework to evaluate emergency medical service. The main criteria in the definition of the cases in the OHCA studies are: 1) the cardiovascular collapse has occurred outside a hospital, and 2) the event has elicited a resuscitation attempt. Neither of these conditions is required for the physician given diagnosis of cardiac arrest according to the International Classification of Diseases 10th edition (ICD-10) code I46 registered as discharge diagnosis at hospitals or emergency departments.

The comprehensive population and health registries in Iceland make this an optimal setting to study the association between relatively low daily exposure to air pollution, and different heart related conditions (7,18,19). The aim of the present study was to explore the association between traffic-related pollutants, NO_2, PM_{10}, $PM_{2.5}$, and SO_2 in the Reykjavik capital area and urgent hospital and emergency department visits for cardiac arrest, ICD-10 code I46, as the primary discharge diagnosis, and to simultaneously adjust for meteorological variables and geothermal-originated pollutants.

Methods

Study base

The Reykjavik capital area is in the southwestern part of Iceland. Traffic emission is the main source of air pollution in the city. Other sources of air pollution include two geothermal power plants: Hellisheidi, located 26 km east-southeast of the city, and Nesjavellir, located 33 km east of the city. Ambient H_2S emission originates from the plants. Reykjavik's capital area spreads over 247.5 km^2 and in 2017 the inhabitants numbered 217,000, equivalent to approximately two-thirds of the total Icelandic population (20). The study base included the residents of the Reykjavik capital area, which consists of seven municipalities (Gardabaer, Hafnarfjordur, Kjosarhreppur, Kopavogur, Mosfellsbaer, Reykjavik, and Seltjarnarnes) identified by 24 zip codes.

Health data

Hospital discharge data were obtained from January 1 2006 to December 31 2017 from computerised records in SAGA (Register of hospital-treated patients in Iceland) for certain heart diseases; the procedures have been described in a previous publication (7). The study included adult inhabitants (≥18 years) of the Reykjavik capital area, identified by zip code. We analysed data on urgent visits to the emergency department and urgent admissions to in-patient wards of Landspitali University Hospital (LUH). The study was confined to new admissions, meaning that no visits by appointment were included. LUH is operated by the Icelandic government and is the only acute care hospital serving the population of the Reykjavik capital area, making this study population-based. In Iceland, the national health insurance scheme is covered by taxes and is available to all residents. For ambulatory visits, patients pay a small fee that amounts to approximately 10 to 15 US dollars, but seniors are exempt from payment. Admission to the hospital ward is free of charge. Every inhabitant of Iceland receives a personal identification number at birth (or at immigration), and the

identification numbers are widely used in Icelandic society and population registries, including the SAGA register. We received the identification numbers in encrypted form, which enabled us to identify repeated visits to LUH. Readmissions to LUH within 10 days with the same ICD-10 primary discharge diagnosis were excluded. From the SAGA register we received the following details: admission date, encrypted identification number, unique number of the admission, age, gender, primary discharge diagnosis for certain codes according to the International Classification of Diseases 10th edition (ICD-10). In this study, both admission to the emergency department and formal admission to the hospital are included, so there is no requirement that a patient stayed overnight. The diagnoses are registered at discharge from the hospital, transfer to another hospital, and death in the hospital. In a previous study (7), the outcomes were heart diseases ICD-10 codes: I20-I25, I44-I50, ischemic heart diseases ICD-10 codes: I20-I25, cardiac arrhythmias and heart failure ICD-10 codes: I44-I50, and atrial fibrillation ICD-10 I48 (7). In the present study, the outcome analysed was cardiac arrest ICD-10 code I46. Emergency department visits and urgent hospital admissions were combined and are called emergency hospital visits.

Air pollutants and meteorological data

Information on pollution was obtained from Grensas monitor station (GRE), operated by the governmental institution Environment Agency of Iceland. GRE is in the centre of the Reykjavik capital area near one of the busiest road intersections in the city. Other stations in the city were not permanently located or were not continuously monitoring throughout the study period and were therefore not used in the study. However, to test whether GRE was reflective of the total capital area, Pearson's correlation was calculated for GRE measurements and measurements from another station located in Dalsmari, Kopavogur municipality, for the period 2014-2017. Results of Pearson's correlation coefficients between

these two measurement stations were for PM_{10} 0.44, for NO_2 0.78, for SO_2 0.98, and for H_2S 0.84. PM2.5 was not measured in Dalsmari.

Pollutants measured at GRE were NO_2, particulate matter with aerodynamic diameter less than 10 µm (PM_{10}), particulate matter with aerodynamic diameter less than 2.5 µm ($PM_{2.5}$), sulphur dioxide (SO_2), and hydrogen sulphide (H_2S), all measured in µg/m^3. The meteorological data was obtained from the governmental institution Icelandic Meteorological Office and included temperature (°C) and relative humidity (RH). PM_{10} and $PM_{2.5}$ were measured with an Andersen EMS IR Thermo (model FH62 I-R), NO_2 with Horiba device (model APNA 360E), and SO_2 and H_2S with the Horiba model APOA 360E. Every 6-12 months the devices are calibrated. Exposure data included 12 years or 4,383 days. Daily averages (midnight to midnight the following day) were calculated from hourly concentrations if at least 75% of one-hour data existed. Missing daily averages for NO_2, PM_{10}, $PM_{2.5}$, SO_2, and H_2S were 383 days (8.7%), 165 days (3.8%), 923 days (21.1%), 200 days (4.6%), and 284 days (6.5%), respectively. Data gaps were seen and can be attributed to inactive measurement devices due to unknown causes, with the exception of 52 days of missing H_2S measurements at the beginning of the study period, as H_2S measurements at GRE started at the end of February 2006. For temperature and RH, 6 days (0.1%) and 6 days (0.1%) were missing, respectively. Minor gaps in the curves were fitted by linear interpolation.

Descriptive statistics were calculated and showed as daily concentration levels in µg/m³ of the pollutants, as well as Spearman's correlation coefficient between pollutants and meteorological factors.

Patient and public involvement

No patient involved.

Analysis

Short-term associations between daily exposure to air pollutants and emergent hospital visits for cardiac arrest (ICD-10 code I46) were assessed using bidirectional time-stratified case-crossover design. The study period was divided into monthly strata, and exposure during case periods (24h) was compared to exposure during control periods, which were matched as the same weekdays within the same month (3-4 control periods per case period) (21,22). The matches control for measured or unmeasured personal confounding characteristics that do not vary over the relatively short time, such as gender, age, and genetic factors. We did several calculations: single pollutant models were calculated in conditional logistic regression, multivariate models containing all traffic-related pollutants, H_2S, and the meteorological variables. Separate analyses were done for subgroups according to gender, age (≥71 and < 71 years), gender, and age combined, winter (November 1st to April 30th), and summer (May 1st to October 31st). It was possible to divide the diagnostic category I46 according to decimals into cardiac arrest with successful resuscitation (I46.0) and other categories without indication of successful resuscitation (I46, I46.1, and I46.9). These two subcategories were also analysed separately as there are indication that the latter category concern mortality. The risk estimates were expressed as odds ratio (OR), and 95% confidence intervals (CI) were calculated for every 10 $\mu g/m^3$ increase of pollutants (24h concentrations).

Different lag structures were applied. Single-day lag structure (lag 0 to lag 4), and multiple-day lag structure (lag 0-1, lag 0-2, lag 0-3, and lag 0-4, moving average of pollutants concentration) were employed in the analyses to explore the temporal association between pollutants and cardiac arrest. The results of the multivariate models with all lag structures are presented in the article, and other results are shown as Supplementary data.

Although readmissions within 10 days with the same primary discharge diagnosis were excluded, it is still possible that some patients first went to the emergency department and were subsequently admitted that same day to in-hospital wards where they might have received a different diagnosis than they were given at the emergency department. To test whether this could distort the main result of the association between increased pollutant concentration and the emergency hospital visits, a sensitivity analysis was done, in which data was restricted to emergency department visits only.

Statistical analysis was done with R version 4.0.3 (https://www.r-project.org/). Statistical tests used in this study were all two-tailed and we considered results statistically significant for $p < 0.05$.

The study was approved by the National Bioethics Committee (ref. no. VSNb2018120011/03.01), the Data Protection Authority (ref. no. 10-050), and the Scientific Committee of LUH.

Results

The basic characteristics of cardiac arrest according to subcategories are shown in Table 1. The total number of visits with primary discharge diagnosis cardiac arrest (ICD-10 code I46) was 453, and repeated visits were extremely rare. The distribution of the 453 visits was even over the 4383-day study period. One visit per day was most common, but there were several days with up to two visits, which was the highest number of visits per day; thus, most days were without visits with cardiac arrest. The median age at the time of visits was 71 years. Descriptive statistics and Spearman's correlation coefficients of traffic-related pollutants, H_2S, and meteorological variables are presented in Table 2. Missing daily average was highest for PM_{10} but did not exceed 25% of the days of the study period. The concentrations of PM_{10} and $PM_{2.5}$ were correlated, particulate matter did not correlate with the gaseous pollutants, and correlations among gaseous pollutants were moderate.

In the single pollutant analyses, positive associations were observed for exposure to PM_{10} at lag 2 and lag 0-2, and unstratified emergency hospital visits for cardiac arrest (ICD-10 codes: I46); the increased risks of cardiac arrest were OR 1.096 (95% CI 1.033-1.162) and OR 1.118 (95% CI 1.031-1.212), respectively, per 10 μg/m³ increase of PM_{10}, as shown in Table A, Supplementary data. A positive association was observed between exposure to NO_2 at lag 4 and the increased risk of cardiac arrest; the increased risk was OR 1.081 (95% CI 1.002-1.166) per 10 μg/m³ increase of NO_2, as shown in Table A, Supplementary data.

In examining the daily lag exposure to PM_{10} and unstratified emergency hospital visits for cardiac arrest, positive associations were observed in the multivariate model; the increased risks of cardiac arrest were OR 1.096 (95% CI 1.033-1.162) for lag 2, OR 1.118 (95% CI 1.031-1.212) for lag 0-2, OR 1.150 (95% CI 1.050-1.261) for lag 0-3, and OR 1.168 (95% CI 1.054-1.295) for lag 0-4 per 10 μg/m³ increase of PM_{10} (Table 3). Significant associations were shown for exposure to NO_2 at lag 4 and for SO_2 at lag 0, and unstratified emergency

hospital visits for cardiac arrest; the increased risks were OR 1.096 (95% CI 1.008-1.192) and OR 1.084 (95% CI 1.002-1.173) per 10 µg/m³ increase of NO_2 and SO_2, respectively (Table 3).

In the multivariate model significant associations were shown between exposure to PM_{10} at lag 2 and at lag 0-2, lag 0-3, and lag 0-4, and increased risks of cardiac arrest (ICD-10 code I46), in the age, gender, age and gender combined, and season strata, i.e., in all the strata except in the stratum of young females (Table 3)(The season strata are shown in Table C, Supplementary data). In Figure 1, OR and 95% CI of cardiac arrest per 10 µg/m³ increase of PM_{10} concentrations in multi-pollutant models are shown at lag 0 to lag 4 for different strata and unstratified.

In the single pollutant analyses, positive associations were observed for exposure to PM_{10} at lag 0-3, and lag 0-4, and emergency hospital visits for cardiac arrest with successful resuscitation (ICD-10 codes: I46.0); the increased risks of cardiac arrest were OR 1.161 (95% CI 1.014-1.329), and OR 1.177 (95% CI 1.013-1.368), respectively, per 10 µg/m³ increase of PM_{10}, as shown in Table B, Supplementary data. A positive association was observed for exposure to $PM_{2.5}$ at lag 3, and lag 4, and the increased risk of cardiac arrest with successful resuscitation; the increased risk was OR 1.090 (95% CI 1.008-1.178), and OR 1.101 (95% CI 1.006-1.204), per 10 µg/m³ increase of $PM_{2.5}$, respectively, as shown in Table B, Supplementary data. A positive association was observed for exposure to PM_{10} at lag 2, and the increased risk of cardiac arrest without indication of successful resuscitation (ICD-10 codes: I46, I46.1, and I46.9); the increased risk was OR 1.079 (95% CI 1.008-1.155), as shown in Table B, Supplementary data.

In the multivariate model a positive association was observed between exposure to PM_{10} and emergency hospital visits for cardiac arrest with successful resuscitation (ICD-10 code: I46.0); the increased risks of cardiac arrest were OR 1.104 (95% CI 1.002-1.216) at lag 2, OR

1.153 (95% CI 1.021-1.301) at lag 0-2, OR 1.202 (95% CI 1.039-1.392) at lag 0-3, and OR 1.209 (95% CI 1.027-1.422) at lag 0-4, per 10 µg/m³ increase of PM_{10}, as shown in Table 4. A positive association was observed between exposure to $PM_{2.5}$ and the increased risk of cardiac arrest with successful resuscitation; the increased risk was OR 1.088 (95% CI 1.001-1.182) at lag 3, and OR 1.104 (95% CI 1.006-1.21) at lag 4, per 10 µg/m³ increase of $PM_{2.5}$, as shown in Table 4. A positive association was observed between exposure to PM_{10} and the increased risk of cardiac arrest without indication of successful resuscitation (ICD-10 codes: I46, I46.1, and I46.9); the increased risk was OR 1.090 (95% CI 1.013-1.173) at lag 2, as shown in Table 4. In Figure 2, OR and 95% CI of cardiac arrest per 10 µg/m³ increase of PM_{10} concentrations in multi-pollutant models are shown at lag 0 to lag 4 when stratified on season and whether there is an indication of successful resuscitation or not.

In the sensitive analysis of the association between daily exposure to PM_{10} and emergency hospital visits for cardiac arrest (ICD-10 code I46), when restricting the calculation to emergency department visits only (353 visits), the results did not change substantially: in the unstratified analysis, the increased risk of cardiac arrest was OR 1.099 (95% CI 1.028-1.175) at lag 2 per 10 µg/m³ increase of PM_{10}.

Discussion

Our study examined the association between ambient air pollution and emergency hospitalization and emergency department visits where the primary discharge diagnosis was cardiac arrest (ICD-10 code I46). To our knowledge, that single outcome has not been used in previous studies of a similar type. The main results of this study were the association between increased PM_{10} and cardiac arrest at lag 2, lag 0-2, lag 0-3, and lag 0-4, so the 24 hours concentrations of PM_{10} seem to be clearly separated from the event registered at the hospital and happened before the admittance. The effects seemed high in most subcategories, in both seasons, and among those who were successfully resuscitated.

Cardiac arrest is a life-threatening event and may be the most serious outcome of CVD. The decimal following the code I46 indicates whether the patients were successfully resuscitated or not. Patients categorised as I46 comprise those who have survived and those who have died, and in the present study these are in nearly equal proportion. The associations between pollutants and mortality and hospital admission are commonly analysed separately (8). The primary discharge diagnosis cardiac arrest (ICD-10 code I46) has in previous studies been included within all CVD, or large subgroups such as cardiac dysrhythmias, and the endpoint closest to this entity may be OHCA. However, there is a l difference between patients with the diagnosis cardiac arrest (ICD-10 code I46) at hospitals and persons included in studies on OHCA. OHCA has often been the subject of studies on association with air pollutants. In a review of 67 studies on OHCA (23), OHCA was associated with high mortality, with a global average survival rate of 7%, but in the present study 42.8% of the registered cases with the ICD-10 code I46, cardiac arrest, were successfully resuscitated, a considerable difference in survival rates. The definition of OHCA is: 1) the cardiovascular collapse has occurred outside a hospital, and 2) the event has elicited a resuscitation attempt, and these conditions is not required for cardiac arrest according to ICD-10 code I46, when this diagnosis is used at hospitals or emergency departments. In addition, the Utstein definition recommends registration of several time points and intervals important for the research and quality assurance related to the resuscitation, but such time elements are not required in the hospital discharge registries based on the ICD-10. Some studies have shown that the risks of OHCA were associated with a short-term increase in exposure to particulate matter, sometimes $PM_{2.5}$, or ultrafine particulate matter (11-14), and sometimes PM_{10} (15), with various associations with O_3, other caseous pollutants, and high temperature. An OHCA study conducted in Stockholm, Sweden demonstrated a significant exposure-response association between OHCA risk and O_3, but no association for $PM_{2,5}$ or NO_2, (24), while another OHCA study in Lombardy, Italy, showed, with different methodology, that the concentrations of all the pollutants in the study were significantly higher in days with high incidence of OHCA except for O_3 (25). In these OHCA studies (11-15,24,25) no difference is made between those who survive the event and those who do not survive. In the previously mentioned UK study (8) on the association between air pollution and hospital admission for different cardiovascular events, exposure to NO_2 was significant, while in the same publication some of the mortality outcomes were associated with exposure to $PM_{2.5}$ but not to NO_2 (8), indicating the possibility of different pathogenetic pathways for the outcomes, as has been discussed briefly in the case of NO_2 (4), and in the comprehensive review of the causal role of particulate material (2). The category cardiac arrest in the ICD-10 coding system represents a small group compared to other CVD diagnoses and seems to be concealed within the larger summary group of cardiac arrhythmias (10) or omitted from the analysis (8). In this respect, our recent study on the same dataset is not an exception: increased risk of cardiac arrhythmias (ICD-10 codes I44 to I50) was associated with an increase in NO_2 exposure (7), a finding that hides the association between cardiac arrest (ICD-10 code I46) and exposure to PM_{10} as demonstrated in the present study.

Among the strengths of this study is that it is population-based, as the hospital and emergency department data were obtained from the only emergency health care institution, the LUH, serving the population in the catchment area of the Reykjavik capital. The design of the study is also a strength, as the bidirectional time-stratified case-crossover approach virtually excludes confounding of individual characteristics and the matching adjusted for weekly pattern and time trends. Another strength of the study is its use of the encrypted identification number of each patient in the Register of hospital-treated patients, which ensures the correct counting and identification of the cases and their admissions. Furthermore, it is noteworthy that visits of the cases receiving the primary discharge diagnosis cardiac arrest (453 cases) were evenly distributed over the study period (4383 days), so the distribution diminished the risk of overlapping the sets of case and control days.

That said, there are few limitations. First, the concentration of the pollutants derived from one monitoring station in the Reykjavik capital area, and not from individual exposure measurements. The results from these measurements did, however, correlate well with measurements from another monitoring station located in the capital area during three years of the study period. Another limitation is that only the primary discharge diagnosis was included in the study, meaning that the cases may have underlying diseases that could modify the result.

Furthermore, the quality of the routine discharge diagnosis at the LUH has not been investigated in a separate study for accuracy or reliability, which is a weakness our study shares with the many studies based on hospital records. The primary discharge diagnosis of cardiac arrest (ICD-10 code I46) set at emergency admission to the hospital and emergency department does not indicate whether the causes were cardiac- or trauma related, and there may be doubt as to where the patient developed the cardiac arrest, i.e., whether the event

initially occurred outside or inside the hospital. The study population consisted of patients aged 18 years and older, which limits the generalisability of the results to those under 18.

The present study concentrates on traffic related pollutants; however, emissions from the volcanic eruptions occurring in Iceland during the study period may have confounded the results. The Eyjafjallajökull eruption in 2010 was found to have minor health effect on the local population, but not the population in the Reykjavik capital area (26). The Holuhraun eruption in 2014 to 2015 emitted a massive amount of SO_2 and mature volcanic plume, and the exposure to these was associated with an increase in the dispensing of asthma medication and an increase in health care utilisation for respiratory diseases in the Reykjavik capital area during four months in the year 2014 (27,28). The present study was not designed to catch the possible effect of these emissions on the cardiovascular health of the population of the Reykjavik capital area, and its role remains unknown with that respect.

We made several stratifications to explore the possible association between air pollutants and emergency hospital visits for cardiac arrest in this study. Because of this, some concerns may emerge about multiple comparisons; however, this has been dealt with in the literature (29).

Conclusions

This study was, to our knowledge, the first to utilise the new endpoint of cardiac arrest (ICD-10 code I46) according to the hospital discharge registry. This outcome has in previous epidemiological studies been included in larger groups of CVDs, and its special status may have been overshadowed by the more common diagnosis of CVDs. Our results indicate a positive association between short-term increase in PM_{10} and emergency hospital visits for cardiac arrest in the Reykjavik capital area, known for having low levels of traffic-related pollution. The effects were found in most subgroups, and were highest among the elderly, and in the winter season, and among those who were successfully resuscitated. Future ecological studies of this type should perhaps concentrate more on precisely defined endpoints; however, doing so will not replace the obvious lack of exact individual exposure measurements for each of the cases.

List of abbreviations

µm	Micrometre
AF	Atrial fibrillation
CI	Confidence interval
CVD	Cardiovascular diseases
ED	Emergency department
GRE	Air quality measurement station located at Grensasvegur-Miklabraut intersection in Reykjavik
H_2S	Hydrogen sulphide
ICD-10	International Classification of Diseases 10th edition
IHD	Ischemic heart disease
km	Kilometre
LUH	Landspitali University Hospital
NO_2	Nitrogen dioxide
OR	Odds ratio
PM_{10}	Particulate matter less than 10 µm in aerodynamic diameter
$PM_{2.5}$	Particulate matter less than 2.5 µm in aerodynamic diameter
RH	Relative humidity
SAGA	Register of Hospital-treated Patients in Iceland
SO_2	Sulphur dioxide
yr	Year

Ethical approval and consent to participate

The study was approved by the National Bioethics Committee (ref. no. VSNb2018120011/03.01), the Data Protection Authority (ref. no. 10-050), and the Scientific Committee of LUH.

Availability of data and materials

The hospital data contain sensitive individual-level information which is not publicly available. It can be made available to researchers after obtaining approval of a formal application to the National Bioethics Committee and the Scientific Committee of LUH. The dataset of air pollution used and analysed during the current study are available from the corresponding author on reasonable request.

Competing interest

The authors declare that they have no competing interests.

Funding

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Authors' contribution

SH, RGF, VR designed the study; SH, RGF, BTE, VR planned the analysis; SH, GG, VR collected the data; SH, RGF, BTE analysed the data; VR wrote the first draft; SH, RGF, BTE, OSG, GG, VR read the manuscript, interpreted the conclusion, and agreed on the final version.

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Table 1 Descriptive statistics of emergency hospital visits for cardiac arrest (ICD-10: I46) to Landspitali University Hospital, according to subgroups, January 1st, 2006 to December 31st, 2017.

Discharge diagnosis (ICD-10)	No. of visits (%)	No. of patients
Cardiac arrest (I46)	453 (100)	447
Females	125 (28)	123
Males	328 (72)	324
Older (≥71yr)	192 (42)	190
Younger (<71yr)	261 (58)	257
Older females	57	56
Younger females	68	67
Older males	135	134
Younger males	193	190
Winter	236 (52)	236
Summer	217 (48)	214
Cardiac arrest (I46)	5	5
Cardiac arrest with successful resuscitation (I46.0)	194	192
Sudden cardiac death, so described (I46.1)	23	23
Cardiac arrest, unspecified (I46.9)	231	229
Emergency department visits, only	313	312

Winter: November 1st to April 30th.
Summer: May 1st to October 31st.

Table 2. Descriptive statistics of 24-hour concentration levels (µg/m³) of pollutants and meteorological data in the Reykjavík capital area during the study period, 2006-2017, and Spearman's correlation between daily concentrations of pollutants

	PM_{10}	$PM_{2,5}$	NO_2	SO_2	H_2S	TEMP (°C)	RH (%)
24-h availability n (%)	4218 (96.2)	3460 (78.9)	4000 (91.3)	4183 (95.4)	4099 (93.5)	4377 (99.9)	4377 (99.9)
Mean (SD)	20.5 (19.7)	12.5 (21.8)	20.7 (15.0)	2.51 (13.8)	2.98 (5.2)	5.5 (4.9)	74.9 (10.6)
Summer* mean (SD)	17.4 (14.9)	10.8 (16.2)	16.2 (9.9)	2.48 (14.1)	2.08 (3.1)	9.1 (3.2)	74.6 (9.8)
Winter** mean (SD)	23.6 (23.2)	14.2 (26.1)	25.3 (17.6)	2.54 (13.5)	3.90 (6.6)	1.9 (3.4)	75.1 (11.3)
Range	2.4-381	0-423	0-119	0-409	0-96	-10.5-17.7	37-97
Median	15.1	7.0	16.6	1.1	1.2	5.6	77.0
Interquartile range	11.6	8.2	15.8	1.2	2.7	7.9	15.0
Spearman's correlation							
PM_{10}	1.00						
$PM_{2,5}$	0.76	1.00					
NO_2	0.09	0.00	1.00				
SO_2	0.08	0.08	0.50	1.00			
H_2S	-0.08	-0.11	0.31	0.39	1.00		
TEMP (°C)	-0.16	-0.08	-0.44	-0.17	-0.23	1.00	
RH (%)	-0.30	-0.56	0.09	-0.03	0.04	0.12	1.00

* May 1st to October 31st.
** November 1st to April 30th.
SD: standard deviation; H_2S: hydrogen sulphide; NO_2: nitrogen dioxide; PM_{10}: particulate matter ≤10µm in diameter; $PM_{2.5}$: particulate matter ≤2.5µm in diameter; RH: relative humidity; SO_2: sulphur dioxide; TEMP: temperature.

Table 3 Number of visits (n), odds ratios (OR) and 95% confidence intervals (CI) for the daily emergency hospital visits for cardiac arrest (ICD-10 code: I46) in Reykjavik capital area associated with 10 μg/m³ increase in NO_2, PM_{10}, $PM_{2.5}$, SO_2 and H_2S, adjusted for each pollutant, temperature and relative humidity, unstratified and stratified by gender, age, and season, at lag 0 to lag 4, lag 0-1, lag 0-2, lag 0-3, and lag 0-4.

		NO_2		PM_{10}		$PM_{2.5}$		SO_2		H_2S	
Categories/Visits (n)	Lag	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
All (453)	0	0.989	0.904-1.083	1.017	0.957-1.082	0.990	0.930-1.053	1.084	1.002-1.173	1.187	0.972-1.449
	1	1.003	0.916-1.099	1.041	0.987-1.097	0.994	0.936-1.055	0.983	0.873-1.107	1.056	0.829-1.344
	2	0.972	0.885-1.068	1.096	1.033-1.162	0.993	0.935-1.054	0.999	0.935-1.067	1.118	0.892-1.402
	3	1.052	0.963-1.150	1.038	0.988-1.090	1.022	0.968-1.079	0.991	0.916-1.074	1.191	0.980-1.449
	4	1.096	1.008-1.192	1.029	0.963-1.099	1.054	0.992-1.020	1.003	0.940-1.070	0.915	0.714-1.171
	0-1	0.982	0.876-1.101	1.049	0.978-1.124	0.988	0.922-1.059	1.084	0.971-1.211	1.214	0.923-1.597
	0-2	0.957	0.838-1.093	1.118	1.031-1.212	0.989	0.918-1.066	1.070	0.943-1.212	1.301	0.936-1.810
	0-3	0.981	0.846-1.137	1.150	1.050-1.261	0.998	0.921-1.081	1.061	0.922-1.221	1.423	1.007-2.011
	0-4	1.039	0.889-1.215	1.168	1.054-1.295	1.019	0.934-1.112	1.057	0.588-1.928	1.313	0.897-1.921
Females (125)	0	1.223	1.011-1.481	0.982	0.857-1.126	0.900	0.763-1.063	0.256	0.039-1.665	1.270	0.797-2.024
	1	1.029	0.860-1.231	1.006	0.928-1.091	0.895	0.764-1.049	0.740	0.237-2.316	1.036	0.688-1.561
	2	1.009	0.839-1.212	1.193	1.059-1.344	0.958	0.843-1.089	0.284	0.051-1.582	0.902	0.531-1.532
	3	1.029	0.860-1.232	1.040	0.959-1.129	0.983	0.857-1.127	0.286	0.064-1.287	1.156	0.759-1.760
	4	1.175	0.997-1.384	0.927	0.806-1.068	1.036	0.909-1.181	0.495	0.154-1.591	1.006	0.639-1.583
	0-1	1.214	0.948-1.555	1.016	0.893-1.157	0.867	0.724-1.038	0.404	0.076-2.132	1.184	0.698-2.008
	0-2	1.174	0.893-1.543	1.110	0.958-1.287	0.889	0.740-1.068	0.236	0.034-1.664	1.172	0.605-2.273
	0-3	1.177	0.867-1.597	1.162	0.982-1.374	0.901	0.748-1.085	0.134	0.015-1.166	1.350	0.665-2.740
	0-4	1.278	0.939-1.740	1.133	0.935-1.372	0.914	0.754-1.108	0.118	0.012-1.125	1.276	0.593-2.743
Males (328)	0	0.935	0.841-1.041	1.036	0.966-1.112	1.012	0.946-1.083	1.093	1.009-1.184	1.218	0.972-1.526
	1	0.989	0.888-1.101	1.067	0.993-1.147	1.013	0.951-1.079	0.992	0.882-1.116	1.094	0.805-1.486
	2	0.982	0.878-1.098	1.058	0.992-1.128	0.997	0.932-1.067	1.000	0.937-1.067	1.242	0.962-1.604
	3	1.087	0.978-1.208	1.028	0.966-1.094	1.031	0.972-1.094	0.996	0.921-1.077	1.238	0.988-1.550
	4	1.079	0.975-1.194	1.070	0.988-1.158	1.066	0.995-1.142	1.007	0.944-1.073	0.895	0.666-1.203
	0-1	0.924	0.808-1.057	1.077	0.989-1.174	1.015	0.943-1.092	1.102	0.984-1.233	1.302	0.936-1.810
	0-2	0.902	0.771-1.055	1.120	1.015-1.237	1.012	0.933-1.099	1.088	0.958-1.235	1.503	1.013-2.229
	0-3	0.942	0.793-1.120	1.139	1.020-1.273	1.022	0.935-1.117	1.086	0.940-1.255	1.628	1.078-2.457
	0-4	0.985	0.818-1.186	1.174	1.037-1.328	1.047	0.949-1.154	1.087	0.937-1.260	1.499	0.955-2.351
Older ≥71 (192)	0	1.035	0.901-1.188	0.995	0.898-1.102	1.038	0.940-1.147	1.089	0.967-1.226	1.096	0.815-1.475
	1	0.985	0.853-1.137	1.000	0.891-1.122	1.001	0.910-1.101	0.974	0.833-1.140	1.065	0.763-1.485
	2	1.099	0.953-1.267	1.186	1.066-1.320	1.034	0.942-1.135	0.989	0.901-1.085	1.210	0.883-1.659
	3	1.030	0.894-1.188	1.054	0.981-1.134	1.032	0.931-1.144	0.823	0.513-1.318	1.315	0.992-1.744
	4	1.071	0.943-1.216	1.057	0.969-1.152	1.024	0.938-1.117	1.000	0.895-1.117	0.887	0.618-1.272
	0-1	0.999	0.839-1.190	0.997	0.872-1.141	1.019	0.912-1.138	1.065	0.917-1.236	1.154	0.776-1.717
	0-2	1.055	0.862-1.291	1.151	1.005-1.319	1.036	0.921-1.164	1.045	0.891-1.226	1.266	0.796-2.014
	0-3	1.060	0.848-1.325	1.197	1.033-1.386	1.038	0.910-1.185	0.993	0.824-1.197	1.460	0.906-2.354
	0-4	1.087	0.860-1.374	1.243	1.056-1.463	1.056	0.915-1.218	0.998	0.824-1.208	1.371	0.808-2.324
Younger <71 (261)	0	0.961	0.853-1.083	1.037	0.958-1.122	0.962	0.885-1.045	1.083	0.975-1.204	1.242	0.941-1.640
	1	1.019	0.905-1.148	1.055	0.993-1.122	0.989	0.916-1.068	0.998	0.833-1.195	1.031	0.724-1.469
	2	0.892	0.784-1.014	1.059	0.978-1.147	0.965	0.889-1.048	1.005	0.914-1.105	1.019	0.723-1.438
	3	1.076	0.957-1.209	1.025	0.958-1.097	1.020	0.956-1.088	1.069	0.941-1.214	1.094	0.814-1.470
	4	1.123	1.002-1.259	0.992	0.893-1.101	1.083	0.991-1.183	1.007	0.930-1.091	0.926	0.653-1.312
	0-1	0.973	0.837-1.132	1.075	0.990-1.166	0.970	0.887-1.060	1.108	0.941-1.306	1.236	0.840-1.818
	0-2	0.890	0.744-1.065	1.117	1.007-1.238	0.959	0.869-1.058	1.108	0.907-1.353	1.286	0.799-2.069
	0-3	0.930	0.761-1.136	1.136	1.009-1.279	0.975	0.881-1.080	1.149	0.915-1.445	1.349	0.808-2.253
	0-4	1.162	0.720-1.874	1.133	0.856-1.499	0.951	0.708-1.277	0.047	0.002-1.342	2.088	0.734-5.942

Table 3 Continued

Older females (57)	0	1.394	1.036-1.876	0.926	0.750-1.142	0.772	0.523-1.140	0.420	0.024-7.404	0.847	0.418-1.713
	1	0.970	0.717-1.312	1.020	0.840-1.238	0.927	0.767-1.119	0.454	0.045-4.562	1.168	0.676-2.019
	2	1.228	0.926-1.628	1.177	1.010-1.371	0.983	0.840-1.151	0.150	0.008-4.657	0.534	0.182-1.565
	3	1.002	0.778-1.291	1.039	0.945-1.144	0.966	0.781-1.194	0.630	0.101-3.918	1.074	0.633-1.823
	4	1.128	0.908-1.401	0.925	0.772-1.108	0.935	0.761-1.148	3.684	0.414-32.751	0.736	0.351-1.545
	0-1	1.330	0.907-1.950	0.967	0.753-1.242	0.861	0.653-1.136	0.470	0.028-7.870	0.994	0.472-2.093
	0-2	1.435	0.941-2.189	1.105	0.869-1.404	0.933	0.732-1.189	0.195	0.006-6.790	0.777	0.270-2.242
	0-3	1.364	0.879-2.115	1.167	0.916-1.486	0.931	0.726-1.194	0.174	0.006-5.284	0.951	0.338-2.669
	0-4	1.401	0.924-2.124	1.116	0.847-1.469	0.918	0.701-1.201	0.421	0.017-10.137	0.727	0.217-2.434
Younger females (68)	0	1.131	0.873-1.465	1.052	0.864-1.281	0.930	0.776-1.113	0.184	0.017-2.013	2.148	1.038-4.446
	1	1.074	0.853-1.350	1.013	0.926-1.109	0.857	0.649-1.130	0.896	0.250-3.212	0.958	0.509-1.800
	2	0.853	0.661-1.100	1.186	0.976-1.440	0.901	0.714-1.137	0.481	0.072-3.209	1.194	0.638-2.232
	3	1.062	0.815-1.384	1.037	0.879-1.224	0.999	0.834-1.197	0.097	0.007-1.338	1.248	0.608-2.560
	4	1.186	0.910-1.546	0.880	0.693-1.118	1.197	0.964-1.486	0.187	0.023-1.544	1.137	0.603-2.146
	0-1	1.149	0.828-1.595	1.044	0.900-1.211	0.892	0.696-1.142	0.363	0.045-2.893	1.624	0.711-3.711
	0-2	1.001	0.687-1.459	1.124	0.921-1.371	0.866	0.653-1.150	0.277	0.027-2.883	1.763	0.701-4.434
	0-3	1.013	0.652-1.573	1.167	0.910-1.496	0.896	0.674-1.192	0.105	0.006-1.872	2.165	0.764-6.133
	0-4	1.162	0.720-1.874	1.133	0.856-1.499	0.951	0.708-1.277	0.047	0.002-1.342	2.088	0.734-5.942
Older males (135)	0	0.940	0.795-1.111	1.021	0.907-1.150	1.079	0.969-1.202	1.097	0.971-1.240	1.222	0.877-1.703
	1	1.000	0.846-1.183	0.985	0.846-1.145	1.032	0.925-1.151	0.996	0.851-1.164	1.116	0.722-1.725
	2	1.095	0.919-1.305	1.167	1.001-1.362	1.039	0.920-1.172	0.984	0.897-1.079	1.483	1.019-2.159
	3	1.053	0.881-1.258	1.058	0.947-1.182	1.059	0.940-1.192	0.831	0.518-1.334	1.457	1.000-2.121
	4	1.006	0.850-1.191	1.126	1.005-1.262	1.051	0.952-1.161	1.003	0.895-1.123	0.938	0.910-1.440
	0-1	0.920	0.748-1.132	1.010	0.856-1.191	1.067	0.943-1.207	1.090	0.938-1.268	1.381	0.848-2.248
	0-2	0.948	0.745-1.208	1.138	0.959-1.350	1.078	0.937-1.240	1.062	0.906-1.245	1.738	1.000-3.021
	0-3	0.966	0.739-1.263	1.177	0.972-1.424	1.092	0.924-1.289	1.020	0.846-1.230	1.963	1.062-3.628
	0-4	0.949	0.709-1.272	1.280	1.037-1.579	1.125	0.942-1.344	1.033	0.851-1.254	1.907	0.990-3.673
Younger males (193)	0	0.941	0.818-1.081	1.050	0.960-1.147	0.971	0.883-1.067	1.093	0.981-1.217	1.194	0.871-1.637
	1	0.984	0.855-1.134	1.097	1.009-1.193	1.005	0.929-1.087	1.001	0.834-1.203	1.076	0.694-1.668
	2	0.922	0.792-1.074	1.018	0.926-1.118	0.976	0.894-1.066	1.011	0.919-1.113	0.974	0.640-1.484
	3	1.111	0.970-1.272	1.017	0.942-1.099	1.025	0.956-1.098	1.082	0.945-1.238	1.108	0.798-1.538
	4	1.134	0.997-1.291	1.017	0.905-1.143	1.076	0.975-1.188	1.013	0.936-1.096	0.850	0.559-1.292
	0-1	0.932	0.781-1.113	1.110	1.003-1.229	0.989	0.899-1.087	1.123	0.948-1.329	1.208	0.767-1.902
	0-2	0.868	0.704-1.071	1.127	0.995-1.276	0.979	0.882-1.086	1.134	0.919-1.400	1.244	0.697-2.222
	0-3	0.929	0.738-1.169	1.125	0.979-1.293	0.993	0.891-1.107	1.186	0.924-1.522	1.318	0.716-2.426
	0-4	1.020	0.801-1.300	1.123	0.961-1.312	1.017	0.902-1.146	1.185	0.903-1.556	1.173	0.596-2.306

Table 4 Number of visits (n), odds ratios (OR) and 95% confidence intervals (CI) for the daily emergency hospital visits for cardiac arrest with successful resuscitation(ICD-10 code: I46.0) and other cardiac arrest categories grouped together (ICD-10 codes I46, I46.1 and I46.9) in Reykjavik capital area associated with 10 µg/m³ increase in NO_2, PM_{10}, $PM_{2.5}$, SO_2, and H_2S, adjusted for each pollutant, temperature and relative humidity, at lag 0 to lag 4, lag 0-1, lag 0-2, lag 0-3, and lag 0-4.

		NO_2		PM_{10}		$PM_{2,5}$		SO_2		H_2S	
Categories/Visits (n)	**Lag**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
I46.0 (194)	0	0.988	0.856-1.139	1.057	0.967-1.156	0.983	0.875-1.105	1.386	0.758-2.534	1.008	0.735-1.383
	1	1.012	0.881-1.163	1.053	0.982-1.129	0.999	0.894-1.115	0.845	0.471-1.515	1.055	0.707-1.577
	2	0.953	0.826-1.100	1.104	1.002-1.216	1.037	0.957-1.125	1.078	0.893-1.301	1.177	0.797-1.737
	3	1.072	0.937-1.227	1.035	0.941-1.138	1.088	1.001-1.182	0.995	0.910-1.089	1.141	0.794-1.642
	4	1.194	1.023-1.393	1.040	0.936-1.157	1.104	1.006-1.211	0.292	0.084-1.010	1.313	0.847-2.036
	0-1	0.992	0.832-1.183	1.083	0.985-1.190	0.987	0.870-1.121	1.167	0.932-1.462	1.050	0.663-1.664
	0-2	0.952	0.774-1.171	1.153	1.021-1.301	1.017	0.899-1.150	1.196	0.941-1.520	1.203	0.680-2.129
	0-3	0.986	0.781-1.246	1.202	1.039-1.392	1.058	0.936-1.197	1.120	0.879-1.426	1.323	0.693-2.527
	0-4	1.047	0.818-1.340	1.209	1.027-1.422	1.093	0.957-1.248	1.015	0.785-1.314	1.421	0.702-2.877
I46, I46.1, I46.9 (259)	0	0.983	0.875-1.105	0.991	0.909-1.081	0.992	0.921-1.068	1.055	0.964-1.155	1.327	1.012-1.739
	1	0.998	0.882-1.130	1.024	0.940-1.116	0.991	0.923-1.065	0.996	0.876-1.132	1.055	0.778-1.430
	2	0.985	0.869-1.116	1.090	1.013-1.173	0.945	0.861-1.036	0.987	0.914-1.067	1.123	0.843-1.497
	3	1.041	0.923-1.176	1.027	0.968-1.089	0.960	0.876-1.052	0.993	0.829-1.190	1.191	0.943-1.505
	4	1.082	0.975-1.201	1.030	0.945-1.121	1.012	0.929-1.102	1.056	0.968-1.152	0.781	0.564-1.082
	0-1	0.972	0.835-1.130	1.011	0.908-1.126	0.987	0.908-1.072	1.051	0.927-1.190	1.312	0.928-1.856
	0-2	0.958	0.803-1.142	1.093	0.976-1.223	0.968	0.879-1.066	1.030	0.895-1.185	1.386	0.922-2.084
	0-3	0.968	0.796-1.177	1.108	0.982-1.250	0.951	0.852-1.062	1.033	0.869-1.227	1.485	0.984-2.240
	0-4	1.019	0.830-1.252	1.126	0.983-1.290	0.963	0.852-1.087	1.079	0.905-1.286	1.283	0.813-2.027

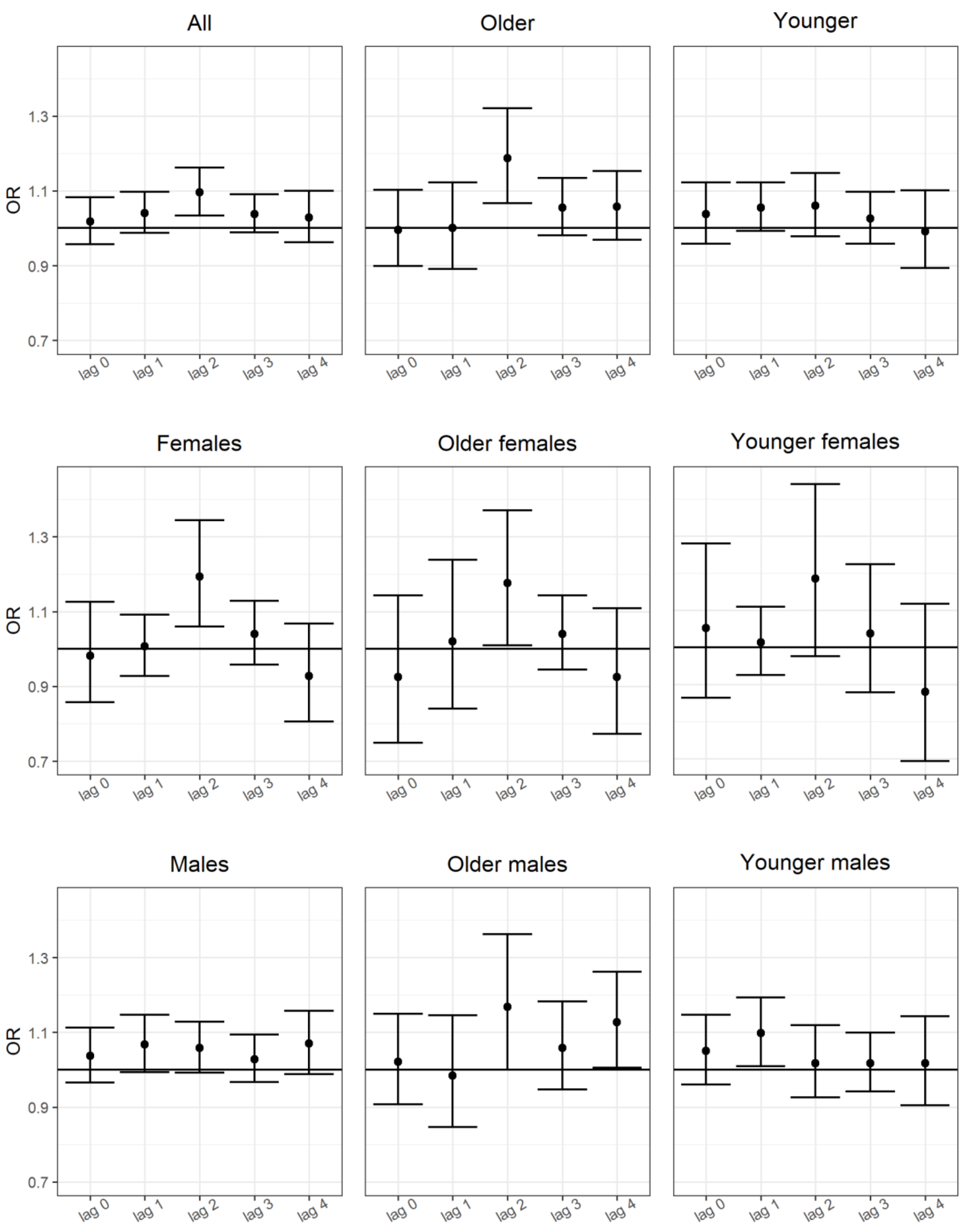

Figure 1. The odds ratio (OR) and bars showing 95% confidence intervals of cardiac arrest (ICD-10 code I46) per 10 µg/m^3 increase in PM_{10} concentrations in multiple-pollutant models at lag 0 to lag 4 for unstratified material and different strata.

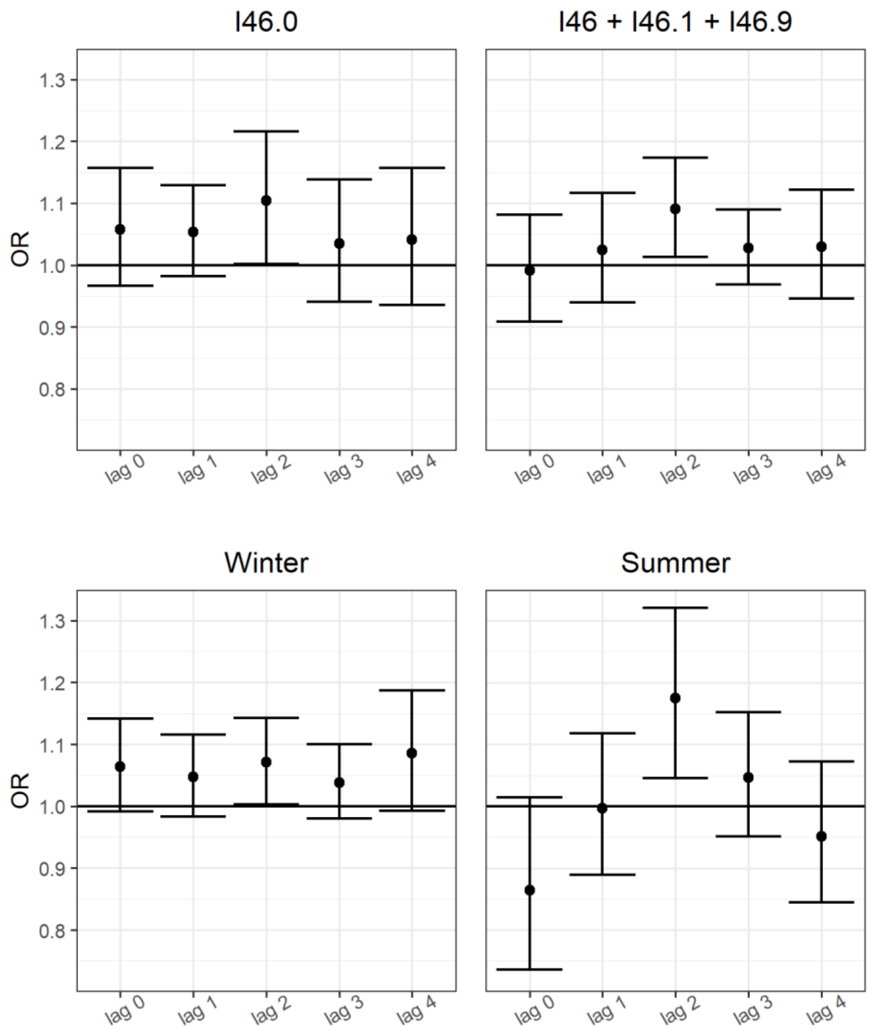

Figure 2. The odds ratio (OR) and bars showing 95% confidence intervals of cardiac arrest with successful resuscitation (ICD-10 code: I46.0) and other cardiac arrest categories grouped together (ICD-10 codes I46, I46.1 and I46.9), as well as cardiac arrest (ICD-10 code: I46) stratified to winter and summer, per 10 µg/m^3 increase in PM_{10} concentrations in multiple-pollutant models at lag 0 to lag 4.

Table A Number of visits (n), odds ratios (OR) and 95% confidence intervals (CI) for the daily emergency hospital visits for cardiac arrest (ICD-10 code: I46) in Reykjavik capital area associated with 10 µg/m³ increase in NO_2, PM_{10}, $PM_{2.5}$, SO_2, and H_2S, in single pollutant models, unstratified and stratified by gender, age, and season, at lag 0 to lag 4, lag 0-1, and lag 0-2.

		NO_2		PM_{10}		$PM_{2.5}$		SO_2		H_2S	
Categories/Visits (n)	**Lag**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
All (453)	0	1.028	0.948-1.115	1.020	0.961-1.081	0.994	0.934-1.058	1.085	1.003-1.173	1.199	0.990-1.451
	1	1.012	0.933-1.098	1.037	0.985-1.091	0.993	0.936-1.054	0.985	0.876-1.107	1.044	0.827-1.317
	2	0.986	0.907-1.071	1.077	1.020-1.137	0.997	0.940-1.058	1.005	0.941-1.073	1.047	0.848-1.294
	3	1.062	0.981-1.151	1.032	0.984-1.081	1.024	0.970-1.081	1.001	0.925-1.082	1.195	0.993-1.439
	4	1.081	1.002-1.166	1.036	0.974-1.103	1.051	0.989-1.116	1.007	0.947-1.072	0.969	0.764-1.228
	0-1	1.030	0.933-1.137	1.045	0.977-1.116	0.992	0.926-1.062	1.082	0.970-1.207	1.207	0.934-1.560
	0-2	1.017	0.908-1.139	1.097	1.016-1.184	0.992	0.921-1.069	1.076	0.950-1.219	1.228	0.907-1.663
Females (125)	0	1.215	1.033-1.429	1.002	0.891-1.126	0.906	0.765-1.073	0.683	0.166-2.800	1.341	0.874-2.058
	1	1.052	0.902-1.228	1.028	0.953-1.109	0.905	0.772-1.060	0.782	0.276-2.211	1.052	0.719-1.540
	2	1.002	0.858-1.171	1.175	1.058-1.304	0.972	0.856-1.104	0.292	0.066-1.287	0.769	0.470-1.260
	3	1.042	0.893-1.215	1.042	0.963-1.128	0.992	0.867-1.134	0.387	0.105-1.431	1.094	0.733-1.631
	4	1.153	1.002-1.327	0.955	0.843-1.081	1.027	0.901-1.171	0.689	0.254-1.870	1.072	0.695-1.653
	0-1	1.222	0.993-1.503	1.033	0.921-1.160	0.875	0.726-1.056	0.655	0.158-2.710	1.243	0.774-1.996
	0-2	1.175	0.937-1.474	1.130	0.990-1.289	0.898	0.748-1.078	0.375	0.073-1.923	1.064	0.603-1.880
Males (328)	0	0.974	0.886-1.071	1.026	0.958-1.098	1.015	0.949-1.086	1.086	1.004-1.176	1.167	0.943-1.444
	1	0.997	0.906-1.098	1.044	0.975-1.118	1.013	0.951-1.079	0.988	0.879-1.110	1.039	0.775-1.393
	2	0.979	0.887-1.081	1.043	0.981-1.108	1.005	0.940-1.074	1.008	0.945-1.075	1.144	0.902-1.450
	3	1.070	0.975-1.175	1.026	0.967-1.088	1.031	0.972-1.093	1.005	0.931-1.084	1.226	0.991-1.516
	4	1.053	0.962-1.152	1.075	0.998-1.157	1.057	0.988-1.132	1.009	0.949-1.073	0.930	0.700-1.236
	0-1	0.979	0.873-1.098	1.050	0.968-1.140	1.017	0.946-1.094	1.085	0.972-1.212	1.192	0.878-1.618
	0-2	0.969	0.849-1.106	1.080	0.983-1.188	1.016	0.937-1.102	1.084	0.955-1.230	1.304	0.910-1.867
Older ≥71 (192)	0	1.063	0.938-1.204	0.988	0.898-1.087	1.039	0.941-1.148	1.091	0.970-1.228	1.162	0.880-1.534
	1	1.005	0.884-1.142	0.997	0.894-1.113	1.000	0.910-1.100	0.973	0.834-1.135	1.078	0.784-1.483
	2	1.094	0.963-1.241	1.149	1.043-1.266	1.026	0.939-1.121	1.009	0.924-1.103	1.153	0.870-1.528
	3	1.042	0.919-1.182	1.044	0.973-1.120	1.026	0.928-1.135	0.886	0.621-1.264	1.263	0.974-1.638
	4	1.048	0.934-1.175	1.053	0.971-1.143	1.020	0.935-1.112	0.999	0.898-1.112	0.898	0.634-1.271
	0-1	1.047	0.902-1.216	0.988	0.870-1.121	1.024	0.917-1.142	1.062	0.918-1.229	1.190	0.829-1.707
	0-2	1.100	0.927-1.306	1.111	0.979-1.261	1.032	0.920-1.158	1.060	0.904-1.244	1.293	0.853-1.959
Younger <71 (261)	0	1.005	0.903-1.117	1.041	0.966-1.121	0.969	0.893-1.051	1.079	0.973-1.198	1.234	0.948-1.605
	1	1.018	0.915-1.131	1.049	0.989-1.112	0.989	0.916-1.067	1.002	0.841-1.196	1.007	0.718-1.414
	2	0.911	0.814-1.021	1.033	0.959-1.112	0.976	0.900-1.059	1.000	0.906-1.103	0.932	0.674-1.289
	3	1.077	0.971-1.194	1.022	0.958-1.089	1.023	0.960-1.091	1.072	0.943-1.219	1.120	0.847-1.481
	4	1.108	1.002-1.226	1.014	0.921-1.117	1.085	0.995-1.183	1.012	0.938-1.092	1.042	0.751-1.447
	0-1	1.017	0.892-1.160	1.068	0.988-1.155	0.974	0.892-1.063	1.106	0.939-1.302	1.225	0.849-1.766
	0-2	0.958	0.824-1.115	1.089	0.988-1.199	0.967	0.878-1.066	1.100	0.901-1.344	1.161	0.746-1.806
Older females (57)	0	1.312	1.025-1.678	0.973	0.811-1.167	0.740	0.494-1.110	0.980	0.126-7.599	0.987	0.523-1.863
	1	0.963	0.749-1.238	1.073	0.907-1.270	0.934	0.775-1.126	0.599	0.073-4.883	1.054	0.632-1.757
	2	1.126	0.887-1.429	1.195	1.039-1.375	0.999	0.858-1.162	0.149	0.010-2.192	0.453	0.181-1.136
	3	1.013	0.810-1.267	1.042	0.949-1.143	0.968	0.780-1.202	0.777	0.151-4.010	1.071	0.651-1.759
	4	1.157	0.960-1.394	0.975	0.842-1.128	0.937	0.765-1.148	4.023	0.561-28.834	0.871	0.449-1.688
	0-1	1.211	0.890-1.648	1.036	0.833-1.288	0.852	0.636-1.141	0.701	0.064-7.649	1.035	0.539-1.989
	0-2	1.256	0.898-1.755	1.178	0.956-1.451	0.919	0.722-1.171	0.302	0.019-4.803	0.758	0.323-1.778

Table A Continued

Younger females (68)	0	1.141	0.914-1.424	1.024	0.879-1.194	0.956	0.808-1.130	0.521	0.077-3.537	1.909	0.996-3.659
	1	1.114	0.915-1.355	1.018	0.934-1.109	0.855	0.652-1.123	0.855	0.265-2.751	1.050	0.593-1.858
	2	0.916	0.740-1.134	1.149	0.981-1.345	0.926	0.744-1.153	0.428	0.075-2.441	1.045	0.599-1.825
	3	1.069	0.864-1.323	1.042	0.897-1.211	1.008	0.847-1.199	0.168	0.019-1.457	1.139	0.579-2.240
	4	1.149	0.928-1.422	0.916	0.736-1.141	1.167	0.937-1.455	0.323	0.066-1.582	1.296	0.720-2.334
	0-1	1.231	0.930-1.629	1.032	0.901-1.183	0.894	0.700-1.141	0.632	0.107-3.717	1.593	0.767-3.308
	0-2	1.110	0.815-1.511	1.098	0.924-1.304	0.875	0.668-1.146	0.424	0.056-3.220	1.485	0.677-3.254
Older males (135)	0	0.982	0.844-1.142	0.994	0.888-1.112	1.079	0.972-1.199	1.092	0.970-1.229	1.212	0.888-1.654
	1	1.020	0.879-1.183	0.952	0.823-1.100	1.031	0.925-1.149	0.976	0.837-1.137	1.094	0.727-1.646
	2	1.081	0.931-1.256	1.109	0.981-1.254	1.041	0.933-1.163	1.013	0.928-1.105	1.380	0.995-1.913
	3	1.056	0.907-1.230	1.047	0.942-1.165	1.046	0.932-1.173	0.891	0.629-1.264	1.360	0.971-1.903
	4	0.984	0.847-1.144	1.105	0.994-1.229	1.045	0.949-1.152	0.995	0.892-1.110	0.908	0.604-1.366
	0-1	1.001	0.841-1.191	0.965	0.825-1.128	1.073	0.951-1.210	1.064	0.919-1.232	1.272	0.822-1.968
	0-2	1.049	0.857-1.282	1.073	0.914-1.260	1.083	0.946-1.241	1.066	0.907-1.251	1.590	0.972-2.600
Younger males (193)	0	0.969	0.858-1.094	1.046	0.961-1.139	0.973	0.886-1.069	1.082	0.974-1.202	1.129	0.841-1.514
	1	0.982	0.865-1.114	1.078	0.996-1.166	1.004	0.929-1.085	1.006	0.844-1.200	0.986	0.648-1.500
	2	0.910	0.796-1.039	0.999	0.913-1.093	0.985	0.904-1.074	1.003	0.912-1.104	0.884	0.595-1.314
	3	1.079	0.958-1.215	1.017	0.947-1.092	1.026	0.958-1.098	1.084	0.948-1.239	1.116	0.821-1.517
	4	1.097	0.978-1.230	1.045	0.938-1.163	1.070	0.972-1.177	1.016	0.944-1.094	0.952	0.640-1.417
	0-1	0.963	0.827-1.121	1.088	0.989-1.197	0.989	0.901-1.085	1.112	0.942-1.312	1.123	0.734-1.718
	0-2	0.915	0.768-1.091	1.084	0.965-1.219	0.984	0.888-1.091	1.113	0.907-1.365	1.041	0.610-1.778
Winter (236)	0	1.059	0.968-1.157	1.060	0.994-1.131	0.973	0.898-1.053	1.103	0.980-1.240	1.237	1.002-1.527
	1	1.008	0.921-1.104	1.055	0.994-1.119	0.979	0.904-1.060	0.981	0.806-1.195	0.962	0.732-1.264
	2	1.010	0.922-1.106	1.056	0.995-1.120	0.984	0.905-1.071	0.979	0.892-1.073	1.052	0.833-1.327
	3	1.094	1.003-1.193	1.028	0.974-1.085	0.996	0.926-1.070	1.000	0.923-1.084	1.230	1.009-1.500
	4	1.090	1.004-1.184	1.084	1.002-1.174	1.082	0.991-1.181	0.986	0.911-1.066	1.006	0.777-1.301
	0-1	1.049	0.941-1.170	1.088	1.009-1.173	0.970	0.887-1.060	1.098	0.951-1.268	1.191	0.891-1.593
	0-2	1.049	0.926-1.187	1.126	1.030-1.231	0.968	0.877-1.068	1.048	0.888-1.238	1.221	0.866-1.723
Summer (217)	0	0.910	0.754-1.098	0.873	0.748-1.018	1.038	0.936-1.150	1.067	0.958-1.189	1.038	0.654-1.649
	1	1.031	0.854-1.244	0.980	0.875-1.098	1.014	0.925-1.110	0.987	0.853-1.141	1.361	0.849-2.182
	2	0.873	0.711-1.073	1.154	1.032-1.292	1.010	0.930-1.098	1.144	0.927-1.412	1.028	0.620-1.704
	3	0.920	0.756-1.120	1.043	0.950-1.146	1.074	0.984-1.172	1.006	0.705-1.436	0.951	0.538-1.679
	4	1.033	0.853-1.251	0.962	0.859-1.078	1.024	0.940-1.115	1.322	0.892-1.959	0.815	0.460-1.442
	0-1	0.953	0.759-1.196	0.906	0.773-1.062	1.031	0.924-1.149	1.061	0.905-1.244	1.265	0.730-2.192
	0-2	0.883	0.673-1.158	1.013	0.864-1.187	1.028	0.919-1.151	1.114	0.911-1.363	1.253	0.661-2.376

Table B Number of visits (n), odds ratios (OR) and 95% confidence intervals (CI) for the daily emergency hospital visits for cardiac arrest with successful resuscitation(ICD-10 code: I46.0) and other cardiac arrest categories grouped together (ICD-10 codes I46, I46.1, and I46.9) in Reykjavik capital area associated with 10 µg/m³ increase in NO_2, PM_{10}, $PM_{2.5}$, SO_2, and H_2S, in single pollutant models, at lag 0 to lag 4, lag 0-1, lag 0-2, lag 0-3, and lag 0-4.

		NO_2		PM_{10}		$PM_{2,5}$		SO_2		H_2S	
Categories/Visits (n)	**Lag**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
I46.0 (194)	0	1.037	0.913-1.177	1.056	0.970-1.149	0.984	0.877-1.104	1.374	0.762-2.477	1.043	0.773-1.406
	1	1.043	0.923-1.178	1.045	0.978-1.117	0.998	0.895-1.114	0.865	0.534-1.401	1.070	0.729-1.571
	2	0.995	0.874-1.132	1.073	0.980-1.176	1.043	0.963-1.129	1.053	0.878-1.264	1.098	0.754-1.601
	3	1.085	0.967-1.218	1.052	0.967-1.144	1.090	1.008-1.178	0.999	0.914-1.092	1.193	0.890-1.655
	4	1.108	0.978-1.256	1.036	0.938-1.144	1.101	1.006-1.204	0.570	0.222-1.460	1.372	0.916-2.053
	0-1	1.060	0.911-1.234	1.076	0.983-1.177	0.990	0.875-1.119	1.153	0.924-1.439	1.087	0.711-1.661
	0-2	1.049	0.881-1.249	1.118	0.998-1.252	1.023	0.909-1.152	1.157	0.911-1.471	1.158	0.684-1.960
	0-3	0.102	0.911-1.335	1.161	1.014-1.329	1.071	0.952-1.204	1.110	0.866-1.423	1.313	0.736-2.342
	0-4	1.147	0.940-1.401	1.177	1.013-1.368	1.103	0.973-1.250	1.013	0.788-1.302	1.504	0.801-2.825
I46, I46.1, I46.9 (259)	0	1.023	0.921-1.136	0.990	0.912-1.074	0.999	0.928-1.075	1.061	0.971-1.160	1.338	1.034-1.730
	1	0.989	0.885-1.104	1.025	0.945-1.111	0.991	0.923-1.064	1.003	0.886-1.135	1.029	0.768-1.379
	2	0.979	0.878-1.092	1.079	1.008-1.155	0.952	0.870-1.042	0.997	0.925-1.075	1.025	0.793-1.326
	3	1.042	0.933-1.164	1.023	0.967-1.083	0.957	0.874-1.048	1.007	0.851-1.191	1.196	0.954-1.498
	4	1.066	0.969-1.172	1.037	0.957-1.122	1.012	0.930-1.101	1.061	0.973-1.156	0.813	0.595-1.112
	0-1	1.009	0.886-1.150	1.010	0.914-1.116	0.993	0.915-1.078	1.058	0.936-1.197	1.285	0.931-1.773
	0-2	0.995	0.858-1.154	1.079	0.972-1.198	0.974	0.885-1.072	1.047	0.910-1.206	1.265	0.874-1.832
	0-3	1.018	0.865-1.199	1.089	0.975-1.218	0.958	0.859-1.069	1.054	0.888-1.251	1.350	0.931-1.957
	0-4	1.058	0.892-1.254	1.110	0.979-1.259	0.962	0.853-1.086	1.090	0.919-1.294	1.225	0.817-1.836

Table C Number of visits (n), odds ratios (OR) and 95% confidence intervals (CI) for the daily emergency hospital visits for cardiac arrest (ICD-10 code: I46) in Reykjavik capital area associated with 10 $\mu g/m^3$ increase in NO_2, PM_{10}, $PM_{2.5}$, SO_2 and H_2S, adjusted for each pollutant, temperature and relative humidity, stratified by season, at lag 0 to lag 4, lag 0-1, lag 0-2, lag 0-3, and lag 0-4.

		NO2		PM10		PM2,5		SO2		H2S	
Categories/Visits (n)	**Lag**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Winter (236)	0	1.003	0.906-1.111	1.064	0.992-1.141	0.958	0.884-1.039	1.119	0.990-1.265	1.224	0.980-1.529
	1	1.030	0.927-1.145	1.047	0.984-1.115	0.982	0.905-1.065	0.957	0.781-1.172	0.988	0.741-1.319
	2	1.021	0.919-1.133	1.071	1.003-1.143	0.988	0.908-1.076	0.972	0.886-1.067	1.129	0.878-1.451
	3	1.082	0.979-1.195	1.038	0.980-1.100	0.995	0.926-1.069	0.990	0.912-1.074	1.207	0.976-1.493
	4	1.087	0.988-1.195	1.085	0.993-1.187	1.089	0.995-1.191	0.979	0.900-1.064	0.951	0.722-1.252
	0-1	1.013	0.889-1.154	1.089	1.003-1.182	0.961	0.877-1.054	1.104	0.953-1.279	1.200	0.876-1.645
	0-2	1.016	0.873-1.183	1.148	1.041-1.266	0.965	0.872-1.068	1.037	0.874-1.230	1.301	0.889-1.904
	0-3	1.056	0.892-1.249	1.187	1.061-1.328	0.965	0.866-1.075	1.016	0.848-1.218	1.451	0.980-2.149
	0-4	1.109	0.927-1.326	1.240	1.089-1.412	0.989	0.881-1.111	0.996	0.833-1.191	1.362	0.882-2.104
Summer (217)	0	0.914	0.743-1.126	0.864	0.736-1.014	1.036	0.934-1.148	1.083	0.967-1.214	1.043	0.633-1.717
	1	0.993	0.814-1.211	0.997	0.889-1.118	1.008	0.920-1.105	0.984	0.852-1.136	1.441	0.888-2.340
	2	0.821	0.658-1.023	1.175	1.046-1.320	0.992	0.912-1.079	1.175	0.915-1.509	1.009	0.583-1.744
	3	0.927	0.753-1.142	1.047	0.951-1.152	1.073	0.982-1.172	1.041	0.723-1.499	0.964	0.540-1.720
	4	1.036	0.841-1.275	0.951	0.844-1.072	1.022	0.938-1.114	1.373	0.863-2.187	0.759	0.416-1.384
	0-1	0.903	0.703-1.160	0.910	0.773-1.071	1.027	0.920-1.147	1.073	0.917-1.257	1.363	0.763-2.435
	0-2	0.800	0.594-1.076	1.033	0.878-1.216	1.014	0.907-1.135	1.132	0.920-1.393	1.360	0.684-2.703
	0-3	0.764	0.546-1.070	1.061	0.891-1.263	1.039	0.921-1.172	1.176	0.902-1.534	1.354	0.617-2.970
	0-4	0.802	0.556-1.156	1.021	0.843-1.236	1.056	0.924-1.207	1.257	0.925-1.708	1.133	0.479-2.679

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *case-control studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	2, 6-9
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls	6-7
		(*b*) For matched studies, give matching criteria and the number of controls per case	9
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*6, 7 ,9*
Bias	9	Describe any efforts to address potential sources of bias	9-10
Study size	10	Explain how the study size was arrived at	7-9
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	9
		(*c*) Explain how missing data were addressed	8
		(*d*) If applicable, explain how matching of cases and controls was addressed	9
		(*e*) Describe any sensitivity analyses	9-10
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10, table 1
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10, tables 1, 2
		(b) Indicate number of participants with missing data for each variable of interest	NA
Outcome data	15*	Report numbers in each exposure category, or summary measures of exposure	tables 3 , 4
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11-13
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	11-13
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	13
Discussion			
Key results	18	Summarise key results with reference to study objectives	14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14-15, 16-17
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	19

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Ambient air pollution and emergency department visits and hospitalisation for cardiac arrest: a population-based case-crossover study in Reykjavik, Iceland

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Abstract

Objectives To assess the association between traffic-related ambient air pollution and emergency hospital visits for cardiac arrest.

Design Case-crossover design was used with a lag time to 4 days.

Setting The Reykjavik capital area and the study population were the inhabitants 18 years and older identified by encrypted personal identification number and zip codes.

Participants and exposure Cases were those with emergency visits to Landspitali University Hospital during the period 2006 to 2017 and who were given the primary discharge diagnosis of cardiac arrest according to The International Classification of Diseases 10th edition (ICD-10), code I46. The pollutants were NO_2, PM_{10}, $PM_{2.5}$, and SO_2 with adjustment for H_2S, temperature and relative humidity.

Main outcome measure Odds ratio (OR) and 95% confidence intervals (CI) per 10 µg/m^3 increase in concentration of pollutants.

Results: The 24-h mean NO_2 was 20.7 µg/m^3, mean PM_{10} was 20.5 µg/m^3, mean $PM_{2.5}$ was 12.5 µg/m^3, and mean SO_2 was 2.5 µg/m^3. PM_{10} level was positively associated with the number of emergency hospital visits (n=453) for cardiac arrest. Each 10 µg/m^3 increase in PM_{10} was associated with increased risk of cardiac arrest (ICD-10: I46), odds ratio (OR) 1.093 (95%CI 1.033-1.162) on lag 2, OR 1.118 (95%CI 1.031-1.212) on lag 0-2, OR 1.150 (95% CI 1.050-1.261) on lag 0-3, and OR 1.168 (95% CI 1.054-1.295) on lag 0-4. Significant associations were shown between exposure to PM_{10} on lag 2 and on lag 0-2 and increased risk of cardiac arrest in the age, gender, and season strata.

Conclusions: A new endpoint was used for the first time in this study: cardiac arrest (ICD-10 code I46) according to hospital discharge registry. Short-term increase in PM_{10} concentrations

was associated with cardiac arrest. Future ecological studies of this type and their related discussions should perhaps concentrate more on precisely defined endpoints.

Key words Cardiac arrest, urgent hospital visits, successful resuscitation, multivariate models, cardiovascular diseases

Strength and limitations of this study

- The study is population-based, relies on comprehensive population registries, and include information of daily concentrations of the pollutants which cover more than 75% of the days in the study period.
- The methodology allows within-subject comparison while adjusting for various time trends such as seasonality, and day of week.
- The concentration of the pollutants derived from one monitoring station, and not from individual exposure measurements.
- The population is small, and therefore the total number of cases were few, resulting in low statistical power.

Introduction

Epidemiological studies have found increased risk of cardiovascular morbidity and mortality in association with particulate matter (PM) in air pollution (1,2), and the overall evidence is considered to support the existence of a causal relationship between PM exposure and cardiovascular morbidity, primarily due to fine particles (2). Both short-term and long-term PM air pollution contribute to cardiovascular morbidity and mortality (1,2). Urban ambient air pollution is a complex mixture of gases, particles and liquid, and in an attempt to monitor air quality, certain pollutants are traditionally measured. However, adverse cardiovascular health impacts of exposure to a combination of air pollutants are not completely understood at present. A recent multilocation analysis found that a short term increase in NO_2 on the previous day was associated with an increased risk of daily total, cardiovascular, and respiratory mortality (3). In a systemic review and meta-analysis of short-term exposure to NO_2 and ischemic heart diseases, the authors concluded that the relationship was likely causal (4), but uncertainties remained due to possible confounding in the epidemiological studies and lack of evidence from mechanistic studies. Several epidemiological studies have found that NO_2 and PM are associated with cardiovascular diseases (CVD), and the endpoints studied have included not only mortality from CVD (3), but also discharge diagnosis at hospitals and emergency departments for a wide range of CVD, ischemic heart disease, myocardial infraction, and different cardiac dysrhythmias (5-10). In a large US study (9), acute myocardial infarction, and multiple other cardiovascular outcomes, like cardiac dysrhythmia and heart failure were found to be associated with particulate air pollution; however, in that analysis it was only possible to consider potential confounding by ozone, not by other pollutants. In a case-crossover study in China, an association was found between particulate matter, NO_2, and carbon monoxide, and number of hospital admissions for cardiac arrhythmia (10). In another case-crossover study in the UK (8), the risk of emergency hospital admissions for CVD, arrhythmias, atrial fibrillation, and heart failure was associated with an increased concentration of NO_2; however, cardiac arrest was not included as an outcome in the study. Cardiac arrest was mentioned in the aforementioned Chinese study (10) but was not analysed separately.

There are several studies on the association of air pollution and out of hospital cardiac arrest (OHCA) (11-15). The risk of OHCA were associated with a short-term increase in exposure to particulate matter, sometimes $PM_{2.5}$, or ultrafine particulate matter (11-14), and sometimes PM_{10} (15), with various associations with O_3, other caseous pollutants, and high temperature. The collection of cases in the OHCA studies use special registers as a source, regarding Utstein definition (16,17) with the original purpose to provide a structured framework to evaluate emergency medical service. The main criteria in the definition of the cases in the OHCA studies are: 1) the cardiovascular collapse has occurred outside a hospital, and 2) the event has elicited a resuscitation attempt. Neither of these conditions is required for the physician given diagnosis of cardiac arrest according to the International Classification of Diseases 10th edition (ICD-10) code I46 registered as discharge diagnosis at hospitals or emergency departments.

The comprehensive population and health registries in Iceland make this an optimal setting to study the association between relatively low daily exposure to air pollution, and different heart related conditions (7,18,19). The aim of the present study was to explore the association between traffic-related pollutants, NO_2, PM_{10}, $PM_{2.5}$, and SO_2 in the Reykjavik capital area and urgent hospital and emergency department visits for cardiac arrest, ICD-10 code I46, as the primary discharge diagnosis, and to simultaneously adjust for meteorological variables and geothermal-originated pollutants.

Methods

Study base

The Reykjavik capital area is in the southwestern part of Iceland. Traffic emission is the main source of air pollution in the city. Other sources of air pollution include two geothermal power plants: Hellisheidi, located 26 km east-southeast of the city, and Nesjavellir, located 33 km east of the city. Ambient H_2S emission originates from the plants. Reykjavik's capital area spreads over 247.5 km^2 and in 2017 the inhabitants numbered 217,000, equivalent to approximately two-thirds of the total Icelandic population (20). The study base included the residents of the Reykjavik capital area, which consists of seven municipalities (Gardabaer, Hafnarfjordur, Kjosarhreppur, Kopavogur, Mosfellsbaer, Reykjavik, and Seltjarnarnes) identified by 24 zip codes.

Health data

Hospital discharge data were obtained from January 1 2006 to December 31 2017 from computerised records in SAGA (Register of hospital-treated patients in Iceland) for certain heart diseases; the procedures have been described in a previous publication (7). The study included adult inhabitants (≥18 years) of the Reykjavik capital area, identified by zip code. We analysed data on urgent visits to the emergency department and urgent admissions to in-patient wards of Landspitali University Hospital (LUH). The study was confined to new admissions, meaning that no visits by appointment were included. LUH is operated by the Icelandic government and is the only acute care hospital serving the population of the Reykjavik capital area, making this study population-based. In Iceland, the national health insurance scheme is covered by taxes and is available to all residents. For ambulatory visits, patients pay a small fee that amounts to approximately 10 to 15 US dollars, but seniors are exempt from payment. Admission to the hospital ward is free of charge. Every inhabitant of Iceland receives a personal identification number at birth (or at immigration), and the

identification numbers are widely used in Icelandic society and population registries, including the SAGA register. We received the identification numbers in encrypted form, which enabled us to identify repeated visits to LUH. Readmissions to LUH within 10 days with the same ICD-10 primary discharge diagnosis were excluded. From the SAGA register we received the following details: admission date, encrypted identification number, unique number of the admission, age, gender, primary discharge diagnosis for certain codes according to the International Classification of Diseases 10^{th} edition (ICD-10). In this study, both admission to the emergency department and formal admission to the hospital are included, so there is no requirement that a patient stayed overnight. The diagnoses are registered at discharge from the hospital, transfer to another hospital, and death in the hospital. In a previous study (7), the outcomes were heart diseases ICD-10 codes: I20-I25, I44-I50, ischemic heart diseases ICD-10 codes: I20-I25, cardiac arrhythmias and heart failure ICD-10 codes: I44-I50, and atrial fibrillation ICD-10 I48 (7). In the present study, the outcome analysed was cardiac arrest ICD-10 code I46. Emergency department visits and urgent hospital admissions were combined and are called emergency hospital visits.

Air pollutants and meteorological data

Information on pollution was obtained from Grensas monitor station (GRE), operated by the governmental institution Environment Agency of Iceland. GRE is in the centre of the Reykjavik capital area near one of the busiest road intersections in the city. Other stations in the city were not permanently located or were not continuously monitoring throughout the study period and were therefore not used in the study. However, to test whether GRE was reflective of the total capital area, Pearson's correlation was calculated for GRE measurements and measurements from another station located in Dalsmari, Kopavogur municipality, for the period 2014-2017. Results of Pearson's correlation coefficients between

these two measurement stations were for PM_{10} 0.44, for NO_2 0.78, for SO_2 0.98, and for H_2S 0.84. PM2.5 was not measured in Dalsmari.

Pollutants measured at GRE were NO_2, particulate matter with aerodynamic diameter less than 10 µm (PM_{10}), particulate matter with aerodynamic diameter less than 2.5 µm ($PM_{2.5}$), sulphur dioxide (SO_2), and hydrogen sulphide (H_2S), all measured in µg/m³. The meteorological data was obtained from the governmental institution Icelandic Meteorological Office and included temperature (°C) and relative humidity (RH). PM_{10} and $PM_{2.5}$ were measured with an Andersen EMS IR Thermo (model FH62 I-R), NO_2 with Horiba device (model APNA 360E), and SO_2 and H_2S with the Horiba model APOA 360E. Every 6-12 months the devices are calibrated. Exposure data included 12 years or 4,383 days. Daily averages (midnight to midnight the following day) were calculated from hourly concentrations if at least 75% of one-hour data existed. Missing daily averages for NO_2, PM_{10}, $PM_{2.5}$, SO_2, and H_2S were 383 days (8.7%), 165 days (3.8%), 923 days (21.1%), 200 days (4.6%), and 284 days (6.5%), respectively. Data gaps were seen and can be attributed to inactive measurement devices due to unknown causes, with the exception of 52 days of missing H_2S measurements at the beginning of the study period, as H_2S measurements at GRE started at the end of February 2006. For temperature and RH, 6 days (0.1%) and 6 days (0.1%) were missing, respectively. Minor gaps in the curves were fitted by linear interpolation.

Descriptive statistics were calculated and showed as daily concentration levels in µg/m³ of the pollutants, as well as Spearman's correlation coefficient between pollutants and meteorological factors.

Analysis

Short-term associations between daily exposure to air pollutants and emergent hospital visits for cardiac arrest (ICD-10 code I46) were assessed using bidirectional time-stratified case-crossover design. The study period was divided into monthly strata, and exposure during case periods (24h) was compared to exposure during control periods, which were matched as the same weekdays within the same month (3-4 control periods per case period) (21,22). The matches control for measured or unmeasured personal confounding characteristics that do not vary over the relatively short time, such as gender, age, and genetic factors. We did several calculations: single pollutant models were calculated in conditional logistic regression, multivariate models containing all traffic-related pollutants, H_2S, and the meteorological variables. Separate analyses were done for subgroups according to gender, age (≥71 and < 71 years), gender, and age combined, winter (November 1st to April 30th), and summer (May 1st to October 31st). It was possible to divide the diagnostic category I46 according to decimals into cardiac arrest with successful resuscitation (I46.0) and other categories without indication of successful resuscitation (I46, I46.1, and I46.9). These two subcategories were also analysed separately as there are indication that the latter category concern mortality. The risk estimates were expressed as odds ratio (OR), and 95% confidence intervals (CI) were calculated for every 10 $\mu g/m^3$ increase of pollutants (24h concentrations).

Different lag structures were applied. Single-day lag structure (lag 0 to lag 4), and multiple-day lag structure (lag 0-1, lag 0-2, lag 0-3, and lag 0-4, moving average of pollutants concentration) were employed in the analyses to explore the temporal association between pollutants and cardiac arrest. The results of the multivariate models with all lag structures are presented in the article, and other results are shown as Supplementary data.

Although readmissions within 10 days with the same primary discharge diagnosis were excluded, it is still possible that some patients first went to the emergency department and were subsequently admitted that same day to in-hospital wards where they might have received a different diagnosis than they were given at the emergency department. To test whether this could distort the main result of the association between increased pollutant concentration and the emergency hospital visits, a sensitivity analysis was done, in which data was restricted to emergency department visits only.

Statistical analysis was done with R version 4.0.3 (https://www.r-project.org/). Statistical tests used in this study were all two-tailed and we considered results statistically significant for $p < 0.05$.

The study was approved by the National Bioethics Committee (ref. no. VSNb2018120011/03.01), the Data Protection Authority (ref. no. 10-050), and the Scientific Committee of LUH.

Results

The basic characteristics of cardiac arrest according to subcategories are shown in Table 1. The total number of visits with primary discharge diagnosis cardiac arrest (ICD-10 code I46) was 453, and repeated visits were extremely rare. The distribution of the 453 visits was even over the 4383-day study period. One visit per day was most common, but there were several days with up to two visits, which was the higesthighest number of visits per day; thus, most days were without visits with cardiac arrest. The median age at the time of visits was 71 years. Descriptive statistics and Spearman's correlation coefficients of traffic-related pollutants, H_2S, and meteorological variables are presented in Table 2. Missing daily average was highest for PM_{10} but did not exceed 25% of the days of the study period. The concentrations of PM_{10} and $PM_{2.5}$ were correlated, particulate matter did not correlate with the gaseous pollutants, and correlations among gaseous pollutants were moderate.

In the single pollutant analyses, positive associations were observed for exposure to PM_{10} at lag 2 and lag 0-2, and unstratified emergency hospital visits for cardiac arrest (ICD-10 codes: I46); the increased risks of cardiac arrest were OR 1.096 (95% CI 1.033-1.162) and OR 1.118 (95% CI 1.031-1.212), respectively, per 10 µg/m³ increase of PM_{10}, as shown in Table A, Supplementary data. A positive association was observed between exposure to NO_2 at lag 4 and the increased risk of cardiac arrest; the increased risk was OR 1.081 (95% CI 1.002-1.166) per 10 µg/m³ increase of NO_2, as shown in Table A, Supplementary data.

In examining the daily lag exposure to PM_{10} and unstratified emergency hospital visits for cardiac arrest, positive associations were observed in the multivariate model; the increased risks of cardiac arrest were OR 1.096 (95% CI 1.033-1.162) for lag 2, OR 1.118 (95% CI 1.031-1.212) for lag 0-2, OR 1.150 (95% CI 1.050-1.261) for lag 0-3, and OR 1.168 (95% CI 1.054-1.295) for lag 0-4 per 10 µg/m³ increase of PM_{10} (Table 3). Significant associations were shown for exposure to NO_2 at lag 4 and for SO_2 at lag 0, and unstratified emergency

hospital visits for cardiac arrest; the increased risks were OR 1.096 (95% CI 1.008-1.192) and OR 1.084 (95% CI 1.002-1.173) per 10 µg/m³ increase of NO_2 and SO_2, respectively (Table 3).

When applying the multivariate model in the stratified analyses of daily pollutants exposure and the association of emergency hospital visits for cardiac arrest (ICD-10 code I46), a discernible pattern emerges. Significant In the multivariate model significant associations were shown between exposure to PM_{10} at lag 2 and/or exposure to PM_{10} at lag 0-2, lag 0-3, and lag 0-4, and increased risks of cardiac arrest (ICD-10 code I46), in the age, gender, age and gender combined, and season strata, i.e., in all the strata except in the stratum of young females (Table 3). In Figure 1, OR and 95% CI of cardiac arrest per 10 µg/m³ increase of PM_{10} concentrations in multi-pollutant models are shown at lag 0 to lag 4 for different strata and unstratified.

In the single pollutant analyses, positive associations were observed for exposure to PM_{10} at lag 0-3, and lag 0-4, and emergency hospital visits for cardiac arrest with successful resuscitation (ICD-10 codes: I46.0); the increased risks of cardiac arrest were OR 1.161 (95% CI 1.014-1.329), and OR 1.177 (95% CI 1.013-1.368), respectively, per 10 µg/m³ increase of PM_{10}, as shown in Table B, Supplementary data. A positive association was observed for exposure to $PM_{2.5}$ at lag 3, and lag 4, and the increased risk of cardiac arrest with successful resuscitation; the increased risk was OR 1.090 (95% CI 1.008-1.178), and OR 1.101 (95% CI 1.006-1.204), per 10 µg/m³ increase of $PM_{2.5}$, respectively, as shown in Table B, Supplementary data. A positive association was observed for exposure to PM_{10} at lag 2, and the increased risk of cardiac arrest without indication of successful resuscitation (ICD-10 codes: I46, I46.1, and I46.9); the increased risk was OR 1.079 (95% CI 1.008-1.155), as shown in Table B, Supplementary data.

When we applied the multivariate model to the stratification of whether the cardiac arrests were indicated with successful resuscitation (ICD-10 code I46.0) or not (ICD-10 code I46, I46.1, and I46.9) and the association with daily pollutant exposure, a similar pattern emerges to that of the single pollutants analyses, shown in Table 4; however, the OR were somewhat higher and were observed at more lags and pollutants. A In the multivariate model a positive association was observed between exposure to PM_{10} and emergency hospital visits for cardiac arrest with successful resuscitation (ICD-10 codes: I46.0); the increased risks of cardiac arrest were OR 1.104 (95% CI 1.002-1.216) at lag 2, OR 1.153 (95% CI 1.021-1.301) at lag 0-2, OR 1.202 (95% CI 1.039-1.392) at lag 0-3, and OR 1.209 (95% CI 1.027-1.422) at lag 0-4, per 10 $\mu g/m^3$ increase of PM_{10}, as shown in Table 4. A positive association was observed between exposure to $PM_{2.5}$ and the increased risk of cardiac arrest with successful resuscitation; the increased risk was OR 1.088 (95% CI 1.001-1.182) at lag 3, and OR 1.104 (95% CI 1.006-1.21) at lag 4, per 10 $\mu g/m^3$ increase of $PM_{2.5}$, as shown in Table 4. A positive association was observed for exposure to NO_2 and the increased risk of cardiac arrest with successful resuscitation; the increased risk was OR 1.194 (95% CI 1.023-1.393) at lag 4, as shown in Table 4. A positive association was observed between exposure to PM_{10} and the increased risk of cardiac arrest without indication of successful resuscitation (ICD-10 codes: I46, I46.1, and I46.9); the increased risk was OR 1.090 (95% CI 1.013-1.173) at lag 2, as shown in Table 4. In Figure 2, OR and 95% CI of cardiac arrest per 10 $\mu g/m^3$ increase of PM_{10} concentrations in multi-pollutant models are shown at lag 0 to lag 4 when stratified on season and whether there is an indication of successful resuscitation or not.

In the sensitive analysis of the association between daily exposure to PM_{10} and emergency hospital visits for cardiac arrest (ICD-10 code I46), when restricting the calculation to emergency department visits only (353 visits), the results did not change substantially: in the unstratified analysis, the increased risk of cardiac arrest was OR 1.099 (95% CI 1.028-1.175) at lag 2 per 10 μg/m³ increase of PM_{10}.

Discussion

Our study examined the association between ambient air pollution and emergency hospitalization and emergency department visits where the primary discharge diagnosis was cardiac arrest (ICD-10 code I46). To our knowledge, that single outcome has not been used in previous studies of a similar type. The main results of this study were the association between increased PM_{10} and cardiac arrest at lag 2, lag 0-2, lag 0-3, and lag 0-4, so the 24 hours concentrations of PM_{10} seem to be clearly separated from the event registered at the hospital and happened before the admittance. The effects seemed high in most subcategories, in both seasons, and among those who were successfully resuscitated.

Cardiac arrest is a life-threatening event and may be the most serious outcome of CVD. The decimal following the code I46 indicates whether the patients were successfully resuscitated or not. Patients categorised as I46 comprise those who have survived and those who have died, and in the present study these are in nearly equal proportion. The associations between pollutants and mortality and hospital admission are commonly analysed separately (8). The primary discharge diagnosis cardiac arrest (ICD-10 code I46) has in previous studies been included within all CVD, or large subgroups such as cardiac dysrhythmias, and the endpoint closest to this entity may be OHCA. However, there is a ~~substantial~~ difference between patients with the diagnosis cardiac arrest (ICD-10 code I46) at hospitals and persons included in studies on OHCA. OHCA has often been the subject of studies on association with air pollutants. In a review of 67 studies on OHCA (23), OHCA was associated with high mortality, with a global average survival rate of 7%, but in the present study 42.8% of the registered cases with the ICD-10 code I46, cardiac arrest, were successfully resuscitated, a considerable difference in survival rates. The definition of OHCA is: 1) the cardiovascular collapse has occurred outside a hospital, and 2) the event has elicited a resuscitation attempt~~.~~ ~~Neither of~~, and these conditions is not required for cardiac arrest according to ICD-10 code

I46, when this diagnosis is used at hospitals or emergency departments. In addition, the Utstein definition recommends registration of several time points and intervals important for the research and quality assurance related to the resuscitation, but such time elements are not required in the hospital discharge registries based on the ICD-10. Some studies have shown that the risks of OHCA were associated with a short-term increase in exposure to particulate matter, sometimes $PM_{2.5}$, or ultrafine particulate matter (11-14), and sometimes PM_{10} (15), with various associations with O_3, other caseous pollutants, and high temperature. An OHCA study conducted in Stockholm, Sweden demonstrated a significant exposure-response association between OHCA risk and O_3, but no association for $PM_{2,5}$ or NO_2, (24), while another OHCA study in Lombardy, Italy, showed, with different methodology, that the concentrations of all the pollutants in the study were significantly higher in days with high incidence of OHCA except for O_3 (25). In these OHCA studies (11-15,24,25) no difference is made between those who survive the event and those who do not survive. In the previously mentioned UK study (8) on the association between air pollution and hospital admission for different cardiovascular events, exposure to NO_2 was significant, while in the same publication some of the mortality outcomes were associated with exposure to $PM_{2.5}$ but not to NO_2 (8), indicating the possibility of different pathogenetic pathways for the outcomes, as has been discussed briefly in the case of NO_2 (4), and in the comprehensive review of the causal role of particulate material (2). The category cardiac arrest in the ICD-10 coding system represents a small group compared to other CVD diagnoses and seems to be concealed within the larger summary group of cardiac arrhythmias (10) or omitted from the analysis (8). In this respect, our recent study on the same dataset is not an exception: increased risk of cardiac arrhythmias (ICD-10 codes I44 to I50) was associated with an increase in NO_2 exposure (7), a finding that hides the association between cardiac arrest (ICD-10 code I46) and exposure to PM_{10} as demonstrated in the present study.

Among the strengths of this study is that it is population-based, as the hospital and emergency department data were obtained from the only emergency health care institution, the LUH, serving the population in the catchment area of the Reykjavik capital. The design of the study is also a strength, as the bidirectional time-stratified case-crossover approach virtually excludes confounding of individual characteristics and the matching adjusted for weekly pattern and time trends. Another strength of the study is its use of the encrypted identification number of each patient in the Register of hospital-treated patients, which ensures the correct counting and identification of the cases and their admissions. Furthermore, it is noteworthy that visits of the cases receiving the primary discharge diagnosis cardiac arrest (453 cases) were evenly distributed over the study period (4383 days), so the distribution diminished the risk of overlapping the sets of case and control days.

That said, there are few limitations. First, the concentration of the pollutants derived from one monitoring station in the Reykjavik capital area, and not from individual exposure measurements. The results from these measurements did, however, correlate well with measurements from another monitoring station located in the capital area during three years of the study period. Another limitation is that only the primary discharge diagnosis was included in the study, meaning that the cases may have underlying diseases that could modify the result.

Furthermore, the quality of the routine discharge diagnosis at the LUH has not been investigated in a separate study for accuracy or reliability, which is a weakness our study shares with the many studies based on hospital records. The primary discharge diagnosis of cardiac arrest (ICD-10 code I46) set at emergency admission to the hospital and emergency department does not indicate whether the causes were cardiac- or trauma related, and there may be doubt as to where the patient developed the cardiac arrest, i.e., whether the event

initially occurred outside or inside the hospital. The study population consisted of patients aged 18 years and older, which limits the generalisability of the results to those under 18.

The present study concentrates on traffic related pollutants; however, emissions from the volcanic eruptions occurring in Iceland during the study period may have confounded the results. The Eyjafjallajökull eruption in 2010 was found to have minor health effect on the local population, but not the population in the Reykjavik capital area (26). The Holuhraun eruption in 2014 to 2015 emitted a massive amount of SO_2 and mature volcanic plume, and the exposure to these was associated with an increase in the dispensing of asthma medication and an increase in health care utilisation for respiratory diseases in the Reykjavik capital area during four months in the year 2014 (27,28). The present study was not designed to catch the possible effect of these emissions on the cardiovascular health of the population of the Reykjavik capital area, and its role remains unknown with that respect.

We made several stratifications to explore the possible association between air pollutants and emergency hospital visits for cardiac arrest in this study. Because of this, some concerns may emerge about multiple comparisons; however, this has been dealt with in the literature (29).

Conclusions

This study was, to our knowledge, the first to utilise the new endpoint of cardiac arrest (ICD-10 code I46) according to the hospital discharge registry. This outcome has in previous epidemiological studies been included in larger groups of CVDs, and its special status may have been overshadowed by the more common diagnosis of CVDs. Our results indicate a positive association between short-term increase in PM_{10} and emergency hospital visits for cardiac arrest in the Reykjavik capital area, known for having low levels of traffic-related pollution. The effects were found in most subgroups, and were highest among the elderly, and in the winter season, and among those who were successfully resuscitated. Future ecological studies of this type should perhaps concentrate more on precisely defined endpoints; however, doing so will not replace the obvious lack of exact individual exposure measurements for each of the cases.

List of abbreviations

µm	Micrometre
AF	Atrial fibrillation
CI	Confidence interval
CVD	Cardiovascular diseases
ED	Emergency department
GRE	Air quality measurement station located at Grensasvegur-Miklabraut intersection in Reykjavik
H_2S	Hydrogen sulphide
ICD-10	International Classification of Diseases 10th edition
IHD	Ischemic heart disease
km	Kilometre
LUH	Landspitali University Hospital
NO_2	Nitrogen dioxide
OR	Odds ratio
PM_{10}	Particulate matter less than 10 µm in aerodynamic diameter
$PM_{2.5}$	Particulate matter less than 2.5 µm in aerodynamic diameter
RH	Relative humidity
SAGA	Register of Hospital-treated Patients in Iceland
SO_2	Sulphur dioxide
yr	Year

Ethical approval and consent to participate

The study was approved by the National Bioethics Committee (ref. no. VSNb2018120011/03.01), the Data Protection Authority (ref. no. 10-050), and the Scientific Committee of LUH.

Availability of data and materials

The hospital data contain sensitive individual-level information which is not publicly available. It can be made available to researchers after obtaining approval of a formal application to the National Bioethics Committee and the Scientific Committee of LUH. The dataset of air pollution used and analysed during the current study are available from the corresponding author on reasonable request.

Competing interest

The authors declare that they have no competing interests.

Funding

The study had no external funding.

Authors' contribution

SH, RGF, VR designed the study; SH, RGF, BTE, VR planned the analysis; SH, GG, VR collected the data; SH, RGF, BTE analysed the data; VR wrote the first draft; SH, RGF, BTE, OSG, GG, VR read the manuscript, interpreted the conclusion, and agreed on the final version.

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Table 1. Descriptive statistics of emergency hospital visits for cardiac arrest (ICD-10: I46) to Landspitali University Hospital, according to subgroups, January 1st, 2006 to December 31st, 2017.

Discharge diagnosis (ICD-10)	No. of visits (%)	No. of patients
Cardiac arrest (I46)	453 (100)	447
Females	125 (28)	123
Males	328 (72)	324
Older (≥71yr)	192 (42)	190
Younger (<71yr)	261 (58)	257
Older females	57	56
Younger females	68	67
Older males	135	134
Younger males	193	190
Winter	236 (52)	236
Summer	217 (48)	214
Cardiac arrest (I46)	5	5
Cardiac arrest with successful resuscitation (I46.0)	194	192
Sudden cardiac death, so described (I46.1)	23	23
Cardiac arrest, unspecified (I46.9)	231	229
Emergency department visits, only	313	312

Winter: November 1st to April 30th.
Summer: May 1st to October 31st.

Table 2. Descriptive statistics of 24-hour concentration levels (μg/m³) of pollutants and meteorological data in the Reykjavík capital area during the study period, 2006-2017, and Spearman's correlation between daily concentrations of pollutants

	PM_{10}	$PM_{2,5}$	NO_2	SO_2	H_2S	TEMP (°C)	RH (%)
24-h availability n (%)	4218 (96.2)	3460 (78.9)	4000 (91.3)	4183 (95.4)	4099 (93.5)	4377 (99.9)	4377 (99.9)
Mean (SD)	20.5 (19.7)	12.5 (21.8)	20.7 (15.0)	2.51 (13.8)	2.98 (5.2)	5.5 (4.9)	74.9 (10.6)
Summer* mean (SD)	17.4 (14.9)	10.8 (16.2)	16.2 (9.9)	2.48 (14.1)	2.08 (3.1)	9.1 (3.2)	74.6 (9.8)
Winter** mean (SD)	23.6 (23.2)	14.2 (26.1)	25.3 (17.6)	2.54 (13.5)	3.90 (6.6)	1.9 (3.4)	75.1 (11.3)
Range	2.4-381	0-423	0-119	0-409	0-96	-10.5-17.7	37-97
Median	15.1	7.0	16.6	1.1	1.2	5.6	77.0
Interquartile range	11.6	8.2	15.8	1.2	2.7	7.9	15.0
Spearman's correlation							
PM_{10}	1.00						
$PM_{2,5}$	0.76	1.00					
NO_2	0.09	0.00	1.00				
SO_2	0.08	0.08	0.50	1.00			
H_2S	-0.08	-0.11	0.31	0.39	1.00		
TEMP (°C)	-0.16	-0.08	-0.44	-0.17	-0.23	1.00	
RH (%)	-0.30	-0.56	0.09	-0.03	0.04	0.12	1.00

* May 1st to October 31st.

** November 1st to April 30th.

SD: standard deviation; H_2S: hydrogen sulphide; NO_2: nitrogen dioxide; PM_{10}: particulate matter ≤10μm in diameter; $PM_{2.5}$: particulate matter ≤2.5μm in diameter; RH: relative humidity; SO_2: sulphur dioxide; TEMP: temperature.

Table 3 Number of visits (n), odds ratios (OR) and 95% confidence intervals (CI) for the daily emergency hospital visits for cardiac arrest (ICD-10 code: I46) in Reykjavik capital area associated with 10 μg/m³ increase in NO_2, PM_{10}, $PM_{2.5}$, SO_2 and H_2S, adjusted for each pollutant, temperature and relative humidity, unstratified and stratified by gender, age, and season, at lag 0 to lag 4, lag 0-1, lag 0-2, lag 0-3, and lag 0-4.

		NO_2		PM_{10}		$PM_{2.5}$		SO_2		H_2S	
Categories/Visits (n)	**Lag**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
All (453)	0	0.989	0.904-1.083	1.017	0.957-1.082	0.990	0.930-1.053	1.084	1.002-1.173	1.187	0.972-1.449
	1	1.003	0.916-1.099	1.041	0.987-1.097	0.994	0.936-1.055	0.983	0.873-1.107	1.056	0.829-1.344
	2	0.972	0.885-1.068	1.096	1.033-1.162	0.993	0.935-1.054	0.999	0.935-1.067	1.118	0.892-1.402
	3	1.052	0.963-1.150	1.038	0.988-1.090	1.022	0.968-1.079	0.991	0.916-1.074	1.191	0.980-1.449
	4	1.096	1.008-1.192	1.029	0.963-1.099	1.054	0.992-1.020	1.003	0.940-1.070	0.915	0.714-1.171
	0-1	0.982	0.876-1.101	1.049	0.978-1.124	0.988	0.922-1.059	1.084	0.971-1.211	1.214	0.923-1.597
	0-2	0.957	0.838-1.093	1.118	1.031-1.212	0.989	0.918-1.066	1.070	0.945-1.212	1.301	0.936-1.810
	0-3	0.981	0.846-1.137	1.150	1.050-1.261	0.998	0.921-1.081	1.061	0.922-1.221	1.423	1.007-2.011
	0-4	1.039	0.889-1.215	1.168	1.054-1.295	1.019	0.934-1.112	1.057	0.588-1.928	1.313	0.897-1.921
Females (125)	0	1.223	1.011-1.481	0.982	0.857-1.126	0.900	0.763-1.063	0.256	0.039-1.665	1.270	0.797-2.024
	1	1.029	0.860-1.231	1.006	0.928-1.091	0.895	0.764-1.049	0.740	0.237-2.316	1.036	0.688-1.561
	2	1.009	0.839-1.212	1.193	1.059-1.344	0.958	0.843-1.089	0.284	0.051-1.582	0.902	0.531-1.532
	3	1.029	0.860-1.232	1.040	0.959-1.129	0.983	0.857-1.127	0.286	0.064-1.287	1.156	0.759-1.760
	4	1.175	0.997-1.384	0.927	0.806-1.068	1.036	0.909-1.181	0.495	0.154-1.591	1.006	0.639-1.583
	0-1	1.214	0.948-1.555	1.016	0.893-1.157	0.867	0.724-1.038	0.404	0.076-2.132	1.184	0.698-2.008
	0-2	1.174	0.893-1.543	1.110	0.958-1.287	0.889	0.740-1.068	0.236	0.034-1.664	1.172	0.605-2.273
	0-3	1.177	0.867-1.597	1.162	0.982-1.374	0.901	0.748-1.085	0.134	0.015-1.166	1.350	0.665-2.740
	0-4	1.278	0.939-1.740	1.133	0.935-1.372	0.914	0.754-1.108	0.118	0.012-1.125	1.276	0.593-2.743
Males (328)	0	0.935	0.841-1.041	1.036	0.966-1.112	1.012	0.946-1.083	1.093	1.009-1.184	1.218	0.972-1.526
	1	0.989	0.888-1.101	1.067	0.993-1.147	1.013	0.951-1.079	0.992	0.882-1.116	1.094	0.805-1.486
	2	0.982	0.878-1.098	1.058	0.992-1.128	0.997	0.932-1.067	1.000	0.937-1.067	1.242	0.962-1.604
	3	1.087	0.978-1.208	1.028	0.966-1.094	1.031	0.972-1.094	0.996	0.921-1.077	1.238	0.988-1.550
	4	1.079	0.975-1.194	1.070	0.988-1.158	1.066	0.995-1.142	1.007	0.944-1.073	0.895	0.666-1.203
	0-1	0.924	0.808-1.057	1.077	0.989-1.174	1.015	0.943-1.092	1.102	0.984-1.233	1.302	0.936-1.810
	0-2	0.902	0.771-1.055	1.120	1.015-1.237	1.012	0.933-1.099	1.088	0.958-1.235	1.503	1.013-2.229
	0-3	0.942	0.793-1.120	1.139	1.020-1.273	1.022	0.935-1.117	1.086	0.940-1.255	1.628	1.078-2.457
	0-4	0.985	0.818-1.186	1.174	1.037-1.328	1.047	0.949-1.154	1.087	0.937-1.260	1.499	0.955-2.351
Older ≥71 (192)	0	1.035	0.901-1.188	0.995	0.898-1.102	1.038	0.940-1.147	1.089	0.967-1.226	1.096	0.815-1.475
	1	0.985	0.853-1.137	1.000	0.891-1.122	1.001	0.910-1.101	0.974	0.833-1.140	1.065	0.763-1.485
	2	1.099	0.953-1.267	1.186	1.066-1.320	1.034	0.942-1.135	0.989	0.901-1.085	1.210	0.883-1.659
	3	1.030	0.894-1.188	1.054	0.981-1.134	1.032	0.931-1.144	0.823	0.513-1.318	1.315	0.992-1.744
	4	1.071	0.943-1.216	1.057	0.969-1.152	1.024	0.938-1.117	1.000	0.895-1.117	0.887	0.618-1.272
	0-1	0.999	0.839-1.190	0.997	0.872-1.141	1.019	0.912-1.138	1.065	0.917-1.236	1.154	0.776-1.717
	0-2	1.055	0.862-1.291	1.151	1.005-1.319	1.036	0.921-1.164	1.045	0.891-1.226	1.266	0.796-2.014
	0-3	1.060	0.848-1.325	1.197	1.033-1.386	1.038	0.910-1.185	0.993	0.824-1.197	1.460	0.906-2.354
	0-4	1.087	0.860-1.374	1.243	1.056-1.463	1.056	0.915-1.218	0.998	0.824-1.208	1.371	0.808-2.324
Younger <71 (261)	0	0.961	0.853-1.083	1.037	0.958-1.122	0.962	0.885-1.045	1.083	0.975-1.204	1.242	0.941-1.640
	1	1.019	0.905-1.148	1.055	0.993-1.122	0.989	0.916-1.068	0.998	0.833-1.195	1.031	0.724-1.469
	2	0.892	0.784-1.014	1.059	0.978-1.147	0.965	0.889-1.048	1.005	0.914-1.105	1.019	0.723-1.438
	3	1.076	0.957-1.209	1.025	0.958-1.097	1.020	0.956-1.088	1.069	0.941-1.214	1.094	0.814-1.470
	4	1.123	1.002-1.259	0.992	0.893-1.101	1.083	0.991-1.183	1.007	0.930-1.091	0.926	0.653-1.312
	0-1	0.973	0.837-1.132	1.075	0.990-1.166	0.970	0.887-1.060	1.108	0.941-1.306	1.236	0.840-1.818
	0-2	0.890	0.744-1.065	1.117	1.007-1.238	0.959	0.869-1.058	1.108	0.907-1.353	1.286	0.799-2.069

0-3	0.930	0.761-1.136	1.136	1.009-1.279	0.975	0.881-1.080	1.149	0.915-1.445	1.349	0.808-2.253
0-4	1.162	0.720-1.874	1.133	0.856-1.499	0.951	0.708-1.277	0.047	0.002-1.342	2.088	0.734-5.942

Table 3 Continued

Older females (57)	0	1.394	1.036-1.876	0.926	0.750-1.142	0.772	0.523-1.140	0.420	0.024-7.404	0.847	0.418-1.713
	1	0.970	0.717-1.312	1.020	0.840-1.238	0.927	0.767-1.119	0.454	0.045-4.562	1.168	0.676-2.019
	2	1.228	0.926-1.628	1.177	1.010-1.371	0.983	0.840-1.151	0.150	0.005-4.657	0.534	0.182-1.565
	3	1.002	0.778-1.291	1.039	0.945-1.144	0.966	0.781-1.194	0.630	0.101-3.918	1.074	0.633-1.823
	4	1.128	0.908-1.401	0.925	0.772-1.108	0.935	0.761-1.148	3.684	0.414-32.751	0.736	0.351-1.545
	0-1	1.330	0.907-1.950	0.967	0.753-1.242	0.861	0.653-1.136	0.470	0.028-7.870	0.994	0.472-2.093
	0-2	1.435	0.941-2.189	1.105	0.869-1.404	0.933	0.732-1.189	0.195	0.006-6.790	0.777	0.270-2.242
	0-3	1.364	0.879-2.115	1.167	0.916-1.486	0.931	0.726-1.194	0.174	0.006-5.284	0.951	0.338-2.669
	0-4	1.401	0.924-2.124	1.116	0.847-1.469	0.918	0.701-1.201	0.421	0.017-10.137	0.727	0.217-2.434
Younger females (68)	0	1.131	0.873-1.465	1.052	0.864-1.281	0.930	0.776-1.113	0.184	0.017-2.013	2.148	1.038-4.446
	1	1.074	0.853-1.350	1.013	0.926-1.109	0.857	0.649-1.130	0.896	0.250-3.212	0.958	0.509-1.800
	2	0.853	0.661-1.100	1.186	0.976-1.440	0.901	0.714-1.137	0.481	0.072-3.209	1.194	0.638-2.232
	3	1.062	0.815-1.384	1.037	0.879-1.224	0.999	0.834-1.197	0.097	0.007-1.338	1.248	0.608-2.560
	4	1.186	0.910-1.546	0.880	0.693-1.118	1.197	0.964-1.486	0.187	0.023-1.544	1.137	0.603-2.146
	0-1	1.149	0.828-1.595	1.044	0.900-1.211	0.892	0.696-1.142	0.363	0.045-2.893	1.624	0.711-3.711
	0-2	1.001	0.687-1.459	1.124	0.921-1.371	0.866	0.653-1.150	0.277	0.027-2.883	1.763	0.701-4.434
	0-3	1.013	0.652-1.573	1.167	0.910-1.496	0.896	0.674-1.192	0.105	0.006-1.872	2.165	0.764-6.133
	0-4	1.162	0.720-1.874	1.133	0.856-1.499	0.951	0.708-1.277	0.047	0.002-1.342	2.088	0.734-5.942
Older males (135)	0	0.940	0.795-1.111	1.021	0.907-1.150	1.079	0.969-1.202	1.097	0.971-1.240	1.222	0.877-1.703
	1	1.000	0.846-1.183	0.985	0.846-1.145	1.032	0.925-1.151	0.996	0.851-1.164	1.116	0.722-1.725
	2	1.095	0.919-1.305	1.167	1.001-1.362	1.039	0.920-1.172	0.984	0.897-1.079	1.483	1.019-2.159
	3	1.053	0.881-1.258	1.058	0.947-1.182	1.059	0.940-1.192	0.831	0.518-1.334	1.457	1.000-2.121
	4	1.006	0.850-1.191	1.126	1.005-1.262	1.051	0.952-1.161	1.003	0.895-1.123	0.938	0.910-1.440
	0-1	0.920	0.748-1.132	1.010	0.856-1.191	1.067	0.943-1.207	1.090	0.938-1.268	1.381	0.848-2.248
	0-2	0.948	0.745-1.208	1.138	0.959-1.350	1.078	0.937-1.240	1.062	0.906-1.245	1.738	1.000-3.021
	0-3	0.966	0.739-1.263	1.177	0.972-1.424	1.092	0.924-1.289	1.020	0.846-1.230	1.963	1.062-3.628
	0-4	0.949	0.709-1.272	1.280	1.037-1.579	1.125	0.942-1.344	1.033	0.851-1.254	1.907	0.990-3.673
Younger males (193)	0	0.941	0.818-1.081	1.050	0.960-1.147	0.971	0.883-1.067	1.093	0.981-1.217	1.194	0.871-1.637
	1	0.984	0.855-1.134	1.097	1.009-1.193	1.005	0.929-1.087	1.001	0.834-1.203	1.076	0.694-1.668
	2	0.922	0.792-1.074	1.018	0.926-1.118	0.976	0.894-1.066	1.011	0.919-1.113	0.974	0.640-1.484
	3	1.111	0.970-1.272	1.017	0.942-1.099	1.025	0.956-1.098	1.082	0.945-1.238	1.108	0.798-1.538
	4	1.134	0.997-1.291	1.017	0.905-1.143	1.076	0.975-1.188	1.013	0.936-1.096	0.850	0.559-1.292
	0-1	0.932	0.781-1.113	1.110	1.003-1.229	0.989	0.899-1.087	1.123	0.948-1.329	1.208	0.767-1.902
	0-2	0.868	0.704-1.071	1.127	0.995-1.276	0.979	0.882-1.086	1.134	0.919-1.400	1.244	0.697-2.222
	0-3	0.929	0.738-1.169	1.125	0.979-1.293	0.993	0.891-1.107	1.186	0.924-1.522	1.318	0.716-2.426
	0-4	1.020	0.801-1.300	1.123	0.961-1.312	1.017	0.902-1.146	1.185	0.903-1.556	1.173	0.596-2.306
Winter (236)	0	1.003	0.906-1.111	1.064	0.992-1.141	0.958	0.884-1.039	1.119	0.990-1.265	1.224	0.980-1.529
	1	1.030	0.927-1.145	1.047	0.984-1.115	0.982	0.905-1.065	0.957	0.781-1.172	0.988	0.741-1.319
	2	1.021	0.919-1.133	1.071	1.003-1.143	0.988	0.908-1.076	0.972	0.886-1.067	1.129	0.878-1.451
	3	1.082	0.979-1.195	1.038	0.980-1.100	0.995	0.926-1.069	0.990	0.912-1.074	1.207	0.976-1.493
	4	1.087	0.988-1.195	1.085	0.993-1.187	1.089	0.995-1.191	0.979	0.900-1.064	0.951	0.722-1.252
	0-1	1.013	0.889-1.154	1.089	1.003-1.182	0.961	0.877-1.054	1.104	0.953-1.279	1.200	0.876-1.645
	0-2	1.016	0.873-1.183	1.148	1.041-1.266	0.965	0.872-1.068	1.037	0.874-1.230	1.301	0.889-1.904
	0-3	1.056	0.892-1.249	1.187	1.061-1.328	0.965	0.866-1.075	1.016	0.848-1.218	1.451	0.980-2.149
	0-4	1.109	0.927-1.326	1.240	1.089-1.412	0.989	0.881-1.111	0.996	0.833-1.191	1.362	0.882-2.104
Summer (217)	0	0.914	0.743-1.126	0.864	0.736-1.014	1.036	0.934-1.148	1.083	0.967-1.214	1.043	0.633-1.717
	1	0.993	0.814-1.211	0.997	0.889-1.118	1.008	0.920-1.105	0.984	0.852-1.136	1.441	0.888-2.340

2	0.821	0.658-1.023	1.175	1.046-1.320	0.992	0.912-1.079	1.175	0.915-1.509	1.009	0.583-1.744
3	0.927	0.753-1.142	1.047	0.951-1.152	1.073	0.982-1.172	1.041	0.723-1.499	0.964	0.540-1.720
4	1.036	0.841-1.275	0.951	0.844-1.072	1.022	0.938-1.114	1.373	0.863-2.187	0.759	0.416-1.384
0-1	0.903	0.703-1.160	0.910	0.773-1.071	1.027	0.920-1.147	1.073	0.917-1.257	1.363	0.763-2.435
0-2	0.800	0.594-1.076	1.033	0.878-1.216	1.014	0.907-1.135	1.132	0.920-1.393	1.360	0.684-2.703
0-3	0.764	0.546-1.070	1.061	0.891-1.263	1.039	0.921-1.172	1.176	0.902-1.534	1.354	0.617-2.970
0-4	0.802	0.556-1.156	1.021	0.843-1.236	1.056	0.924-1.207	1.257	0.925-1.708	1.133	0.479-2.679

Table 4 Number of visits (n), odds ratios (OR) and 95% confidence intervals (CI) for the daily emergency hospital visits for cardiac arrest with successful resuscitation(ICD-10 code: I46.0) and other cardiac arrest categories grouped together (ICD-10 codes I46, I46.1 and I46.9) in Reykjavik capital area associated with 10 μg/m³ increase in NO_2, PM_{10}, $PM_{2.5}$, SO_2, and H_2S, adjusted for each pollutant, temperature and relative humidity, at lag 0 to lag 4, lag 0-1, lag 0-2, lag 0-3, and lag 0-4.

		NO_2		PM_{10}		$PM_{2.5}$		SO_2		H_2S	
Categories/Visits (n)	**Lag**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
I46.0 (194)	0	0.988	0.856-1.139	1.057	0.967-1.156	0.983	0.875-1.105	1.386	0.758-2.534	1.008	0.735-1.383
	1	1.012	0.881-1.163	1.053	0.982-1.129	0.999	0.894-1.115	0.845	0.471-1.515	1.055	0.707-1.577
	2	0.953	0.826-1.100	1.104	1.002-1.216	1.037	0.957-1.125	1.078	0.893-1.301	1.177	0.797-1.737
	3	1.072	0.937-1.227	1.035	0.941-1.138	1.088	1.001-1.182	0.995	0.910-1.089	1.141	0.794-1.642
	4	1.194	1.023-1.393	1.040	0.936-1.157	1.104	1.006-1.211	0.292	0.084-1.010	1.313	0.847-2.036
	0-1	0.992	0.832-1.183	1.083	0.985-1.190	0.987	0.870-1.121	1.167	0.932-1.462	1.050	0.663-1.664
	0-2	0.952	0.774-1.171	1.153	1.021-1.301	1.017	0.899-1.150	1.196	0.941-1.520	1.203	0.680-2.129
	0-3	0.986	0.781-1.246	1.202	1.039-1.392	1.058	0.936-1.197	1.120	0.879-1.426	1.323	0.693-2.527
	0-4	1.047	0.818-1.340	1.209	1.027-1.422	1.093	0.957-1.248	1.015	0.785-1.314	1.421	0.702-2.877
I46, I46.1, I46.9 (259)	0	0.983	0.875-1.105	0.991	0.909-1.081	0.992	0.921-1.068	1.055	0.964-1.155	1.327	1.012-1.739
	1	0.998	0.882-1.130	1.024	0.940-1.116	0.991	0.923-1.065	0.996	0.876-1.132	1.055	0.778-1.430
	2	0.985	0.869-1.116	1.090	1.013-1.173	0.945	0.861-1.036	0.987	0.914-1.067	1.123	0.843-1.497
	3	1.041	0.923-1.176	1.027	0.968-1.089	0.960	0.876-1.052	0.993	0.829-1.190	1.191	0.943-1.505
	4	1.082	0.975-1.201	1.030	0.945-1.121	1.012	0.929-1.102	1.056	0.968-1.152	0.781	0.564-1.082
	0-1	0.972	0.835-1.130	1.011	0.908-1.126	0.987	0.908-1.072	1.051	0.927-1.190	1.312	0.928-1.856
	0-2	0.958	0.803-1.142	1.093	0.976-1.223	0.968	0.879-1.066	1.030	0.895-1.185	1.386	0.922-2.084
	0-3	0.968	0.796-1.177	1.108	0.982-1.250	0.951	0.852-1.062	1.033	0.869-1.227	1.485	0.984-2.240
	0-4	1.019	0.830-1.252	1.126	0.983-1.290	0.963	0.852-1.087	1.079	0.905-1.286	1.283	0.813-2.027

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Ambient air pollution and emergency department visits and hospitalisation for cardiac arrest: a population-based case-crossover study in Reykjavik, Iceland

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Abstract

Objectives To assess the association between traffic-related ambient air pollution and emergency hospital visits for cardiac arrest.

Design Case-crossover design was used with a lag time to 4 days.

Setting The Reykjavik capital area and the study population was the inhabitants 18 years and older identified by encrypted personal identification numbers and zip codes.

Participants and exposure Cases were those with emergency visits to Landspitali University Hospital during the period 2006 to 2017 and who were given the primary discharge diagnosis of cardiac arrest according to The International Classification of Diseases 10th edition (ICD-10), code I46. The pollutants were NO_2, PM_{10}, $PM_{2.5}$, and SO_2 with adjustment for H_2S, temperature and relative humidity.

Main outcome measure Odds ratio (OR) and 95% confidence intervals (CI) per 10 $\mu g/m^3$ increase in concentration of pollutants.

Results: The 24-h mean NO_2 was 20.7 $\mu g/m^3$, mean PM_{10} was 20.5 $\mu g/m^3$, mean $PM_{2.5}$ was 12.5 $\mu g/m^3$, and mean SO_2 was 2.5 $\mu g/m^3$. PM_{10} level was positively associated with the number of emergency hospital visits (n=453) for cardiac arrest. Each 10 $\mu g/m^3$ increase in PM_{10} was associated with increased risk of cardiac arrest (ICD-10: I46), odds ratio (OR) 1.096 (95%CI 1.033-1.162) on lag 2, OR 1.118 (95%CI 1.031-1.212) on lag 0-2, OR 1.150 (95% CI 1.050-1.261) on lag 0-3, and OR 1.168 (95% CI 1.054-1.295) on lag 0-4. Significant associations were shown between exposure to PM_{10} on lag 2 and lag 0-2 and increased risk of cardiac arrest in the age, gender, and season strata.

Conclusions: A new endpoint was used for the first time in this study: cardiac arrest (ICD-10 code I46) according to hospital discharge registry. Short-term increase in PM_{10} concentrations

was associated with cardiac arrest. Future ecological studies of this type and their related discussions should perhaps concentrate more on precisely defined endpoints.

Key words Cardiac arrest, urgent hospital visits, successful resuscitation, multivariate models, cardiovascular diseases

Strengths and limitations of this study

- The study is population-based, relies on comprehensive population registries, and includes information on daily concentrations of the pollutants which cover more than 75% of the days in the study period.
- The methodology allows within-subject comparison while adjusting for various time trends such as seasonality, and day of week.
- The concentration of the pollutants derived from one monitoring station, and not from individual exposure measurements.
- The population is small, and therefore the total number of cases were few, resulting in low statistical power.

Introduction

Epidemiological studies have found increased risk of cardiovascular morbidity and mortality in association with particulate matter (PM) in air pollution (1,2), and the overall evidence is considered to support the existence of a causal relationship between PM exposure and cardiovascular morbidity, primarily due to fine particles (2). Both short-term and long-term PM air pollution contributes to cardiovascular morbidity and mortality (1,2). Urban ambient air pollution is a complex mixture of gases, particles and liquid, and in an attempt to monitor air quality, certain pollutants are traditionally measured. However, adverse cardiovascular health impacts of exposure to a combination of air pollutants are not completely understood at present. A recent multilocation analysis found that a short-term increase in NO_2 on the previous day was associated with an increased risk of daily total, cardiovascular, and respiratory mortality (3). In a systemic review and meta-analysis of short-term exposure to NO_2 and ischemic heart diseases, the authors concluded that the relationship was likely causal (4), but uncertainties remained due to possible confounding in the epidemiological studies and lack of evidence from mechanistic studies. Several epidemiological studies have found that NO_2 and PM are associated with cardiovascular diseases (CVD), and the endpoints studied have included not only mortality from CVD (3), but also discharge diagnosis at hospitals and emergency departments for a wide range of CVD, ischemic heart disease, myocardial infarction, and different cardiac dysrhythmias (5-10). In a large US study (9), acute myocardial infarction, and multiple other cardiovascular outcomes, like cardiac dysrhythmia and heart failure were found to be associated with particulate air pollution; however, in that analysis it was only possible to consider potential confounding by ozone, not by other pollutants. In a case-crossover study in China, an association was found between particulate matter, NO_2, and carbon monoxide, and the number of hospital admissions for cardiac arrhythmia (10). In another case-crossover study in the UK (8), the risk of emergency hospital admissions for CVD, arrhythmias, atrial fibrillation, and heart failure was associated with an increased concentration of NO_2; however, cardiac arrest was not included as an outcome in the study. Cardiac arrest was mentioned in the aforementioned Chinese study (10) but was not analysed separately.

There are several studies on the association between air pollution and out-of-hospital cardiac arrest (OHCA) (11-15). The risk of OHCA was associated with a short-term increase in exposure to particulate matter, sometimes $PM_{2.5}$, or ultrafine particulate matter (11-14), and sometimes PM_{10} (15), with various associations with O_3, other gaseous pollutants, and high temperature. The collection of cases in the OHCA studies use special registers as a source, regarding Utstein definition (16,17) with the original purpose to provide a structured framework to evaluate emergency medical service. The main criteria in the definition of the cases in the OHCA studies are: 1) the cardiovascular collapse has occurred outside a hospital, and 2) the event has elicited a resuscitation attempt. Neither of these conditions is required for the physician given diagnosis of cardiac arrest according to the International Classification of Diseases 10th edition (ICD-10) code I46 registered as discharge diagnosis at hospitals or emergency departments.

The comprehensive population and health registries in Iceland make this an optimal setting to study the association between relatively low daily exposure to air pollution, and different heart-related conditions (7,18,19). The aim of the present study was to explore the association between traffic-related pollutants, NO_2, PM_{10}, $PM_{2.5}$, and SO_2 in the Reykjavik capital area and urgent hospital and emergency department visits for cardiac arrest, ICD-10 code I46, as the primary discharge diagnosis, and to simultaneously adjust for meteorological variables and geothermal-originated pollutants.

Methods

Study base

The Reykjavik capital area is in the southwestern part of Iceland. Traffic emission is the main source of air pollution in the city. Other sources of air pollution include two geothermal power plants: Hellisheidi, located 26 km east-southeast of the city, and Nesjavellir, located 33 km east of the city. Ambient H_2S emissions originate from the plants. Reykjavik's capital area spreads over 247.5 km^2 and in 2017 the inhabitants numbered 217,000, equivalent to approximately two-thirds of the total Icelandic population (20). The study base included the residents of the Reykjavik capital area, which consists of seven municipalities (Gardabaer, Hafnarfjordur, Kjosarhreppur, Kopavogur, Mosfellsbaer, Reykjavik, and Seltjarnarnes) identified by 24 zip codes.

Health data

Hospital discharge data were obtained from January 1 2006 to December 31 2017 from computerised records in SAGA (Register of hospital-treated patients in Iceland) for certain heart diseases; the procedures have been described in a previous publication (7). The study included adult inhabitants (≥18 years) of the Reykjavik capital area, identified by zip code. We analysed data on urgent visits to the emergency department and urgent admissions to in-patient wards of Landspitali University Hospital (LUH). The study was confined to new admissions, meaning that no visits by appointment were included. LUH is operated by the Icelandic government and is the only acute care hospital serving the population of the Reykjavik capital area, making this study population-based. In Iceland, the national health insurance scheme is covered by taxes and is available to all residents. For ambulatory visits, patients pay a small fee that amounts to approximately 10 to 15 US dollars, but seniors are exempt from payment. Admission to the hospital ward is free of charge. Every inhabitant of Iceland receives a personal identification number at birth (or at immigration), and the

identification numbers are widely used in Icelandic society and population registries, including the SAGA register. We received the identification numbers in encrypted form, which enabled us to identify repeated visits to LUH. Readmissions to LUH within 10 days with the same ICD-10 primary discharge diagnosis were excluded. From the SAGA register we received the following details: admission date, encrypted identification number, unique number of the admission, age, gender, and primary discharge diagnosis for certain codes according to the International Classification of Diseases 10th edition (ICD-10). In this study, both admission to the emergency department and formal admission to the hospital are included, so there is no requirement that a patient stayed overnight. The diagnoses are registered at discharge from the hospital, transfer to another hospital, and death in the hospital. In a previous study (7), the outcomes were heart diseases ICD-10 codes: I20-I25, I44-I50, ischemic heart diseases ICD-10 codes: I20-I25, cardiac arrhythmias and heart failure ICD-10 codes: I44-I50, and atrial fibrillation ICD-10 I48 (7). In the present study, the outcome analysed was cardiac arrest ICD-10 code I46. Emergency department visits and urgent hospital admissions were combined and are called emergency hospital visits.

Air pollutants and meteorological data

Information on pollution was obtained from Grensas monitor station (GRE), operated by the governmental institution Environment Agency of Iceland. GRE is in the centre of the Reykjavik capital area near one of the busiest road intersections in the city. Other stations in the city were not permanently located or were not continuously monitoring throughout the study period and were therefore not used in the study. However, to test whether GRE was reflective of the total capital area, Pearson's correlation was calculated for GRE measurements and measurements from another station located in Dalsmari, Kopavogur municipality, for the period 2014-2017. Results of Pearson's correlation coefficients between

these two measurement stations were for PM_{10} 0.44, for NO_2 0.78, for SO_2 0.98, and for H_2S 0.84. PM2.5 was not measured in Dalsmari.

Pollutants measured at GRE were NO_2, particulate matter with aerodynamic diameter less than 10 µm (PM_{10}), particulate matter with aerodynamic diameter less than 2.5 µm ($PM_{2.5}$), sulphur dioxide (SO_2), and hydrogen sulphide (H_2S), all measured in µg/m³. The meteorological data was obtained from the governmental institution Icelandic Meteorological Office and included temperature (°C) and relative humidity (RH). PM_{10} and $PM_{2.5}$ were measured with an Andersen EMS IR Thermo (model FH62 I-R), NO_2 with Horiba device (model APNA 360E), and SO_2 and H_2S with the Horiba model APOA 360E. Every 6-12 months the devices are calibrated. Exposure data included 12 years or 4,383 days. Daily averages (midnight to midnight the following day) were calculated from hourly concentrations if at least 75% of one-hour data existed. Missing daily averages for NO_2, PM_{10}, $PM_{2.5}$, SO_2, and H_2S were 383 days (8.7%), 165 days (3.8%), 923 days (21.1%), 200 days (4.6%), and 284 days (6.5%), respectively. Data gaps were seen and can be attributed to inactive measurement devices due to unknown causes, with the exception of 52 days of missing H_2S measurements at the beginning of the study period, as H_2S measurements at GRE started at the end of February 2006. For temperature and RH, 6 days (0.1%) and 6 days (0.1%) were missing, respectively. Minor gaps in the curves were fitted by linear interpolation.

Descriptive statistics were calculated and showed as daily concentration levels in µg/m³ of the pollutants, as well as Spearman's correlation coefficient between pollutants and meteorological factors.

Patient and public involvement

No patient was involved.

Analysis

Short-term associations between daily exposure to air pollutants and emergent hospital visits for cardiac arrest (ICD-10 code I46) were assessed using bidirectional time-stratified case-crossover design. The study period was divided into monthly strata, and exposure during case periods (24h) was compared to exposure during control periods, which were matched as the same weekdays within the same month (3-4 control periods per case period) (21,22). The matches control for measured or unmeasured personal confounding characteristics that do not vary over the relatively short time, such as gender, age, and genetic factors. We did several calculations: single pollutant models were calculated in conditional logistic regression, multivariate models containing all traffic-related pollutants, H_2S, and the meteorological variables. Separate analyses were done for subgroups according to gender, age (≥71 and < 71 years), gender and age combined, winter (November 1st to April 30th), and summer (May 1st to October 31st). It was possible to divide the diagnostic category I46 according to decimals into cardiac arrest with successful resuscitation (I46.0) and other categories without indication of successful resuscitation (I46, I46.1, and I46.9). These two subcategories were also analysed separately as there are indications that the latter category concerns mortality. The risk estimates were expressed as odds ratio (OR), and 95% confidence intervals (CI) were calculated for every 10 $\mu g/m^3$ increase of pollutants (24h concentrations).

As the possible response period of discharge diagnosis of cardiac arrest after exposure to air pollutants is not known we conducted the analyses with lags exposures for 0 to 4 days. Lag 0 was the average concentration on the day of the admission, lag 1 was the average concentration on the day before admission, and so on for the higher numbers of lags. Different lag structures were applied. Single-day lag structure (lag 0 to lag 4), and multiple-day lag structure (lag 0-1, lag 0-2, lag 0-3, and lag 0-4, moving average of pollutants concentration) were employed in the analyses to explore the temporal association between pollutants and cardiac arrest. The results of the multivariate models with all lag structures are presented in the article, and other results are shown as Supplementary data.

Although readmissions within 10 days with the same primary discharge diagnosis were excluded, it is still possible that some patients first went to the emergency department and were subsequently admitted that same day to in-hospital wards where they might have received a different diagnosis than they were given at the emergency department. To test whether this could distort the main result of the association between increased pollutant concentration and emergency hospital visits, a sensitivity analysis was done, in which data was restricted to emergency department visits only.

Statistical analysis was done with R version 4.0.3 (https://www.r-project.org/). Statistical tests used in this study were all two-tailed and we considered results statistically significant for $p < 0.05$.

The study was approved by the National Bioethics Committee (ref. no. VSNb2018120011/03.01), the Data Protection Authority (ref. no. 10-050), and the Scientific Committee of LUH.

Results

The basic characteristics of cardiac arrest according to subcategories are shown in Table 1. The total number of visits with primary discharge diagnosis cardiac arrest (ICD-10 code I46) was 453, and repeated visits were extremely rare. The distribution of the 453 visits was even over the 4383-day study period. One visit per day was most common, but there were several days with up to two visits, which was the highest number of visits per day; thus, most days were without visits with cardiac arrest. The median age at the time of visits was 71 years. Descriptive statistics and Spearman's correlation coefficients of traffic-related pollutants, H_2S, and meteorological variables are presented in Table 2. Missing daily average was highest for $PM_{2.5}$ but did not exceed 25% of the days of the study period. The concentrations of PM_{10} and $PM_{2.5}$ were correlated, particulate matter did not correlate with the gaseous pollutants, and correlations among gaseous pollutants were moderate.

In the single pollutant analyses, positive associations were observed for exposure to PM_{10} at lag 2 and lag 0-2, and unstratified emergency hospital visits for cardiac arrest (ICD-10 codes: I46); the increased risks of cardiac arrest were OR 1.077 (95% CI 1.020-1.137) and OR 1.097 (95% CI 1.016-1.184), respectively, per 10 μg/m³ increase of PM_{10}, as shown in Table A, Supplementary data. A positive association was observed between exposure to NO_2 at lag 4 and the increased risk of cardiac arrest; the increased risk was OR 1.081 (95% CI 1.002-1.166) per 10 μg/m³ increase of NO_2, as shown in Table A, Supplementary data.

In examining the daily lag exposure to PM_{10} and unstratified emergency hospital visits for cardiac arrest, positive associations were observed in the multivariate model; the increased risks of cardiac arrest were OR 1.096 (95% CI 1.033-1.162) for lag 2, OR 1.118 (95% CI 1.031-1.212) for lag 0-2, OR 1.150 (95% CI 1.050-1.261) for lag 0-3, and OR 1.168 (95% CI 1.054-1.295) for lag 0-4 per 10 μg/m³ increase of PM_{10} (Table 3). Significant associations were shown for exposure to NO_2 at lag 4 and for SO_2 at lag 0, and unstratified emergency

hospital visits for cardiac arrest; the increased risks were OR 1.096 (95% CI 1.008-1.192) and OR 1.084 (95% CI 1.002-1.173) per 10 μg/m³ increase of NO_2 and SO_2, respectively (Table 3).

In the multivariate model significant associations were shown between exposure to PM_{10} at lag 2 and at lag 0-2, lag 0-3, and lag 0-4, and increased risks of cardiac arrest (ICD-10 code I46), in the age, gender, age and gender combined, and season strata, i.e., in all the strata except in the stratum of young females as shown in Table B, and Table C, Supplementary data. In Figure 1, OR and 95% CI of cardiac arrest per 10 μg/m³ increase of PM_{10} concentrations in multi-pollutant models are shown at lag 0 to lag 4 for different strata and unstratified.

In the single pollutant analyses, positive associations were observed for exposure to PM_{10} at lag 0-3, and lag 0-4, and emergency hospital visits for cardiac arrest with successful resuscitation (ICD-10 codes: I46.0); the increased risks of cardiac arrest were OR 1.161 (95% CI 1.014-1.329), and OR 1.177 (95% CI 1.013-1.368), respectively, per 10 μg/m³ increase of PM_{10}, as shown in Table D, Supplementary data. A positive association was observed for exposure to $PM_{2.5}$ at lag 3, and lag 4, and the increased risk of cardiac arrest with successful resuscitation; the increased risk was OR 1.090 (95% CI 1.008-1.178), and OR 1.101 (95% CI 1.006-1.204), per 10 μg/m³ increase of $PM_{2.5}$, respectively, as shown in Table D, Supplementary data. A positive association was observed for exposure to PM_{10} at lag 2, and the increased risk of cardiac arrest without indication of successful resuscitation (ICD-10 codes: I46, I46.1, and I46.9); the increased risk was OR 1.079 (95% CI 1.008-1.155), as shown in Table D, Supplementary data.

In the multivariate model a positive association was observed between exposure to PM_{10} and emergency hospital visits for cardiac arrest with successful resuscitation (ICD-10 code: I46.0); the increased risks of cardiac arrest were OR 1.104 (95% CI 1.002-1.216) at lag 2, OR

1.153 (95% CI 1.021-1.301) at lag 0-2, OR 1.202 (95% CI 1.039-1.392) at lag 0-3, and OR 1.209 (95% CI 1.027-1.422) at lag 0-4, per 10 μg/m³ increase of PM_{10}, as shown in Table 4. A positive association was observed between exposure to $PM_{2.5}$ and the increased risk of cardiac arrest with successful resuscitation; the increased risk was OR 1.088 (95% CI 1.001-1.182) at lag 3, and OR 1.104 (95% CI 1.006-1.21) at lag 4, per 10 μg/m³ increase of $PM_{2.5}$, as shown in Table 4. A positive association was observed between exposure to PM_{10} and the increased risk of cardiac arrest without indication of successful resuscitation (ICD-10 codes: I46, I46.1, and I46.9); the increased risk was OR 1.090 (95% CI 1.013-1.173) at lag 2, as shown in Table 4. In Figure 2, OR and 95% CI of cardiac arrest per 10 μg/m³ increase of PM_{10} concentrations in multi-pollutant models are shown at lag 0 to lag 4 when stratified on season and whether there is an indication of successful resuscitation or not.

In the sensitive analysis of the association between daily exposure to PM_{10} and emergency hospital visits for cardiac arrest (ICD-10 code I46), when restricting the calculation to emergency department visits only (353 visits), the results did not change substantially: in the unstratified analysis, the increased risk of cardiac arrest was OR 1.099 (95% CI 1.028-1.175) at lag 2 per 10 μg/m³ increase of PM_{10}.

Discussion

Our study examined the association between ambient air pollution and emergency hospitalization and emergency department visits where the primary discharge diagnosis was cardiac arrest (ICD-10 code I46). To our knowledge, that single outcome has not been used in previous studies of a similar type. The main results of this study were the association between increased PM_{10} and cardiac arrest at lag 2, lag 0-2, lag 0-3, and lag 0-4, so the 24-hour concentrations of PM_{10} seem to be clearly separated from the event registered at the hospital and happened before the admittance. The effects seemed high in most subcategories, in both seasons, and among those who were successfully resuscitated.

Cardiac arrest is a life-threatening event and may be the most serious outcome of CVD. The decimal following the code I46 indicates whether the patients were successfully resuscitated or not. Patients categorised as I46 comprise those who have survived and those who have died, and in the present study these are in nearly equal proportion. The associations between pollutants and mortality and hospital admission are commonly analysed separately (8). The primary discharge diagnosis cardiac arrest (ICD-10 code I46) has in previous studies been included within all CVD, or large subgroups such as cardiac dysrhythmias, and the endpoint closest to this entity may be OHCA. However, there is a difference between patients with the diagnosis of cardiac arrest (ICD-10 code I46) at hospitals and persons included in studies on OHCA. OHCA has often been the subject of air pollution studies. In a review of 67 studies on OHCA (23), OHCA was associated with high mortality, with a global average survival rate of 7%, but in the present study 42.8% of the registered cases with the ICD-10 code I46, cardiac arrest, were successfully resuscitated, a considerable difference in survival rates. The definition of OHCA is: 1) the cardiovascular collapse has occurred outside a hospital, and 2) the event has elicited a resuscitation attempt, and these conditions are not required for cardiac arrest according to ICD-10 code I46, when this diagnosis is used at hospitals or emergency departments. In addition, the Utstein definition recommends registration of several time points and intervals important for the research and quality assurance related to the resuscitation, but such time elements are not required in the hospital discharge registries based on the ICD-10. Some studies have shown that the risks of OHCA were associated with a short-term increase in exposure to particulate matter, sometimes $PM_{2.5}$, or ultrafine particulate matter (11-14), and sometimes PM_{10} (15), with various associations with O_3, other gaseous pollutants, and high temperature. An OHCA study conducted in Stockholm, Sweden demonstrated a significant exposure-response association between OHCA risk and O_3, but no association for $PM_{2,5}$ or NO_2, (24), while another OHCA study in Lombardy, Italy, showed, with a different methodology, that the concentrations of all the pollutants in the study were significantly higher in days with high incidence of OHCA except for O_3 (25). In these OHCA studies (11-15,24,25) no difference is made between those who survive the event and those who do not survive. In the previously mentioned UK study (8) on the association between air pollution and hospital admission for different cardiovascular events, exposure to NO_2 was significant, while in the same publication some of the mortality outcomes were associated with exposure to $PM_{2.5}$ but not to NO_2 (8), indicating the possibility of different pathogenetic pathways for the outcomes, as has been discussed briefly in the case of NO_2 (4), and in the comprehensive review of the causal role of particulate material (2). The category cardiac arrest in the ICD-10 coding system represents a small group compared to other CVD diagnoses and seems to be concealed within the larger summary group of cardiac arrhythmias (10) or omitted from the analysis (8). In this respect, our recent study on the same dataset is not an exception: increased risk of cardiac arrhythmias (ICD-10 codes I44 to I50) was associated with an increase in NO_2 exposure (7), a finding that hides the association between cardiac arrest (ICD-10 code I46) and exposure to PM_{10} as demonstrated in the present study.

Among the strengths of this study is that it is population-based, as the hospital and emergency department data were obtained from the only emergency healthcare institution, the LUH, serving the population in the catchment area of the Reykjavik capital. The design of the study is also a strength, as the bidirectional time-stratified case-crossover approach virtually excludes confounding of individual characteristics and the matching adjusted for weekly pattern and time trends. Another strength of the study is its use of the encrypted identification number of each patient in the Register of hospital-treated patients, which ensures the correct counting and identification of the cases and their admissions. Furthermore, it is noteworthy that visits of the cases receiving the primary discharge diagnosis of cardiac arrest (453 cases) were evenly distributed over the study period (4383 days), so the distribution diminished the risk of overlapping the sets of case and control days.

That said, there are few limitations. First, the concentration of the pollutants derived from one monitoring station in the Reykjavik capital area, and not from individual exposure measurements. The results from these measurements did, however, correlate well with measurements from another monitoring station located in the capital area during three years of the study period. Another limitation is that only the primary discharge diagnosis was included in the study, meaning that the cases may have underlying diseases that could modify the result.

Furthermore, the quality of the routine discharge diagnosis at the LUH has not been investigated in a separate study for accuracy or reliability, which is a weakness our study shares with the many studies based on hospital records. The primary discharge diagnosis of cardiac arrest (ICD-10 code I46) set at emergency admission to the hospital and emergency department does not indicate whether the causes were cardiac- or trauma related, and there may be doubt as to where the patient developed the cardiac arrest, i.e., whether the event

initially occurred outside or inside the hospital. The study population consisted of patients aged 18 years and older, which limits the generalisability of the results to those under 18.

The present study concentrates on traffic-related pollutants; however, emissions from the volcanic eruptions occurring in Iceland during the study period may have confounded the results. The Eyjafjallajökull eruption in 2010 was found to have minor health effect on the local population, but not the population in the Reykjavik capital area (26). The Holuhraun eruption in 2014 to 2015 emitted a massive amount of SO_2 and mature volcanic plume, and the exposure to these was associated with an increase in the dispensing of asthma medication and an increase in healthcare utilisation for respiratory diseases in the Reykjavik capital area during four months in the year 2014 (27,28). The present study was not designed to catch the possible effect of these emissions on the cardiovascular health of the population of the Reykjavik capital area, and its role remains unknown in that respect.

We made several stratifications to explore the possible association between air pollutants and emergency hospital visits for cardiac arrest in this study. Because of this, some concerns may emerge about multiple comparisons; however, this has been dealt with in the literature (29).

Conclusions

This study was, to our knowledge, the first to utilise the new endpoint of cardiac arrest (ICD-10 code I46) according to the hospital discharge registry. This outcome has in previous epidemiological studies been included in larger groups of CVDs, and its special status may have been overshadowed by the more common diagnosis of CVDs. Our results indicate a positive association between short-term increase in PM_{10} and emergency hospital visits for cardiac arrest in the Reykjavik capital area, known for having low levels of traffic-related pollution. The effects were found in most subgroups, and were highest among the elderly, in the winter season, and among those who were successfully resuscitated. Future ecological studies of this type should perhaps concentrate more on precisely defined endpoints; however, doing so will not replace the obvious lack of exact individual exposure measurements for each of the cases.

List of abbreviations

µm	Micrometre
AF	Atrial fibrillation
CI	Confidence interval
CVD	Cardiovascular diseases
ED	Emergency department
GRE	Air quality measurement station located at Grensasvegur-Miklabraut intersection in Reykjavik
H_2S	Hydrogen sulphide
ICD-10	International Classification of Diseases 10th edition
IHD	Ischemic heart disease
km	Kilometre
LUH	Landspitali University Hospital
NO_2	Nitrogen dioxide
OR	Odds ratio
PM_{10}	Particulate matter less than 10 µm in aerodynamic diameter
$PM_{2.5}$	Particulate matter less than 2.5 µm in aerodynamic diameter
RH	Relative humidity
SAGA	Register of Hospital-treated Patients in Iceland
SO_2	Sulphur dioxide
yr	Year

Ethical approval and consent to participate

The study was approved by the National Bioethics Committee (ref. no. VSNb2018120011/03.01), the Data Protection Authority (ref. no. 10-050), and the Scientific Committee of LUH.

Availability of data and materials

The hospital data contain sensitive individual-level information which is not publicly available. It can be made available to researchers after obtaining approval of a formal application to the National Bioethics Committee and the Scientific Committee of LUH. The dataset of air pollution used and analysed during the current study are available from the corresponding author on reasonable request.

Competing interest

The authors declare that they have no competing interests.

Funding

The study had no external funding.

Authors' contribution

SH, RGF, VR designed the study; SH, RGF, BTE, VR planned the analysis; SH, GG, VR collected the data; SH, RGF, BTE analysed the data; VR wrote the first draft; SH, RGF, BTE, OSG, GG, VR read the manuscript, interpreted the conclusion, and agreed on the final version.

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Figure 1. The odds ratio (OR) and bars showing 95% confidence intervals of cardiac arrest (ICD10 code I46) per 10 µg/m3

increase in PM10 concentrations in multiple-pollutant models

at lag 0 to lag 4 for unstratified material and different strata.

Figure 2. The odds ratio (OR) and bars showing 95% confidence intervals of cardiac arrest with

successful resuscitation (ICD-10 code: I46.0) and other cardiac arrest categories

grouped together (ICD-10 codes I46, I46.1 and I46.9), as well as cardiac arrest (ICD-10

code: I46) stratified to winter and summer, per 10 µg/m3

increase in PM10

concentrations in multiple-pollutant models at lag 0 to lag 4.

Table 1 Descriptive statistics of emergency hospital visits for cardiac arrest (ICD-10: I46) to Landspitali University Hospital, according to subgroups, January 1st, 2006 to December 31st, 2017.

Discharge diagnosis (ICD-10)	No. of visits (%)	No. of patients
Cardiac arrest (I46)	453 (100)	447
Females	125 (28)	123
Males	328 (72)	324
Older (≥71yr)	192 (42)	190
Younger (<71yr)	261 (58)	257
Older females	57	56
Younger females	68	67
Older males	135	134
Younger males	193	190
Winter	236 (52)	236
Summer	217 (48)	214
Cardiac arrest (I46)	5	5
Cardiac arrest with successful resuscitation (I46.0)	194	192
Sudden cardiac death, so described (I46.1)	23	23
Cardiac arrest, unspecified (I46.9)	231	229
Emergency department visits, only	313	312

Winter: November 1st to April 30th.
Summer: May 1st to October 31st.

Table 2. Descriptive statistics of 24-hour concentration levels (μg/m³) of pollutants and meteorological data in the Reykjavík capital area during the study period, 2006-2017, and Spearman's correlation between daily concentrations of pollutants

	PM_{10}	$PM_{2,5}$	NO_2	SO_2	H_2S	TEMP (°C)	RH (%)
24-h availability n (%)	4218 (96.2)	3460 (78.9)	4000 (91.3)	4183 (95.4)	4099 (93.5)	4377 (99.9)	4377 (99.9)
Mean (SD)	20.5 (19.7)	12.5 (21.8)	20.7 (15.0)	2.51 (13.8)	2.98 (5.2)	5.5 (4.9)	74.9 (10.6)
Summer* mean (SD)	17.4 (14.9)	10.8 (16.2)	16.2 (9.9)	2.48 (14.1)	2.08 (3.1)	9.1 (3.2)	74.6 (9.8)
Winter** mean (SD)	23.6 (23.2)	14.2 (26.1)	25.3 (17.6)	2.54 (13.5)	3.90 (6.6)	1.9 (3.4)	75.1 (11.3)
Range	2.4-381	0-423	0-119	0-409	0-96	-10.5-17.7	37-97
Median	15.1	7.0	16.6	1.1	1.2	5.6	77.0
Interquartile range	11.6	8.2	15.8	1.2	2.7	7.9	15.0
Spearman's correlation							
PM_{10}	1.00						
$PM_{2,5}$	0.76	1.00					
NO_2	0.09	0.00	1.00				
SO_2	0.08	0.08	0.50	1.00			
H_2S	-0.08	-0.11	0.31	0.39	1.00		
TEMP (°C)	-0.16	-0.08	-0.44	-0.17	-0.23	1.00	
RH (%)	-0.30	-0.56	0.09	-0.03	0.04	0.12	1.00

* May 1st to October 31st.
** November 1st to April 30th.
SD: standard deviation; H_2S: hydrogen sulphide; NO_2: nitrogen dioxide; PM_{10}: particulate matter ≤10μm in diameter; $PM_{2.5}$: particulate matter ≤2.5μm in diameter; RH: relative humidity; SO_2: sulphur dioxide; TEMP: temperature.

Table 3 Number of visits (n), odds ratios (OR) and 95% confidence intervals (CI) for the daily emergency hospital visits for cardiac arrest (ICD-10 code: I46) in Reykjavik capital area associated with 10 µg/m³ increase in NO_2, PM_{10}, $PM_{2.5}$, SO_2 and H_2S, adjusted for each pollutant, temperature and relative humidity, unstratified at lag 0 to lag 4, lag 0-1, lag 0-2, lag 0-3, and lag 0-4.

		NO_2	PM_{10}	$PM_{2,5}$	SO_2	H_2S
Categories/Visits (n)	Lag	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
All (453)	0	0.989 (0.904-1.083)	1.017 (0.957-1.082)	0.990 (0.930-1.053)	1.084 (1.002-1.173)	1.187 (0.972-1.449)
	1	1.003 (0.916-1.099)	1.041 (0.987-1.097)	0.994 (0.936-1.055)	0.983 (0.873-1.107)	1.056 (0.829-1.344)
	2	0.972 (0.885-1.068)	1.096 (1.033-1.162)	0.993 (0.935-1.054)	0.999 (0.935-1.067)	1.118 (0.892-1.402)
	3	1.052 (0.963-1.150)	1.038 (0.988-1.090)	1.022 (0.968-1.079)	0.991 (0.916-1.074)	1.191 (0.980-1.449)
	4	1.096 (1.008-1.192)	1.029 (0.963-1.099)	1.054 (0.992-1.020)	1.003 (0.940-1.070)	0.915 (0.714-1.171)
	0-1	0.982 (0.876-1.101)	1.049 (0.978-1.124)	0.988 (0.922-1.059)	1.084 (0.971-1.211)	1.214 (0.923-1.597)
	0-2	0.957 (0.838-1.093)	1.118 (1.031-1.212)	0.989 (0.918-1.066)	1.070 (0.945-1.212)	1.301 (0.936-1.810)
	0-3	0.981 (0.846-1.137)	1.150 (1.050-1.261)	0.998 (0.921-1.081)	1.061 (0.922-1.221)	1.423 (1.007-2.011)
	0-4	1.039 (0.889-1.215)	1.168 (1.054-1.295)	1.019 (0.934-1.112)	1.057 (0.588-1.928)	1.313 (0.897-1.921)

Table 4 Number of visits (n), odds ratios (OR) and 95% confidence intervals (CI) for the daily emergency hospital visits for cardiac arrest with successful resuscitation(ICD-10 code: I46.0) and other cardiac arrest categories grouped together (ICD-10 codes I46, I46.1 and I46.9) in Reykjavik capital area associated with 10 µg/m³ increase in NO_2, PM_{10}, $PM_{2.5}$, SO_2, and H_2S, adjusted for each pollutant, temperature and relative humidity, at lag 0 to lag 4, lag 0-1, lag 0-2, lag 0-3, and lag 0-4.

		NO_2	PM_{10}	$PM_{2,5}$	SO_2	H_2S
Categories/Visits (n)	**Lag**	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
I46.0 (194)	0	0.988 (0.856-1.139)	1.057 (0.967-1.156)	0.983 (0.875-1.105)	1.386 (0.758-2.534)	1.008 (0.735-1.383)
	1	1.012 (0.881-1.163)	1.053 (0.982-1.129)	0.999 (0.894-1.115)	0.845 (0.471-1.515)	1.055 (0.707-1.577)
	2	0.953 (0.826-1.100)	1.104 (1.002-1.216)	1.037 (0.957-1.125)	1.078 (0.893-1.301)	1.177 (0.797-1.737)
	3	1.072 (0.937-1.227)	1.035 (0.941-1.138)	1.088 (1.001-1.182)	0.995 (0.910-1.089)	1.141 (0.794-1.642)
	4	1.194 (1.023-1.393)	1.040 (0.936-1.157)	1.104 (1.006-1.211)	0.292 (0.084-1.010)	1.313 (0.847-2.036)
	0-1	0.992 (0.832-1.183)	1.083 (0.985-1.190)	0.987 (0.870-1.121)	1.167 (0.932-1.462)	1.050 (0.663-1.664)
	0-2	0.952 (0.774-1.171)	1.153 (1.021-1.301)	1.017 (0.899-1.150)	1.196 (0.941-1.520)	1.203 (0.680-2.129)
	0-3	0.986 (0.781-1.246)	1.202 (1.039-1.392)	1.058 (0.936-1.197)	1.120 (0.879-1.426)	1.323 (0.693-2.527)
	0-4	1.047 (0.818-1.340)	1.209 (1.027-1.422)	1.093 (0.957-1.248)	1.015 (0.785-1.314)	1.421 (0.702-2.877)
I46, I46.1, I46.9 (259)	0	0.983 (0.875-1.105)	0.991 (0.909-1.081)	0.992 (0.921-1.068)	1.055 (0.964-1.155)	1.327 (1.012-1.739)
	1	0.998 (0.882-1.130)	1.024 (0.940-1.116)	0.991 (0.923-1.065)	0.996 (0.876-1.132)	1.055 (0.778-1.430)
	2	0.985 (0.869-1.116)	1.090 (1.013-1.173)	0.945 (0.861-1.036)	0.987 (0.914-1.067)	1.123 (0.843-1.497)
	3	1.041 (0.923-1.176)	1.027 (0.968-1.089)	0.960 (0.876-1.052)	0.993 (0.829-1.190)	1.191 (0.943-1.505)
	4	1.082 (0.975-1.201)	1.030 (0.945-1.121)	1.012 (0.929-1.102)	1.056 (0.968-1.152)	0.781 (0.564-1.082)
	0-1	0.972 (0.835-1.130)	1.011 (0.908-1.126)	0.987 (0.908-1.072)	1.051 (0.927-1.190)	1.312 (0.928-1.856)
	0-2	0.958 (0.803-1.142)	1.093 (0.976-1.223)	0.968 (0.879-1.066)	1.030 (0.895-1.185)	1.386 (0.922-2.084)
	0-3	0.968 (0.796-1.177)	1.108 (0.982-1.250)	0.951 (0.852-1.062)	1.033 (0.869-1.227)	1.485 (0.984-2.240)
	0-4	1.019 (0.830-1.252)	1.126 (0.983-1.290)	0.963 (0.852-1.087)	1.079 (0.905-1.286)	1.283 (0.813-2.027)

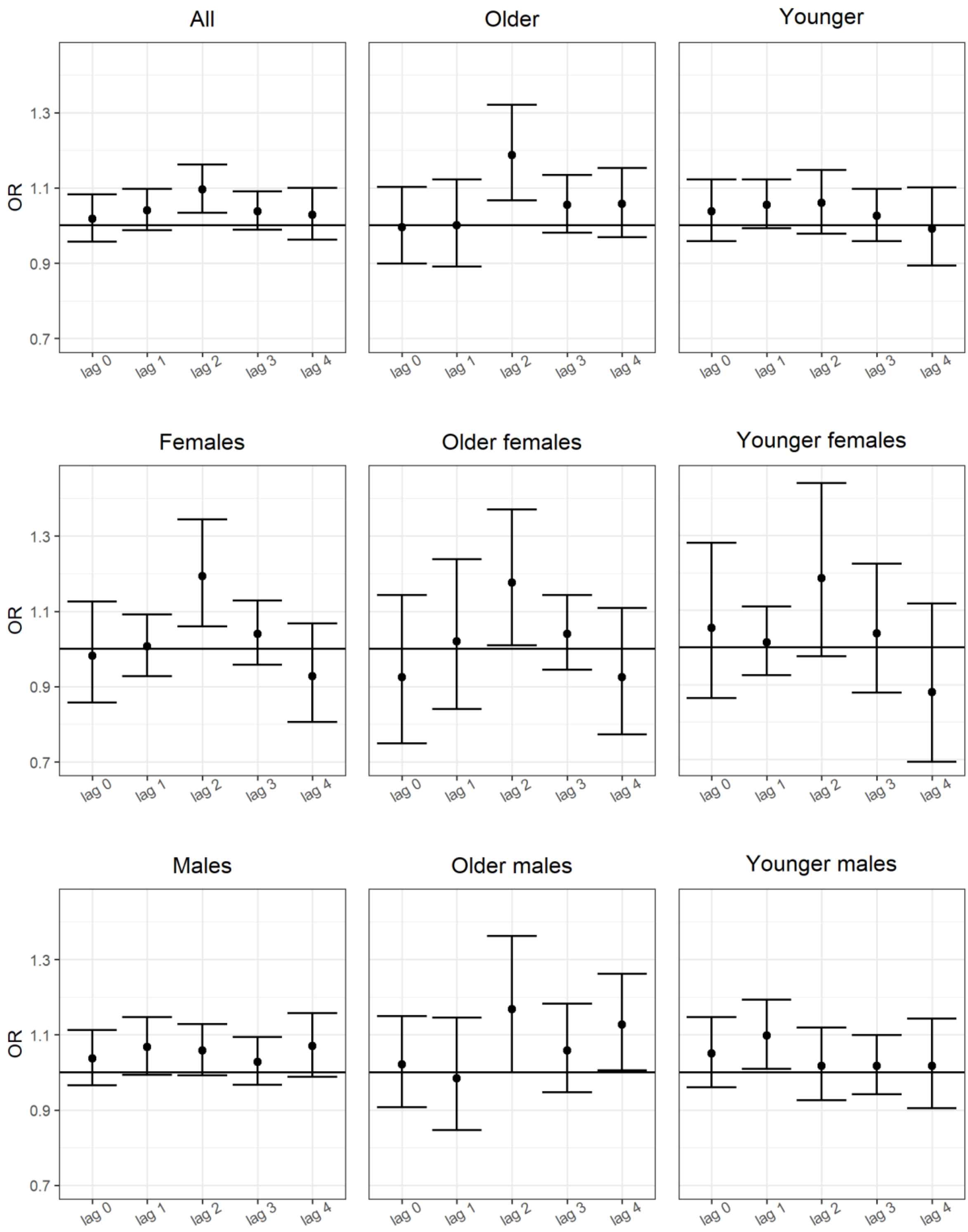

Figure 1. The odds ratio (OR) and bars showing 95% confidence intervals of cardiac arrest (ICD-10 code I46) per 10 µg/m^3 increase in PM_{10} concentrations in multiple-pollutant models at lag 0 to lag 4 for unstratified material and different strata.

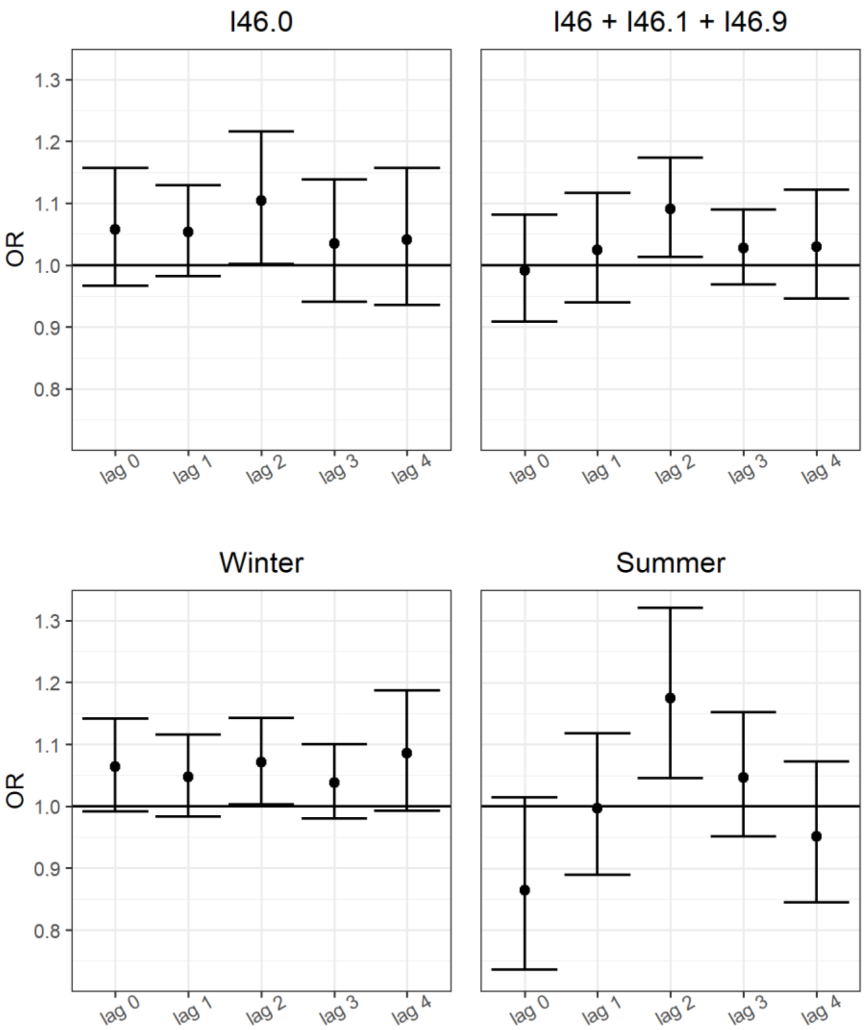

Figure 2. The odds ratio (OR) and bars showing 95% confidence intervals of cardiac arrest with successful resuscitation (ICD-10 code: I46.0) and other cardiac arrest categories grouped together (ICD-10 codes I46, I46.1 and I46.9), as well as cardiac arrest (ICD-10 code: I46) stratified to winter and summer, per 10 µg/m^3 increase in PM_{10} concentrations in multiple-pollutant models at lag 0 to lag 4.

Table A Number of visits (n), odds ratios (OR) and 95% confidence intervals (CI) for the daily emergency hospital visits for cardiac arrest (ICD-10 code: I46) in Reykjavik capital area associated with 10 µg/m³ increase in NO_2, PM_{10}, $PM_{2.5}$, SO_2, and H_2S, in single pollutant models, unstratified and stratified by gender, age, and season, at lag 0 to lag 4, lag 0-1, and lag 0-2.

		NO_2		PM_{10}		$PM_{2.5}$		SO_2		H_2S	
Categories/Visits (n)	**Lag**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
All (453)	0	1.028	0.948-1.115	1.020	0.961-1.081	0.994	0.934-1.058	1.085	1.003-1.173	1.199	0.990-1.451
	1	1.012	0.933-1.098	1.037	0.985-1.091	0.993	0.936-1.054	0.985	0.876-1.107	1.044	0.827-1.317
	2	0.986	0.907-1.071	1.077	1.020-1.137	0.997	0.940-1.058	1.005	0.941-1.073	1.047	0.848-1.294
	3	1.062	0.981-1.151	1.032	0.984-1.081	1.024	0.970-1.081	1.001	0.925-1.082	1.195	0.993-1.439
	4	1.081	1.002-1.166	1.036	0.974-1.103	1.051	0.989-1.116	1.007	0.947-1.072	0.969	0.764-1.228
	0-1	1.030	0.933-1.137	1.045	0.977-1.116	0.992	0.926-1.062	1.082	0.970-1.207	1.207	0.934-1.560
	0-2	1.017	0.908-1.139	1.097	1.016-1.184	0.992	0.921-1.069	1.076	0.950-1.219	1.228	0.907-1.663
Females (125)	0	1.215	1.033-1.429	1.002	0.891-1.126	0.906	0.765-1.073	0.683	0.166-2.800	1.341	0.874-2.058
	1	1.052	0.902-1.228	1.028	0.953-1.109	0.905	0.772-1.060	0.782	0.276-2.211	1.052	0.719-1.540
	2	1.002	0.858-1.171	1.175	1.058-1.304	0.972	0.856-1.104	0.292	0.066-1.287	0.769	0.470-1.260
	3	1.042	0.893-1.215	1.042	0.963-1.128	0.992	0.867-1.134	0.387	0.105-1.431	1.094	0.733-1.631
	4	1.153	1.002-1.327	0.955	0.843-1.081	1.027	0.901-1.171	0.689	0.254-1.870	1.072	0.695-1.653
	0-1	1.222	0.993-1.503	1.033	0.921-1.160	0.875	0.726-1.056	0.655	0.158-2.710	1.243	0.774-1.996
	0-2	1.175	0.937-1.474	1.130	0.990-1.289	0.898	0.748-1.078	0.375	0.073-1.923	1.064	0.603-1.880
Males (328)	0	0.974	0.886-1.071	1.026	0.958-1.098	1.015	0.949-1.086	1.086	1.004-1.176	1.167	0.943-1.444
	1	0.997	0.906-1.098	1.044	0.975-1.118	1.013	0.951-1.079	0.988	0.879-1.110	1.039	0.775-1.393
	2	0.979	0.887-1.081	1.043	0.981-1.108	1.005	0.940-1.074	1.008	0.945-1.075	1.144	0.902-1.450
	3	1.070	0.975-1.175	1.026	0.967-1.088	1.031	0.972-1.093	1.005	0.931-1.084	1.226	0.991-1.516
	4	1.053	0.962-1.152	1.075	0.998-1.157	1.057	0.988-1.132	1.009	0.949-1.073	0.930	0.700-1.236
	0-1	0.979	0.873-1.098	1.050	0.968-1.140	1.017	0.946-1.094	1.085	0.972-1.212	1.192	0.878-1.618
	0-2	0.969	0.849-1.106	1.080	0.983-1.188	1.016	0.937-1.102	1.084	0.955-1.230	1.304	0.910-1.867
Older ≥71 (192)	0	1.063	0.938-1.204	0.988	0.898-1.087	1.039	0.941-1.148	1.091	0.970-1.228	1.162	0.880-1.534
	1	1.005	0.884-1.142	0.997	0.894-1.113	1.000	0.910-1.100	0.973	0.834-1.135	1.078	0.784-1.483
	2	1.094	0.963-1.241	1.149	1.043-1.266	1.026	0.939-1.121	1.009	0.924-1.103	1.153	0.870-1.528
	3	1.042	0.919-1.182	1.044	0.973-1.120	1.026	0.928-1.135	0.886	0.621-1.264	1.263	0.974-1.638
	4	1.048	0.934-1.175	1.053	0.971-1.143	1.020	0.935-1.112	0.999	0.898-1.112	0.898	0.634-1.271
	0-1	1.047	0.902-1.216	0.988	0.870-1.121	1.024	0.917-1.142	1.062	0.918-1.229	1.190	0.829-1.707
	0-2	1.100	0.927-1.306	1.111	0.979-1.261	1.032	0.920-1.158	1.060	0.904-1.244	1.293	0.853-1.959
Younger <71 (261)	0	1.005	0.903-1.117	1.041	0.966-1.121	0.969	0.893-1.051	1.079	0.973-1.198	1.234	0.948-1.605
	1	1.018	0.915-1.131	1.049	0.989-1.112	0.989	0.916-1.067	1.002	0.841-1.196	1.007	0.718-1.414
	2	0.911	0.814-1.021	1.033	0.959-1.112	0.976	0.900-1.059	1.000	0.906-1.103	0.932	0.674-1.289
	3	1.077	0.971-1.194	1.022	0.958-1.089	1.023	0.960-1.091	1.072	0.943-1.219	1.120	0.847-1.481
	4	1.108	1.002-1.226	1.014	0.921-1.117	1.085	0.995-1.183	1.012	0.938-1.092	1.042	0.751-1.447
	0-1	1.017	0.892-1.160	1.068	0.988-1.155	0.974	0.892-1.063	1.106	0.939-1.302	1.225	0.849-1.766
	0-2	0.958	0.824-1.115	1.089	0.988-1.199	0.967	0.878-1.066	1.100	0.901-1.344	1.161	0.746-1.806
Older females (57)	0	1.312	1.025-1.678	0.973	0.811-1.167	0.740	0.494-1.110	0.980	0.126-7.599	0.987	0.523-1.863
	1	0.963	0.749-1.238	1.073	0.907-1.270	0.934	0.775-1.126	0.599	0.073-4.883	1.054	0.632-1.757
	2	1.126	0.887-1.429	1.195	1.039-1.375	0.999	0.858-1.162	0.149	0.010-2.192	0.453	0.181-1.136
	3	1.013	0.810-1.267	1.042	0.949-1.143	0.968	0.780-1.202	0.777	0.151-4.010	1.071	0.651-1.759
	4	1.157	0.960-1.394	0.975	0.842-1.128	0.937	0.765-1.148	4.023	0.561-28.834	0.871	0.449-1.688
	0-1	1.211	0.890-1.648	1.036	0.833-1.288	0.852	0.636-1.141	0.701	0.064-7.649	1.035	0.539-1.989
	0-2	1.256	0.898-1.755	1.178	0.956-1.451	0.919	0.722-1.171	0.302	0.019-4.803	0.758	0.323-1.778

Table A Continued

Younger females (68)	0	1.141	0.914-1.424	1.024	0.879-1.194	0.956	0.808-1.130	0.521	0.077-3.537	1.909	0.996-3.659
	1	1.114	0.915-1.355	1.018	0.934-1.109	0.855	0.652-1.123	0.855	0.265-2.751	1.050	0.593-1.858
	2	0.916	0.740-1.134	1.149	0.981-1.345	0.926	0.744-1.153	0.428	0.075-2.441	1.045	0.599-1.825
	3	1.069	0.864-1.323	1.042	0.897-1.211	1.008	0.847-1.199	0.168	0.019-1.457	1.139	0.579-2.240
	4	1.149	0.928-1.422	0.916	0.736-1.141	1.167	0.937-1.455	0.323	0.066-1.582	1.296	0.720-2.334
	0-1	1.231	0.930-1.629	1.032	0.901-1.183	0.894	0.700-1.141	0.632	0.107-3.717	1.593	0.767-3.308
	0-2	1.110	0.815-1.511	1.098	0.924-1.304	0.875	0.668-1.146	0.424	0.056-3.220	1.485	0.677-3.254
Older males (135)	0	0.982	0.844-1.142	0.994	0.888-1.112	1.079	0.972-1.199	1.092	0.970-1.229	1.212	0.888-1.654
	1	1.020	0.879-1.183	0.952	0.823-1.100	1.031	0.925-1.149	0.976	0.837-1.137	1.094	0.727-1.646
	2	1.081	0.931-1.256	1.109	0.981-1.254	1.041	0.933-1.163	1.013	0.928-1.105	1.380	0.995-1.913
	3	1.056	0.907-1.230	1.047	0.942-1.165	1.046	0.932-1.173	0.891	0.629-1.264	1.360	0.971-1.903
	4	0.984	0.847-1.144	1.105	0.994-1.229	1.045	0.949-1.152	0.995	0.892-1.110	0.908	0.604-1.366
	0-1	1.001	0.841-1.191	0.965	0.825-1.128	1.073	0.951-1.210	1.064	0.919-1.232	1.272	0.822-1.968
	0-2	1.049	0.857-1.282	1.073	0.914-1.260	1.083	0.946-1.241	1.066	0.907-1.251	1.590	0.972-2.600
Younger males (193)	0	0.969	0.858-1.094	1.046	0.961-1.139	0.973	0.886-1.069	1.082	0.974-1.202	1.129	0.841-1.514
	1	0.982	0.865-1.114	1.078	0.996-1.166	1.004	0.929-1.085	1.006	0.844-1.200	0.986	0.648-1.500
	2	0.910	0.796-1.039	0.999	0.913-1.093	0.985	0.904-1.074	1.003	0.912-1.104	0.884	0.595-1.314
	3	1.079	0.958-1.215	1.017	0.947-1.092	1.026	0.958-1.098	1.084	0.948-1.239	1.116	0.821-1.517
	4	1.097	0.978-1.230	1.045	0.938-1.163	1.070	0.972-1.177	1.016	0.944-1.094	0.952	0.640-1.417
	0-1	0.963	0.827-1.121	1.088	0.989-1.197	0.989	0.901-1.085	1.112	0.942-1.312	1.123	0.734-1.718
	0-2	0.915	0.768-1.091	1.084	0.965-1.219	0.984	0.888-1.091	1.113	0.907-1.365	1.041	0.610-1.778
Winter (236)	0	1.059	0.968-1.157	1.060	0.994-1.131	0.973	0.898-1.053	1.103	0.980-1.240	1.237	1.002-1.527
	1	1.008	0.921-1.104	1.055	0.994-1.119	0.979	0.904-1.060	0.981	0.806-1.195	0.962	0.732-1.264
	2	1.010	0.922-1.106	1.056	0.995-1.120	0.984	0.905-1.071	0.979	0.892-1.073	1.052	0.833-1.327
	3	1.094	1.003-1.193	1.028	0.974-1.085	0.996	0.926-1.070	1.000	0.923-1.084	1.230	1.009-1.500
	4	1.090	1.004-1.184	1.084	1.002-1.174	1.082	0.991-1.181	0.986	0.911-1.066	1.006	0.777-1.301
	0-1	1.049	0.941-1.170	1.088	1.009-1.173	0.970	0.887-1.060	1.098	0.951-1.268	1.191	0.891-1.593
	0-2	1.049	0.926-1.187	1.126	1.030-1.231	0.968	0.877-1.068	1.048	0.888-1.238	1.221	0.866-1.723
Summer (217)	0	0.910	0.754-1.098	0.873	0.748-1.018	1.038	0.936-1.150	1.067	0.958-1.189	1.038	0.654-1.649
	1	1.031	0.854-1.244	0.980	0.875-1.098	1.014	0.925-1.110	0.987	0.853-1.141	1.361	0.849-2.182
	2	0.873	0.711-1.073	1.154	1.032-1.292	1.010	0.930-1.098	1.144	0.927-1.412	1.028	0.620-1.704
	3	0.920	0.756-1.120	1.043	0.950-1.146	1.074	0.984-1.172	1.006	0.705-1.436	0.951	0.538-1.679
	4	1.033	0.853-1.251	0.962	0.859-1.078	1.024	0.940-1.115	1.322	0.892-1.959	0.815	0.460-1.442
	0-1	0.953	0.759-1.196	0.906	0.773-1.062	1.031	0.924-1.149	1.061	0.905-1.244	1.265	0.730-2.192
	0-2	0.883	0.673-1.158	1.013	0.864-1.187	1.028	0.919-1.151	1.114	0.911-1.363	1.253	0.661-2.376

Table B Number of visits (n), odds ratios (OR) and 95% confidence intervals (CI) for the daily emergency hospital visits for cardiac arrest (ICD-10 code: I46) in Reykjavik capital area associated with 10 µg/m³ increase in NO_2, PM_{10}, $PM_{2.5}$, SO_2 and H_2S, adjusted for each pollutant, temperature and relative humidity, stratified by gender, and age at lag 0 to lag 4, lag 0-1, lag 0-2, lag 0-3, and lag 0-4.

		NO_2		PM_{10}		$PM_{2.5}$		SO_2		H_2S	
Categories/Visits (n)	**Lag**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Females (125)	0	1.223	1.011-1.481	0.982	0.857-1.126	0.900	0.763-1.063	0.256	0.039-1.665	1.270	0.797-2.024
	1	1.029	0.860-1.231	1.006	0.928-1.091	0.895	0.764-1.049	0.740	0.237-2.316	1.036	0.688-1.561
	2	1.009	0.839-1.212	1.193	1.059-1.344	0.958	0.843-1.089	0.284	0.051-1.582	0.902	0.531-1.532
	3	1.029	0.860-1.232	1.040	0.959-1.129	0.983	0.857-1.127	0.286	0.064-1.287	1.156	0.759-1.760
	4	1.175	0.997-1.384	0.927	0.806-1.068	1.036	0.909-1.181	0.495	0.154-1.591	1.006	0.639-1.583
	0-1	1.214	0.948-1.555	1.016	0.893-1.157	0.867	0.724-1.038	0.404	0.076-2.132	1.184	0.698-2.008
	0-2	1.174	0.893-1.543	1.110	0.958-1.287	0.889	0.740-1.068	0.236	0.034-1.664	1.172	0.605-2.273
	0-3	1.177	0.867-1.597	1.162	0.982-1.374	0.901	0.748-1.085	0.134	0.015-1.166	1.350	0.665-2.740
	0-4	1.278	0.939-1.740	1.133	0.935-1.372	0.914	0.754-1.108	0.118	0.012-1.125	1.276	0.593-2.743
Males (328)	0	0.935	0.841-1.041	1.036	0.966-1.112	1.012	0.946-1.083	1.093	1.009-1.184	1.218	0.972-1.526
	1	0.989	0.888-1.101	1.067	0.993-1.147	1.013	0.951-1.079	0.992	0.882-1.116	1.094	0.805-1.486
	2	0.982	0.878-1.098	1.058	0.992-1.128	0.997	0.932-1.067	1.000	0.937-1.067	1.242	0.962-1.604
	3	1.087	0.978-1.208	1.028	0.966-1.094	1.031	0.972-1.094	0.996	0.921-1.077	1.238	0.988-1.550
	4	1.079	0.975-1.194	1.070	0.988-1.158	1.066	0.995-1.142	1.007	0.944-1.073	0.895	0.666-1.203
	0-1	0.924	0.808-1.057	1.077	0.989-1.174	1.015	0.943-1.092	1.102	0.984-1.233	1.302	0.936-1.810
	0-2	0.902	0.771-1.055	1.120	1.015-1.237	1.012	0.933-1.099	1.088	0.958-1.235	1.503	1.013-2.229
	0-3	0.942	0.793-1.120	1.139	1.020-1.273	1.022	0.935-1.117	1.086	0.940-1.255	1.628	1.078-2.457
	0-4	0.985	0.818-1.186	1.174	1.037-1.328	1.047	0.949-1.154	1.087	0.937-1.260	1.499	0.955-2.351
Older ≥71 (192)	0	1.035	0.901-1.188	0.995	0.898-1.102	1.038	0.940-1.147	1.089	0.967-1.226	1.096	0.815-1.475
	1	0.985	0.853-1.137	1.000	0.891-1.122	1.001	0.910-1.101	0.974	0.833-1.140	1.065	0.763-1.485
	2	1.099	0.953-1.267	1.186	1.066-1.320	1.034	0.942-1.135	0.989	0.901-1.085	1.210	0.883-1.659
	3	1.030	0.894-1.188	1.054	0.981-1.134	1.032	0.931-1.144	0.823	0.513-1.318	1.315	0.992-1.744
	4	1.071	0.943-1.216	1.057	0.969-1.152	1.024	0.938-1.117	1.000	0.895-1.117	0.887	0.618-1.272
	0-1	0.999	0.839-1.190	0.997	0.872-1.141	1.019	0.912-1.138	1.065	0.917-1.236	1.154	0.776-1.717
	0-2	1.055	0.862-1.291	1.151	1.005-1.319	1.036	0.921-1.164	1.045	0.891-1.226	1.266	0.796-2.014
	0-3	1.060	0.848-1.325	1.197	1.033-1.386	1.038	0.910-1.185	0.993	0.824-1.197	1.460	0.906-2.354
	0-4	1.087	0.860-1.374	1.243	1.056-1.463	1.056	0.915-1.218	0.998	0.824-1.208	1.371	0.808-2.324
Younger <71 (261)	0	0.961	0.853-1.083	1.037	0.958-1.122	0.962	0.885-1.045	1.083	0.975-1.204	1.242	0.941-1.640
	1	1.019	0.905-1.148	1.055	0.993-1.122	0.989	0.916-1.068	0.998	0.833-1.195	1.031	0.724-1.469
	2	0.892	0.784-1.014	1.059	0.978-1.147	0.965	0.889-1.048	1.005	0.914-1.105	1.019	0.723-1.438
	3	1.076	0.957-1.209	1.025	0.958-1.097	1.020	0.956-1.088	1.069	0.941-1.214	1.094	0.814-1.470
	4	1.123	1.002-1.259	0.992	0.893-1.101	1.083	0.991-1.183	1.007	0.930-1.091	0.926	0.653-1.312
	0-1	0.973	0.837-1.132	1.075	0.990-1.166	0.970	0.887-1.060	1.108	0.941-1.306	1.236	0.840-1.818
	0-2	0.890	0.744-1.065	1.117	1.007-1.238	0.959	0.869-1.058	1.108	0.907-1.353	1.286	0.799-2.069
	0-3	0.930	0.761-1.136	1.136	1.009-1.279	0.975	0.881-1.080	1.149	0.915-1.445	1.349	0.808-2.253
	0-4	1.162	0.720-1.874	1.133	0.856-1.499	0.951	0.708-1.277	0.047	0.002-1.342	2.088	0.734-5.942

Table B Continued

Older females (57)	0	1.394	1.036-1.876	0.926	0.750-1.142	0.772	0.523-1.140	0.420	0.024-7.404	0.847	0.418-1.713
	1	0.970	0.717-1.312	1.020	0.840-1.238	0.927	0.767-1.119	0.454	0.045-4.562	1.168	0.676-2.019
	2	1.228	0.926-1.628	1.177	1.010-1.371	0.983	0.840-1.151	0.150	0.005-4.657	0.534	0.182-1.565
	3	1.002	0.778-1.291	1.039	0.945-1.144	0.966	0.781-1.194	0.630	0.101-3.918	1.074	0.633-1.823
	4	1.128	0.908-1.401	0.925	0.772-1.108	0.935	0.761-1.148	3.684	0.414-32.751	0.736	0.351-1.545
	0-1	1.330	0.907-1.950	0.967	0.753-1.242	0.861	0.653-1.136	0.470	0.028-7.870	0.994	0.472-2.093
	0-2	1.435	0.941-2.189	1.105	0.869-1.404	0.933	0.732-1.189	0.195	0.006-6.790	0.777	0.270-2.242
	0-3	1.364	0.879-2.115	1.167	0.916-1.486	0.931	0.726-1.194	0.174	0.006-5.284	0.951	0.338-2.669
	0-4	1.401	0.924-2.124	1.116	0.847-1.469	0.918	0.701-1.201	0.421	0.017-10.137	0.727	0.217-2.434
Younger females (68)	0	1.131	0.873-1.465	1.052	0.864-1.281	0.930	0.776-1.113	0.184	0.017-2.013	2.148	1.038-4.446
	1	1.074	0.853-1.350	1.013	0.926-1.109	0.857	0.649-1.130	0.896	0.250-3.212	0.958	0.509-1.800
	2	0.853	0.661-1.100	1.186	0.976-1.440	0.901	0.714-1.137	0.481	0.072-3.209	1.194	0.638-2.232
	3	1.062	0.815-1.384	1.037	0.879-1.224	0.999	0.834-1.197	0.097	0.007-1.338	1.248	0.608-2.560
	4	1.186	0.910-1.546	0.880	0.693-1.118	1.197	0.964-1.486	0.187	0.023-1.544	1.137	0.603-2.146
	0-1	1.149	0.828-1.595	1.044	0.900-1.211	0.892	0.696-1.142	0.363	0.045-2.893	1.624	0.711-3.711
	0-2	1.001	0.687-1.459	1.124	0.921-1.371	0.866	0.653-1.150	0.277	0.027-2.883	1.763	0.701-4.434
	0-3	1.013	0.652-1.573	1.167	0.910-1.496	0.896	0.674-1.192	0.105	0.006-1.872	2.165	0.764-6.133
	0-4	1.162	0.720-1.874	1.133	0.856-1.499	0.951	0.708-1.277	0.047	0.002-1.342	2.088	0.734-5.942
Older males (135)	0	0.940	0.795-1.111	1.021	0.907-1.150	1.079	0.969-1.202	1.097	0.971-1.240	1.222	0.877-1.703
	1	1.000	0.846-1.183	0.985	0.846-1.145	1.032	0.925-1.151	0.996	0.851-1.164	1.116	0.722-1.725
	2	1.095	0.919-1.305	1.167	1.001-1.362	1.039	0.920-1.172	0.984	0.897-1.079	1.483	1.019-2.159
	3	1.053	0.881-1.258	1.058	0.947-1.182	1.059	0.940-1.192	0.831	0.518-1.334	1.457	1.000-2.121
	4	1.006	0.850-1.191	1.126	1.005-1.262	1.051	0.952-1.161	1.003	0.895-1.123	0.938	0.910-1.440
	0-1	0.920	0.748-1.132	1.010	0.856-1.191	1.067	0.943-1.207	1.090	0.938-1.268	1.381	0.848-2.248
	0-2	0.948	0.745-1.208	1.138	0.959-1.350	1.078	0.937-1.240	1.062	0.906-1.245	1.738	1.000-3.021
	0-3	0.966	0.739-1.263	1.177	0.972-1.424	1.092	0.924-1.289	1.020	0.846-1.230	1.963	1.062-3.628
	0-4	0.949	0.709-1.272	1.280	1.037-1.579	1.125	0.942-1.344	1.033	0.851-1.254	1.907	0.990-3.673
Younger males (193)	0	0.941	0.818-1.081	1.050	0.960-1.147	0.971	0.883-1.067	1.093	0.981-1.217	1.194	0.871-1.637
	1	0.984	0.855-1.134	1.097	1.009-1.193	1.005	0.929-1.087	1.001	0.834-1.203	1.076	0.694-1.668
	2	0.922	0.792-1.074	1.018	0.926-1.118	0.976	0.894-1.066	1.011	0.919-1.113	0.974	0.640-1.484
	3	1.111	0.970-1.272	1.017	0.942-1.099	1.025	0.956-1.098	1.082	0.945-1.238	1.108	0.798-1.538
	4	1.134	0.997-1.291	1.017	0.905-1.143	1.076	0.975-1.188	1.013	0.936-1.096	0.850	0.559-1.292
	0-1	0.932	0.781-1.113	1.110	1.003-1.229	0.989	0.899-1.087	1.123	0.948-1.329	1.208	0.767-1.902
	0-2	0.868	0.704-1.071	1.127	0.995-1.276	0.979	0.882-1.086	1.134	0.919-1.400	1.244	0.697-2.222
	0-3	0.929	0.738-1.169	1.125	0.979-1.293	0.993	0.891-1.107	1.186	0.924-1.522	1.318	0.716-2.426
	0-4	1.020	0.801-1.300	1.123	0.961-1.312	1.017	0.902-1.146	1.185	0.903-1.556	1.173	0.596-2.306

Table C Number of visits (n), odds ratios (OR) and 95% confidence intervals (CI) for the daily emergency hospital visits for cardiac arrest (ICD-10 code: I46) in Reykjavik capital area associated with 10 µg/m³ increase in NO_2, PM_{10}, $PM_{2.5}$, SO_2 and H_2S, adjusted for each pollutant, temperature and relative humidity, stratified by season, at lag 0 to lag 4, lag 0-1, lag 0-2, lag 0-3, and lag 0-4.

		NO2		PM10		PM2,5		SO2		H2S	
Categories/Visits (n)	**Lag**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Winter (236)	0	1.003	0.906-1.111	1.064	0.992-1.141	0.958	0.884-1.039	1.119	0.990-1.265	1.224	0.980-1.529
	1	1.030	0.927-1.145	1.047	0.984-1.115	0.982	0.905-1.065	0.957	0.781-1.172	0.988	0.741-1.319
	2	1.021	0.919-1.133	1.071	1.003-1.143	0.988	0.908-1.076	0.972	0.886-1.067	1.129	0.878-1.451
	3	1.082	0.979-1.195	1.038	0.980-1.100	0.995	0.926-1.069	0.990	0.912-1.074	1.207	0.976-1.493
	4	1.087	0.988-1.195	1.085	0.993-1.187	1.089	0.995-1.191	0.979	0.900-1.064	0.951	0.722-1.252
	0-1	1.013	0.889-1.154	1.089	1.003-1.182	0.961	0.877-1.054	1.104	0.953-1.279	1.200	0.876-1.645
	0-2	1.016	0.873-1.183	1.148	1.041-1.266	0.965	0.872-1.068	1.037	0.874-1.230	1.301	0.889-1.904
	0-3	1.056	0.892-1.249	1.187	1.061-1.328	0.965	0.866-1.075	1.016	0.848-1.218	1.451	0.980-2.149
	0-4	1.109	0.927-1.326	1.240	1.089-1.412	0.989	0.881-1.111	0.996	0.833-1.191	1.362	0.882-2.104
Summer (217)	0	0.914	0.743-1.126	0.864	0.736-1.014	1.036	0.934-1.148	1.083	0.967-1.214	1.043	0.633-1.717
	1	0.993	0.814-1.211	0.997	0.889-1.118	1.008	0.920-1.105	0.984	0.852-1.136	1.441	0.888-2.340
	2	0.821	0.658-1.023	1.175	1.046-1.320	0.992	0.912-1.079	1.175	0.915-1.509	1.009	0.583-1.744
	3	0.927	0.753-1.142	1.047	0.951-1.152	1.073	0.982-1.172	1.041	0.723-1.499	0.964	0.540-1.720
	4	1.036	0.841-1.275	0.951	0.844-1.072	1.022	0.938-1.114	1.373	0.863-2.187	0.759	0.416-1.384
	0-1	0.903	0.703-1.160	0.910	0.773-1.071	1.027	0.920-1.147	1.073	0.917-1.257	1.363	0.763-2.435
	0-2	0.800	0.594-1.076	1.033	0.878-1.216	1.014	0.907-1.135	1.132	0.920-1.393	1.360	0.684-2.703
	0-3	0.764	0.546-1.070	1.061	0.891-1.263	1.039	0.921-1.172	1.176	0.902-1.534	1.354	0.617-2.970
	0-4	0.802	0.556-1.156	1.021	0.843-1.236	1.056	0.924-1.207	1.257	0.925-1.708	1.133	0.479-2.679

Table D Number of visits (n), odds ratios (OR) and 95% confidence intervals (CI) for the daily emergency hospital visits for cardiac arrest with successful resuscitation(ICD-10 code: I46.0) and other cardiac arrest categories grouped together (ICD-10 codes I46, I46.1, and I46.9) in Reykjavik capital area associated with 10 µg/m³ increase in NO_2, PM_{10}, $PM_{2.5}$, SO_2, and H_2S, in single pollutant models, at lag 0 to lag 4, lag 0-1, lag 0-2, lag 0-3, and lag 0-4.

		NO_2		PM_{10}		$PM_{2,5}$		SO_2		H_2S	
Categories/Visits (n)	**Lag**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
I46.0 (194)	0	1.037	0.913-1.177	1.056	0.970-1.149	0.984	0.877-1.104	1.374	0.762-2.477	1.043	0.773-1.406
	1	1.043	0.923-1.178	1.045	0.978-1.117	0.998	0.895-1.114	0.865	0.534-1.401	1.070	0.729-1.571
	2	0.995	0.874-1.132	1.073	0.980-1.176	1.043	0.963-1.129	1.053	0.878-1.264	1.098	0.754-1.601
	3	1.085	0.967-1.218	1.052	0.967-1.144	1.090	1.008-1.178	0.999	0.914-1.092	1.193	0.890-1.655
	4	1.108	0.978-1.256	1.036	0.938-1.144	1.101	1.006-1.204	0.570	0.222-1.460	1.372	0.916-2.053
	0-1	1.060	0.911-1.234	1.076	0.983-1.177	0.990	0.875-1.119	1.153	0.924-1.439	1.087	0.711-1.661
	0-2	1.049	0.881-1.249	1.118	0.998-1.252	1.023	0.909-1.152	1.157	0.911-1.471	1.158	0.684-1.960
	0-3	0.102	0.911-1.335	1.161	1.014-1.329	1.071	0.952-1.204	1.110	0.866-1.423	1.313	0.736-2.342
	0-4	1.147	0.940-1.401	1.177	1.013-1.368	1.103	0.973-1.250	1.013	0.788-1.302	1.504	0.801-2.825
I46, I46.1, I46.9 (259)	0	1.023	0.921-1.136	0.990	0.912-1.074	0.999	0.928-1.075	1.061	0.971-1.160	1.338	1.034-1.730
	1	0.989	0.885-1.104	1.025	0.945-1.111	0.991	0.923-1.064	1.003	0.886-1.135	1.029	0.768-1.379
	2	0.979	0.878-1.092	1.079	1.008-1.155	0.952	0.870-1.042	0.997	0.925-1.075	1.025	0.793-1.326
	3	1.042	0.933-1.164	1.023	0.967-1.083	0.957	0.874-1.048	1.007	0.851-1.191	1.196	0.954-1.498
	4	1.066	0.969-1.172	1.037	0.957-1.122	1.012	0.930-1.101	1.061	0.973-1.156	0.813	0.595-1.112
	0-1	1.009	0.886-1.150	1.010	0.914-1.116	0.993	0.915-1.078	1.058	0.936-1.197	1.285	0.931-1.773
	0-2	0.995	0.858-1.154	1.079	0.972-1.198	0.974	0.885-1.072	1.047	0.910-1.206	1.265	0.874-1.832
	0-3	1.018	0.865-1.199	1.089	0.975-1.218	0.958	0.859-1.069	1.054	0.888-1.251	1.350	0.931-1.957
	0-4	1.058	0.892-1.254	1.110	0.979-1.259	0.962	0.853-1.086	1.090	0.919-1.294	1.225	0.817-1.836

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *case-control studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2-3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	2, 6-9
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls	6-7
		(*b*) For matched studies, give matching criteria and the number of controls per case	9
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*6, 7 ,9*
Bias	9	Describe any efforts to address potential sources of bias	9-10
Study size	10	Explain how the study size was arrived at	7-9
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	9
		(*c*) Explain how missing data were addressed	8
		(*d*) If applicable, explain how matching of cases and controls was addressed	9
		(*e*) Describe any sensitivity analyses	9-10
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10, table 1
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10, tables 1, 2
		(b) Indicate number of participants with missing data for each variable of interest	NA
Outcome data	15*	Report numbers in each exposure category, or summary measures of exposure	tables 3 , 4
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	11-13
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	11-13
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	13
Discussion			
Key results	18	Summarise key results with reference to study objectives	14
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	14-15, 16-17
Generalisability	21	Discuss the generalisability (external validity) of the study results	16
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	19

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.