

BMJ Open

BMJ Open is committed to open peer review. As part of this commitment we make the peer review history of every article we publish publicly available.

When an article is published we post the peer reviewers' comments and the authors' responses online. We also post the versions of the paper that were used during peer review. These are the versions that the peer review comments apply to.

The versions of the paper that follow are the versions that were submitted during the peer review process. They are not the versions of record or the final published versions. They should not be cited or distributed as the published version of this manuscript.

BMJ Open is an open access journal and the full, final, typeset and author-corrected version of record of the manuscript is available on our site with no access controls, subscription charges or pay-per-view fees (<http://bmjopen.bmj.com>).

If you have any questions on BMJ Open's open peer review process please email info.bmjopen@bmj.com

BMJ Open

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

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2022-066743
Article Type:	Original research
Date Submitted by the Author:	18-Jul-2022
Complete List of Authors:	Halldorsdottir, Solveig; Centre of Public Health Science Finnbjornsdottir, Ragnhildur Gudrun; Environment Agency of Iceland Elvarsson, Bjarki; Marine and Freshwater Research Institute Gunnarsdottir, Oddny Sigurborg; Landspítali University Hospital Gudmundsson, Gunnar; University of Iceland Rafnsson, Vilhjalmur; University of Iceland, Department of Preventive Medicine
Keywords:	EPIDEMIOLOGY, Cardiology < INTERNAL MEDICINE, Adult cardiology < CARDIOLOGY

SCHOLARONE™
Manuscripts



I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our [licence](#).

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which [Creative Commons](#) licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

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

Authors:

Solveig Halldorsdottir¹ solveighall@gmail.com

Ragnhildur Gudrun Finnbjornsdottir² ragnhildur.finnbjornsdottir@gmail.com

Bjarki Thor Elvarsson³ bjarki.elvarsson@gmail.com

Oddny Sigurborg Gunnarsdottir⁴ oddnygunn@gmail.com

Gunnar Gudmundsson^{5,6} ggudmund@landspitali.is

Vilhjalmur Rafnsson^{7*} vilraf@hi.is

¹University of Iceland, Centre of Public Health Science, Reykjavik, Iceland

²Environment Agency of Iceland, Reykjavik, Iceland

³Marine and Freshwater Research Institute, Reykjavik, Iceland

⁴Landspitali University Hospital, Reykjavik, Iceland

⁵University of Iceland, Faculty of Medicine, Reykjavik, Iceland

⁶Landspitali University Hospital, Department of Respiratory Medicine & Sleep, Reykjavik, Iceland

⁷University of Iceland, Department of Preventive Medicine, Reykjavik, Iceland

*Corresponding author: Vilhjalmur Rafnsson vilraf@hi.is

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 Landspítali 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 NO₂, PM₁₀, PM_{2.5}, and SO₂ with adjustment for H₂S, temperature and relative humidity.

Main outcome measure Odds ratio (OR) and 95% confidence intervals (CI) per 10 µg/m³ increase in concentration of pollutants.

Results: The 24-h mean NO₂ was 20.7 µg/m³, mean PM₁₀ was 20.5 µg/m³, mean PM_{2.5} was 12.5 µg/m³, and mean SO₂ was 2.5 µg/m³. PM₁₀ level was positively associated with the number of emergency hospital visits (n=453) for cardiac arrest. Each 10 µg/m³ increase in PM₁₀ 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 PM₁₀ 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 PM₁₀ 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.

For peer review only

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 NO₂ 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 NO₂ 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 NO₂ 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, NO₂, 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 NO₂; 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, NO₂,

1 PM₁₀, PM_{2.5}, and SO₂ in the Reykjavik capital area and urgent hospital and emergency department visits for
2 cardiac arrest as the primary discharge diagnosis, and to simultaneously adjust for meteorological variables
3 and geothermal-originated pollutants.
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

For peer review only

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 H₂S emission originates from the plants. Reykjavik's capital area spreads over 247.5 km² 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 Landspítali 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

1 according to the International Classification of Diseases 10th edition (ICD-10). In this study, both admission to
2 the emergency department and formal admission to the hospital are included, so there is no requirement that a
3 patient stayed overnight. The diagnoses are registered at discharge from the hospital, transfer to another
4 hospital, and death in the hospital. In a previous study (7), the outcomes were heart diseases ICD-10 codes:
5 I20-I25, I44-I50, ischemic heart diseases ICD-10 codes: I20-I25, cardiac arrhythmias and heart failure ICD-10
6 codes: I44-I50, and atrial fibrillation ICD-10 I48 (7). In the present study, the outcome analysed was cardiac
7 arrest ICD-10 code I46. Emergency department visits and urgent hospital admissions were combined and are
8 called emergency hospital visits.

19 **Air pollutants and meteorological data**

22 Information on pollution was obtained from Grensas monitor station (GRE), operated by the governmental
23 institution Environment Agency of Iceland. GRE is in the centre of the Reykjavik capital area near one of the
24 busiest road intersections in the city. Other stations in the city were not permanently located or were not
25 continuously monitoring throughout the study period and were therefore not used in the study. However, to
26 test whether GRE was reflective of the total capital area, Pearson's correlation was calculated for GRE
27 measurements and measurements from another station located in Dalsmari, Kopavogur municipality, for the
28 period 2014-2017. Results of Pearson's correlation coefficients between these two measurement stations were
29 for PM₁₀ 0.44, for NO₂ 0.78, for SO₂ 0.98, and for H₂S 0.84. PM_{2.5} was not measured in Dalsmari.

41 Pollutants measured at GRE were NO₂, particulate matter with aerodynamic diameter less than 10 µm (PM₁₀),
42 particulate matter with aerodynamic diameter less than 2.5 µm (PM_{2.5}), sulphur dioxide (SO₂), and hydrogen
43 sulphide (H₂S), all measured in µg/m³. The meteorological data was obtained from the governmental
44 institution Icelandic Meteorological Office and included temperature (°C) and relative humidity (RH). PM₁₀
45 and PM_{2.5} were measured with an Andersen EMS IR Thermo (model FH62 I-R), NO₂ with Horiba device
46 (model APNA 360E), and SO₂ and H₂S with the Horiba model APOA 360E. Every 6-12 months the devices
47 are calibrated. Exposure data included 12 years or 4,383 days. Daily averages (midnight to midnight the
48 following day) were calculated from hourly concentrations if at least 75% of one-hour data existed. Missing
49 daily averages for NO₂, PM₁₀, PM_{2.5}, SO₂, and H₂S were 383 days (8.7%), 165 days (3.8%), 923 days (21.1%),
50 200 days (4.6%), and 284 days (6.5%), respectively. Data gaps were seen and can be attributed to inactive

1 measurement devices due to unknown causes, with the exception of 52 days of missing H₂S measurements at
2 the beginning of the study period, as H₂S measurements at GRE started at the end of February 2006. For
3 temperature and RH, 6 days (0.1%) and 6 days (0.1%) were missing, respectively. Minor gaps in the curves
4 were fitted by linear interpolation.
5
6
7
8
9

10 Descriptive statistics were calculated and showed as daily concentration levels in µg/m³ of the pollutants, as
11 well as Spearman's correlation coefficient between pollutants and meteorological factors.
12
13
14
15
16
17

18 Analysis

19
20
21 Short-term associations between daily exposure to air pollutants and emergent hospital visits for cardiac arrest
22 (ICD-10 code I46) were assessed using bidirectional time-stratified case-crossover design. The study period
23 was divided into monthly strata, and exposure during case periods (24h) was compared to exposure during
24 control periods, which were matched as the same weekdays within the same month (3-4 control periods per
25 case period) (14,15). We did several calculations: single pollutant models were calculated in conditional
26 logistic regression, multivariate models containing all traffic-related pollutants, H₂S, and the meteorological
27 variables. Separate analyses were done for subgroups according to gender, age (≥71 and < 71 years), gender,
28 and age combined, winter (November 1st to April 30th), and summer (May 1st to October 31st). It was possible
29 to divide the diagnostic category I46 according to decimals into cardiac arrest with successful resuscitation
30 (I46.0) and other categories without indication of successful resuscitation (I46, I46.1, and I46.9). These two
31 subcategories were also analysed separately as there are indication that the latter category concern mortality.
32 The risk estimates were expressed as odds ratio (OR), and 95% confidence intervals (CI) were calculated for
33 every 10 µg/m³ increase of pollutants (24h concentrations).
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50

51 Different lag structures were applied. Single-day lag structure (lag 0 to lag 4), and multiple-day lag structure
52 (lag 0-1, lag 0-2, lag 0-3, and lag 0-4, moving average of pollutants concentration) were employed in the
53 analyses to explore the temporal association between pollutants and cardiac arrest. The results of the
54 multivariate models with all lag structures are presented in the article, and other results are shown as
55 Supplementary data.
56
57
58
59
60

1 Although readmissions within 10 days with the same primary discharge diagnosis were excluded, it is still
2 possible that some patients first went to the emergency department and were subsequently admitted that same
3 day to in-hospital wards where they might have received a different diagnosis than they were given at the
4 emergency department. To test whether this could distort the main result of the association between increased
5 pollutant concentration and the emergency hospital visits, a sensitivity analysis was done, in which data was
6 restricted to emergency department visits only.
7
8
9
10
11
12

13
14 Statistical analysis was done with R version 4.0.3 (<https://www.r-project.org/>). Statistical tests used in this
15 study were all two-tailed and we considered results statistically significant for $p < 0.05$.
16
17
18
19

20 The study was approved by the National Bioethics Committee (ref. no. VSNb2018120011/03.01), the Data
21 Protection Authority (ref. no. 10-050), and the Scientific Committee of LUH.
22
23
24
25
26
27

28 **Patient and public involvement**

29

30
31 None.
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

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 Landspítali 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 (≥ 71 yr)	192 (42)	190
Younger (< 71 yr)	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 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, H₂S, and meteorological variables are presented in Table 2.

Table 2. Descriptive statistics of 24-hour concentration levels ($\mu\text{g}/\text{m}^3$) 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 ₂ S	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
<i>Spearman's correlation</i>							
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 ₂ S	-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; H₂S: hydrogen sulphide; NO₂: nitrogen dioxide; PM₁₀: particulate matter ≤10µm in diameter; PM_{2.5}: particulate matter ≤2.5µm in diameter; RH: relative humidity; SO₂: sulphur dioxide; TEMP: temperature.

Missing daily average was highest for PM₁₀ but did not exceed 25% of the days of the study period. The concentrations of PM₁₀ 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 PM₁₀ 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 PM₁₀, as shown in Table A, Supplementary data. A positive association was observed between exposure to NO₂ 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 NO₂, as shown in Table A, Supplementary data.

In examining the daily lag exposure to PM₁₀ 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 PM₁₀ (Table 3). Significant associations were shown for exposure to NO₂ at lag 4 and for SO₂ 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 NO₂ and SO₂, 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 PM₁₀ at lag 2 and/or exposure to PM₁₀ 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).

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

For peer review only

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 NO₂, PM₁₀, PM_{2.5}, SO₂ and H₂S, 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.

Categories/Visits (n)	Lag	NO ₂		PM ₁₀		PM _{2.5}		SO ₂		H ₂ S	
		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

Downloaded from <http://bmjopen.bmj.com/> on April 27, 2024 by guest. Protected by copyright.

Table 3 Continued

1	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
2		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
3		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
4		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
5		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
6		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
7		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
8		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
9		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
10	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
11		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
12		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
13		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
14		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
15		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
16		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
17		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
18		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
19	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
20		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
21		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
22		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
23		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
24		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
25		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
26		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
27		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
28	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
29		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
30		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
31		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
32		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
33		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
34		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
35		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
36		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
37	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
38		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
39		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
40		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
41		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
42		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
43		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
44		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
45		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
46	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
47		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
48		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
49		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
50		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
51		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
52		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
53		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
54		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

1 In Figure 1, OR and 95% CI of cardiac arrest per 10 $\mu\text{g}/\text{m}^3$ increase of PM_{10} concentrations in multi-pollutant
2 models are shown at lag 0 to lag 4 for different strata and unstratified.
3
4

5 In the single pollutant analyses, positive associations were observed for exposure to PM_{10} at lag 0-3, and lag 0-
6 4, and emergency hospital visits for cardiac arrest with successful resuscitation (ICD-10 codes: I46.0); the
7 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),
8 respectively, per 10 $\mu\text{g}/\text{m}^3$ increase of PM_{10} , as shown in Table B, Supplementary data. A positive association
9 was observed for exposure to $\text{PM}_{2.5}$ at lag 3, and lag 4, and the increased risk of cardiac arrest with successful
10 resuscitation; the increased risk was OR 1.090 (95% CI 1.008-1.178), and OR 1.101 (95% CI 1.006-1.204),
11 per 10 $\mu\text{g}/\text{m}^3$ increase of $\text{PM}_{2.5}$, respectively, as shown in Table B, Supplementary data. A positive association
12 was observed for exposure to PM_{10} at lag 2, and the increased risk of cardiac arrest without indication of
13 successful resuscitation (ICD-10 codes: I46, I46.1, and I46.9); the increased risk was OR 1.079 (95% CI
14 1.008-1.155), as shown in Table B, Supplementary data.
15
16
17
18
19
20
21
22
23
24
25
26
27
28

29 When we applied the multivariate model to the stratification of whether the cardiac arrests were indicated with
30 successful resuscitation (ICD-10 code I46.0) or not (ICD-10 code I46, I46.1, and I46.9) and the association
31 with daily pollutant exposure, a similar pattern emerges to that of the single pollutants analyses, shown in
32 Table 4; however, the OR were somewhat higher and were observed at more lags and pollutants. A positive
33 association was observed between exposure to PM_{10} and emergency hospital visits for cardiac arrest with
34 successful resuscitation (ICD-10 codes: I46.0); the increased risks of cardiac arrest were OR 1.104 (95% CI
35 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,
36 and OR 1.209 (95% CI 1.027-1.422) at lag 0-4, per 10 $\mu\text{g}/\text{m}^3$ increase of PM_{10} , as shown in Table 4.
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

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 NO₂, PM₁₀, PM_{2.5}, SO₂, and H₂S, 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.

Categories/Visits (n)	Lag	NO ₂		PM ₁₀		PM _{2.5}		SO ₂		H ₂ S	
		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

1 A positive association was observed between exposure to PM_{2.5} and the increased risk of cardiac arrest with
2 successful resuscitation; the increased risk was OR 1.088 (95% CI 1.001-1.182) at lag 3, and OR 1.104 (95%
3 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
4
5 observed for exposure to NO₂ and the increased risk of cardiac arrest with successful resuscitation; the
6
7 increased risk was OR 1.194 (95% CI 1.023-1.393) at lag 4, as shown in Table 4. A positive association was
8
9 observed between exposure to PM₁₀ and the increased risk of cardiac arrest without indication of successful
10
11 resuscitation (ICD-10 codes: I46, I46.1, and I46.9); the increased risk was OR 1.090 (95% CI 1.013-1.173) at
12
13 lag 2, as shown in Table 4. In Figure 2, OR and 95% CI of cardiac arrest per 10 µg/m³ increase of PM₁₀
14
15 concentrations in multi-pollutant models are shown at lag 0 to lag 4 when stratified on season and whether
16
17 there is an indication of successful resuscitation or not.
18
19
20
21
22
23

24 In the sensitive analysis of the association between daily exposure to PM₁₀ and emergency hospital visits for
25
26 cardiac arrest (ICD-10 code I46), when restricting the calculation to emergency department visits only (353
27
28 visits), the results did not change substantially: in the unstratified analysis, the increased risk of cardiac arrest
29
30 was OR 1.099 (95% CI 1.028-1.175) at lag 2 per 10 µg/m³ increase of PM₁₀.
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

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 PM₁₀ 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 PM₁₀ (21), with various associations with O₃, 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 NO₂ was significant, while in the same publication some of the mortality outcomes were associated with exposure to PM_{2.5} but not to NO₂ (8), indicating the possibility of different pathogenetic pathways for the outcomes, as has been discussed briefly in the case of

1 NO₂ (4), and in the comprehensive review of the causal role of particulate material (2). The category cardiac
2 arrest in the ICD-10 coding system represents a small group compared to other CVD diagnoses and seems to
3 be concealed within the larger summary group of cardiac arrhythmias (10) or omitted from the analysis (8). In
4 this respect, our recent study on the same dataset is not an exception: increased risk of cardiac arrhythmias
5 (ICD-10 codes I44 to I50) was associated with an increase in NO₂ exposure (7), a finding that hides the
6 association between cardiac arrest (ICD-10 code I46) and exposure to PM₁₀ as demonstrated in the present
7 study.
8

9
10
11
12
13
14
15
16
17 Among the strengths of this study is that it is population-based, as the hospital and emergency department data
18 were obtained from the only emergency health care institution, the LUH, serving the population in the
19 catchment area of the Reykjavik capital. The design of the study is also a strength, as the bidirectional time-
20 stratified case-crossover approach virtually excludes confounding of individual characteristics and the
21 matching adjusted for weekly pattern and time trends. Another strength of the study is its use of the encrypted
22 identification number of each patient in the Register of hospital-treated patients, which ensures the correct
23 counting and identification of the cases and their admissions. Furthermore, it is noteworthy that visits of the
24 cases receiving the primary discharge diagnosis cardiac arrest (453 cases) were evenly distributed over the
25 study period (4383 days), so the distribution diminished the risk of overlapping the sets of case and control
26 days.
27
28
29
30
31
32
33
34
35
36
37
38

39
40
41 That said, there are few limitations. First, the concentration of the pollutants derived from one monitoring
42 station in the Reykjavik capital area, and not from individual exposure measurements. The results from these
43 measurements did, however, correlate well with measurements from another monitoring station located in the
44 capital area during three years of the study period. Another limitation is that only the primary discharge
45 diagnosis was included in the study, meaning that the cases may have underlying diseases that could modify
46 the result.
47
48
49
50
51
52
53
54

55
56
57 Furthermore, the quality of the routine discharge diagnosis at the LUH has not been investigated in a separate
58 study for accuracy or reliability, which is a weakness our study shares with the many studies based on hospital
59 records. The primary discharge diagnosis of cardiac arrest (ICD-10 code I46) set at emergency admission to
60 the hospital and emergency department does not indicate whether the causes were cardiac- or trauma related,

1 and there may be doubt as to where the patient developed the cardiac arrest, i.e., whether the event initially
2 occurred outside or inside the hospital. The study population consisted of patients aged 18 years and older,
3 which limits the generalisability of the results to those under 18.
4

5
6
7
8 The present study concentrates on traffic related pollutants; however, emissions from the volcanic eruptions
9 occurring in Iceland during the study period may have confounded the results. The Eyjafjallajökull eruption in
10 2010 was found to have minor health effect on the local population, but not the population in the Reykjavik
11 capital area (22). The Holuhraun eruption in 2014 to 2015 emitted a massive amount of SO₂ and mature
12 volcanic plume, and the exposure to these was associated with an increase in the dispensing of asthma
13 medication and an increase in health care utilisation for respiratory diseases in the Reykjavik capital area
14 during four months in the year 2014 (23,24). The present study was not designed to catch the possible effect of
15 these emissions on the cardiovascular health of the population of the Reykjavik capital area, and its role
16 remains unknown with that respect.
17
18
19
20
21
22
23
24
25
26
27
28

29 We made several stratifications to explore the possible association between air pollutants and emergency
30 hospital visits for cardiac arrest in this study. Because of this, some concerns may emerge about multiple
31 comparisons; however, this has been dealt with in the literature (25).
32
33
34
35
36
37
38

39 **Conclusions**

40
41 This study was, to our knowledge, the first to utilise the new endpoint of cardiac arrest (ICD-10 code I46).
42 This outcome has in previous epidemiological studies been included in larger groups of CVDs, and its special
43 status may have been overshadowed by the more common diagnosis of CVDs. Our results indicate a positive
44 association between short-term increase in PM₁₀ and emergency hospital visits for cardiac arrest in the
45 Reykjavik capital area, known for having low levels of traffic-related pollution. The effects were found in
46 most subgroups, and were highest among the elderly, and in the winter season, and among those who were
47 successfully resuscitated. Future ecological studies of this type should perhaps concentrate more on precisely
48 defined endpoints; however, doing so will not replace the obvious lack of exact individual exposure
49 measurements for each of the cases.
50
51
52
53
54
55
56
57
58
59
60

List of abbreviations

1		
2	µm	Micrometre
3		
4	AF	Atrial fibrillation
5		
6	CI	Confidence interval
7		
8	CVD	Cardiovascular diseases
9		
10	ED	Emergency department
11		
12	GRE	Air quality measurement station located at
13		Grensasvegur-Miklabraut intersection in Reykjavik
14		
15	H ₂ S	Hydrogen sulphide
16		
17	ICD-10	International Classification of Diseases 10th edition
18		
19	IHD	Ischemic heart disease
20		
21	km	Kilometre
22		
23	LUH	Landspítali University Hospital
24		
25	NO ₂	Nitrogen dioxide
26		
27	OR	Odds ratio
28		
29	PM ₁₀	Particulate matter less than 10 µm in aerodynamic diameter
30		
31	PM _{2.5}	Particulate matter less than 2.5 µm in aerodynamic diameter
32		
33	RH	Relative humidity
34		
35	SAGA	Register of Hospital-treated Patients in Iceland
36		
37	SO ₂	Sulphur dioxide
38		
39	yr	Year
40		
41		

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.

1
2
3 **Competing interest**
4
5

6 The authors declare that they have no competing interests.
7
8

9 **Funding**
10
11

12 The study had no external funding.
13
14

15 **Authors' contribution**
16
17

18 SH, RGF, VR designed the study; SH, RGF, BTE, VR planned the analysis; SH, GG, VR collected the data;
19

20 SH, RGF, BTE analysed the data; VR wrote the first draft; SH, RGF, BTE, OSG, GG, VR read the
21

22 manuscript, interpreted the conclusion, and agreed on the final version.
23
24

25 **Acknowledgements**
26
27

28 Not applicable.
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

References

1. Brook RD, Franklin B, Cascio W, Hong Y, Howard G, Lipsett M, et al. Air pollution and cardiovascular disease: a statement for healthcare professionals from the Expert Panel on Population and Prevention Science of the American Heart Association. *Circulation*. 2004;109(21):2655-71.
2. Brook RD, Rajagopalan S, Pope CA, 3rd, Brook JR, Bhatnagar A, Diez-Roux AV, et al. Particulate matter air pollution and cardiovascular disease: An update to the scientific statement from the American Heart Association. *Circulation*. 2010;121(21):2331-78.
3. Meng X, Liu C, Chen R, Sera F, Vicedo-Cabrera AM, Milojevic A, et al. Short term associations of ambient nitrogen dioxide with daily total, cardiovascular, and respiratory mortality: multilocation analysis in 398 cities. *BMJ*. 2021;372:n534.
4. Stieb DM, Zheng C, Salama D, Berjawi R, Emode M, Hocking R, et al. Systematic review and meta-analysis of case-crossover and time-series studies of short term outdoor nitrogen dioxide exposure and ischemic heart disease morbidity. *Environ Health*. 2020;19(1):47.
5. Belch JJ, Fitton C, Cox B, Chalmers JD. Associations between ambient air pollutants and hospital admissions: more needs to be done. *Environ. Sci. Pollut. Res*. 2021;28(43):61848-52.
6. Dahlquist M, Frykman V, Kemp-Gudmundsdottir K, Svennberg E, Wellenius GA, P LSL. Short-term associations between ambient air pollution and acute atrial fibrillation episodes. *Environ Int*. 2020;141:105765.
7. Halldorsdottir S, Finnbjornsdottir RG, Elvarsson BT, Gudmundsson G, Rafnsson V. Ambient nitrogen dioxide is associated with emergency hospital visits for atrial fibrillation: a population-based case-crossover study in Reykjavik, Iceland. *Environ Health*. 2022;21(1):2.
8. Milojevic A, Wilkinson P, Armstrong B, Bhaskaran K, Smeeth L, Hajat S. Short-term effects of air pollution on a range of cardiovascular events in England and Wales: case-crossover analysis of the MINAP database, hospital admissions and mortality. *Heart*. 2014;100(14):1093-8.
9. Talbott EO, Rager JR, Benson S, Brink LA, Bilonick RA, Wu C. A case-crossover analysis of the impact of PM(2.5) on cardiovascular disease hospitalizations for selected CDC tracking states. *Environ Res*. 2014;134:455-65.
10. Zheng Q, Liu H, Zhang J, Chen D. The effect of ambient particle matters on hospital admissions for cardiac arrhythmia: a multi-city case-crossover study in China. *Environ Health*. 2018;17(1):60.
11. Carlsen HK, Forsberg B, Meister K, Gíslason T, Oudin A. Ozone is associated with cardiopulmonary and stroke emergency hospital visits in Reykjavík, Iceland 2003-2009. *Environ Health*. 2013;12:28.
12. Finnbjornsdottir RG, Zoëga H, Olafsson O, Thorsteinsson T, Rafnsson V. Association of air pollution and use of glyceryl trinitrate against angina pectoris: a population-based case-crossover study. *Environ Health*. 2013;12(1):38.
13. Statistics Iceland. Population by municipality, sex, citizenship and quarters 2011-2019. <https://hagstofa.is/talnaefni/ibuar/mannfjoldi/yfirlit/> (2020). Accessed 06 Feb 2020.
14. Levy D, Lumley T, Sheppard L, Kaufman J, Checkoway H. Referent selection in case-crossover analyses of acute health effects of air pollution. *Epidemiology*. 2001;12(2):186-92.
15. Maclure M. The case-crossover design: a method for studying transient effects on the risk of acute events. *Am J Epidemiol*. 1991;133(2):144-53.
16. Berdowski J, Berg RA, Tijssen JG, Koster RW. Global incidences of out-of-hospital cardiac arrest and survival rates: Systematic review of 67 prospective studies. *Resuscitation*. 2010;81(11):1479-87.
17. Ensor KB, Raun LH, Persse D. A case-crossover analysis of out-of-hospital cardiac arrest and air pollution. *Circulation*. 2013;127(11):1192-9.
18. Rosenthal FS, Kuisma M, Lanki T, Hussein T, Boyd J, Halonen JI, et al. Association of ozone and particulate air pollution with out-of-hospital cardiac arrest in Helsinki, Finland: evidence for two different etiologies. *J Expo Sci Environ Epidemiol*. 2013;23(3):281-8.
19. Xia R, Zhou G, Zhu T, Li X, Wang G. Ambient Air Pollution and Out-of-Hospital Cardiac Arrest in Beijing, China. *Int J Environ Res Public Health*. 2017;14(4).
20. Zhao B, Johnston FH, Salimi F, Kurabayashi M, Negishi K. Short-term exposure to ambient fine particulate matter and out-of-hospital cardiac arrest: a nationwide case-crossover study in Japan. *Lancet Planet. Health*. 2020;4(1):e15-e23.
21. Tobaldini E, Iodice S, Bonora R, Bonzini M, Brambilla A, Sesana G, et al. Out-of-hospital cardiac arrests in a large metropolitan area: synergistic effect of exposure to air particulates and high temperature. *Eur. J. Prev. Cardiol*. 2020;27(5):513-9.
22. Carlsen HK, Hauksdottir A, Valdimarsdottir UA, Gíslason T, Einarsdottir G, Runolfsson H, et al. Health effects following the Eyjafjallajökull volcanic eruption: a cohort study. *BMJ Open*. 2012;2(6).

- 1 23. Carlsen HK, Ilyinskaya E, Baxter PJ, Schmidt A, Thorsteinsson T, Pfeffer MA, et al. Increased respiratory
2 morbidity associated with exposure to a mature volcanic plume from a large Icelandic fissure eruption. *Nat. Commun.*
3 2021;12(1):2161-.
- 4 24. Carlsen HK, Valdimarsdóttir U, Briem H, Dominici F, Finnbjörnsdóttir RG, Jóhannsson T, et al. Severe volcanic
5 SO exposure and respiratory morbidity in the Icelandic population - a register study.
6 *Environ. Health: Glob. Access Sci. Source.* 2021;20(1):23.
- 7
- 8 25. Rothman KJ. No Adjustments Are Needed for Multiple Comparisons. *Epidemiology.* 1990;1(1):43-6.
- 9
- 10
- 11
- 12
- 13
- 14
- 15
- 16
- 17
- 18
- 19
- 20
- 21
- 22
- 23
- 24
- 25
- 26
- 27
- 28
- 29
- 30
- 31
- 32
- 33
- 34
- 35
- 36
- 37
- 38
- 39
- 40
- 41
- 42
- 43
- 44
- 45
- 46
- 47
- 48
- 49
- 50
- 51
- 52
- 53
- 54
- 55
- 56
- 57
- 58
- 59
- 60

For peer review only

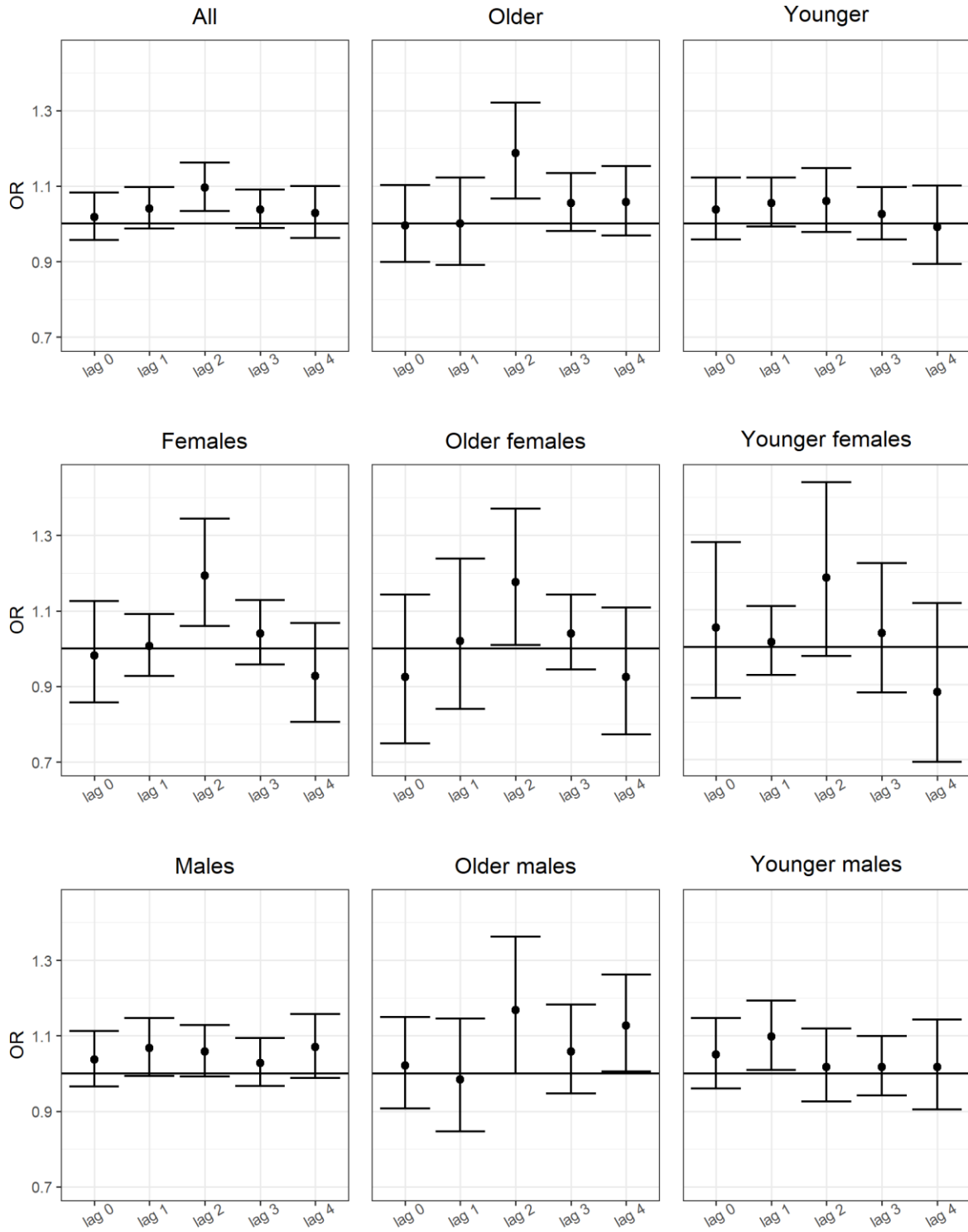


Figure 1. The odds ratio (OR) and bars showing 95% confidence intervals of cardiac arrest (ICD-10 code I46) per 10 $\mu\text{g}/\text{m}^3$ increase in PM_{10} concentrations in multiple-pollutant models at lag 0 to lag 4 for unstratified material and different strata.

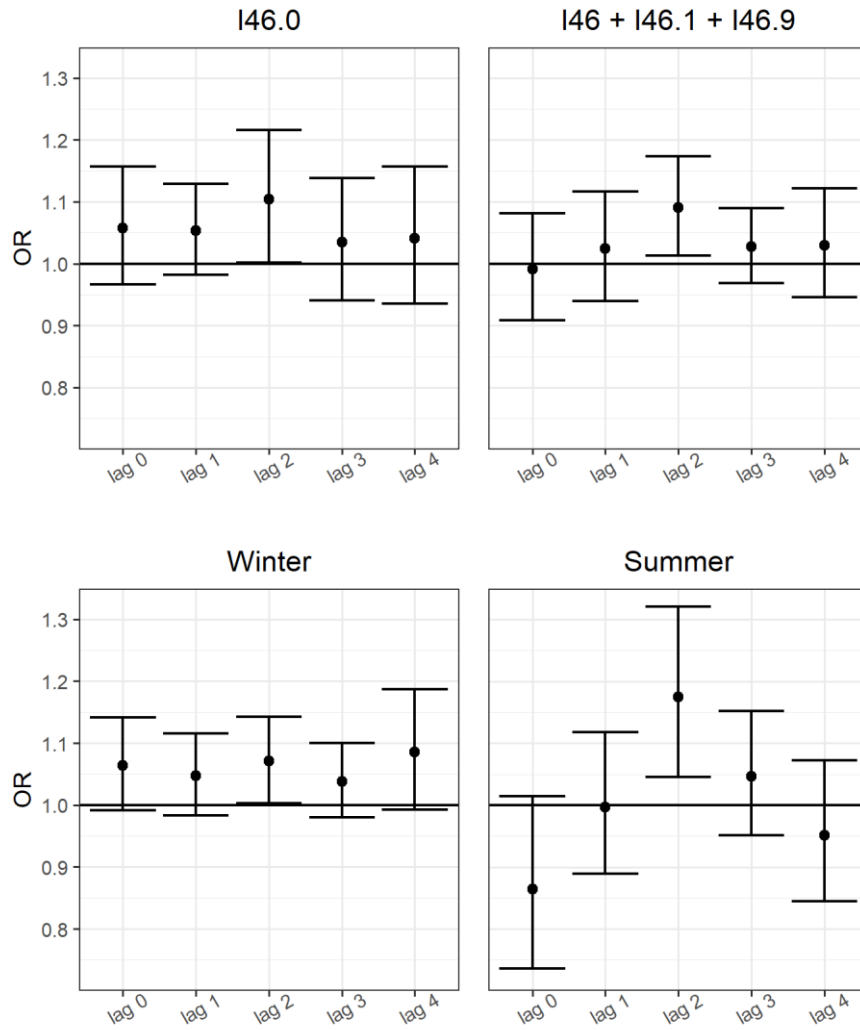


Figure 2. The odds ratio (OR) and bars showing 95% confidence intervals of cardiac arrest with successful resuscitation (ICD-10 code: I46.0) and other cardiac arrest categories grouped together (ICD-10 codes I46, I46.1 and I46.9), as well as cardiac arrest (ICD-10 code: I46) stratified to winter and summer, per $10 \mu\text{g}/\text{m}^3$ 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 NO₂, PM₁₀, PM_{2.5}, SO₂, and H₂S, 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.

Categories/Visits (n)	Lag	NO ₂		PM ₁₀		PM _{2.5}		SO ₂		H ₂ S	
		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

6/bmjopen-2023-066743 on 15 May 2023. Downloaded from <http://bmjopen.bmj.com/> on April 27, 2024 by guest. Protected by copyright.

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 NO₂, PM₁₀, PM_{2.5}, SO₂, and H₂S, in single pollutant models, at lag 0 to lag 4, lag 0-1, lag 0-2, lag 0-3, and lag 0-4.

Categories/Visits (n)	Lag	NO ₂		PM ₁₀		PM _{2.5}		SO ₂		H ₂ S	
		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		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 (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	10, table 1 NA NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest	10, tables 1, 2 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 (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	11-13 NA 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.

BMJ Open

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

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2022-066743.R1
Article Type:	Original research
Date Submitted by the Author:	22-Feb-2023
Complete List of Authors:	Halldorsdottir, Solveig; Centre of Public Health Science Finnbjornsdottir, Ragnhildur Gudrun; Environment Agency of Iceland Elvarsson, Bjarki; Marine and Freshwater Research Institute Gunnarsdottir, Oddny Sigurborg; Landspítali University Hospital Gudmundsson, Gunnar; University of Iceland Rafnsson, Vilhjalmur; University of Iceland, Department of Preventive Medicine
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Public health
Keywords:	EPIDEMIOLOGY, Adult cardiology < CARDIOLOGY, REGISTRIES

SCHOLARONE™
Manuscripts



I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our [licence](#).

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which [Creative Commons](#) licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

1
2
3 Ambient air pollution and emergency department visits and
4 hospitalisation for cardiac arrest: a population-based case-crossover
5 study in Reykjavik, Iceland
6
7
8
9
10
11

12 Authors:

13
14 Solveig Halldorsdottir¹ solveighall@gmail.com

15
16 Ragnhildur Gudrun Finnbjornsdottir² ragnhildur.finnbjornsdottir@gmail.com

17
18 Bjarki Thor Elvarsson³ bjarki.elvarsson@gmail.com

19
20 Oddny Sigurborg Gunnarsdottir⁴ oddnygunn@gmail.com

21
22 Gunnar Gudmundsson^{5,6} ggudmund@landspitali.is

23
24 Vilhjalmur Rafnsson^{7*} vilraf@hi.is
25
26
27
28
29
30
31

32 ¹University of Iceland, Centre of Public Health Science, Reykjavik, Iceland

33
34 ²Environment Agency of Iceland, Reykjavik, Iceland

35
36 ³Marine and Freshwater Research Institute, Reykjavik, Iceland

37
38 ⁴Landspitali University Hospital, Reykjavik, Iceland

39
40 ⁵University of Iceland, Faculty of Medicine, Reykjavik, Iceland

41
42 ⁶Landspitali University Hospital, Department of Respiratory Medicine & Sleep, Reykjavik,
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
Iceland

⁷University of Iceland, Department of Preventive Medicine, Reykjavik, Iceland

*Corresponding author: Vilhjalmur Rafnsson vilraf@hi.is

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 Landspítali 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 NO₂, PM₁₀, PM_{2.5}, and SO₂ with adjustment for H₂S, temperature and relative humidity.

Main outcome measure Odds ratio (OR) and 95% confidence intervals (CI) per 10 µg/m³ increase in concentration of pollutants.

Results: The 24-h mean NO₂ was 20.7 µg/m³, mean PM₁₀ was 20.5 µg/m³, mean PM_{2.5} was 12.5 µg/m³, and mean SO₂ was 2.5 µg/m³. PM₁₀ level was positively associated with the number of emergency hospital visits (n=453) for cardiac arrest. Each 10 µg/m³ increase in PM₁₀ 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 PM₁₀ 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 PM₁₀ concentrations

1
2
3 was associated with cardiac arrest. Future ecological studies of this type and their related
4
5 discussions should perhaps concentrate more on precisely defined endpoints.
6
7

8 **Key words** Cardiac arrest, urgent hospital visits, successful resuscitation, multivariate
9
10 models, cardiovascular diseases
11
12

13 **Strength and limitations of this study**

14

- 15
16 • The study is population-based, relies on comprehensive population registries, and
17 include information of daily concentrations of the pollutants which cover more than
18 75% of the days in the study period.
19
- 20 • The methodology allows within-subject comparison while adjusting for various time
21 trends such as seasonality, and day of week.
22
- 23 • The concentration of the pollutants derived from one monitoring station, and not from
24 individual exposure measurements.
25
- 26 • The population is small, and therefore the total number of cases were few, resulting in
27 low statistical power.
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

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 NO₂ 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 NO₂ 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 NO₂ 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, NO₂, 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

1
2
3 for CVD, arrhythmias, atrial fibrillation, and heart failure was associated with an increased
4 concentration of NO₂; however, cardiac arrest was not included as an outcome in the study.

5
6
7 Cardiac arrest was mentioned in the aforementioned Chinese study (10) but was not analysed
8 separately.
9

10
11
12 There are several studies on the association of air pollution and out of hospital cardiac arrest
13 (OHCA) (11-15). The risk of OHCA were associated with a short-term increase in exposure
14 to particulate matter, sometimes PM_{2.5}, or ultrafine particulate matter (11-14), and sometimes
15 PM₁₀ (15), with various associations with O₃, other caseous pollutants, and high temperature.
16
17 The collection of cases in the OHCA studies use special registers as a source, regarding
18 Utstein definition (16,17) with the original purpose to provide a structured framework to
19 evaluate emergency medical service. The main criteria in the definition of the cases in the
20 OHCA studies are: 1) the cardiovascular collapse has occurred outside a hospital, and 2) the
21 event has elicited a resuscitation attempt. Neither of these conditions is required for the
22 physician given diagnosis of cardiac arrest according to the International Classification of
23 Diseases 10th edition (ICD-10) code I46 registered as discharge diagnosis at hospitals or
24 emergency departments.
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40

41 The comprehensive population and health registries in Iceland make this an optimal setting to
42 study the association between relatively low daily exposure to air pollution, and different
43 heart related conditions (7,18,19). The aim of the present study was to explore the association
44 between traffic-related pollutants, NO₂, PM₁₀, PM_{2.5}, and SO₂ in the Reykjavik capital area
45 and urgent hospital and emergency department visits for cardiac arrest, ICD-10 code I46, as
46 the primary discharge diagnosis, and to simultaneously adjust for meteorological variables
47 and geothermal-originated pollutants.
48
49
50
51
52
53
54
55
56
57
58
59
60

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 H₂S emission originates from the plants. Reykjavik's capital area spreads over 247.5 km² 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, Hafnarfjörður, 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 Landspítali 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

1
2
3 identification numbers are widely used in Icelandic society and population registries,
4 including the SAGA register. We received the identification numbers in encrypted form,
5
6 which enabled us to identify repeated visits to LUH. Readmissions to LUH within 10 days
7
8 with the same ICD-10 primary discharge diagnosis were excluded. From the SAGA register
9
10 we received the following details: admission date, encrypted identification number, unique
11
12 number of the admission, age, gender, primary discharge diagnosis for certain codes
13
14 according to the International Classification of Diseases 10th edition (ICD-10). In this study,
15
16 both admission to the emergency department and formal admission to the hospital are
17
18 included, so there is no requirement that a patient stayed overnight. The diagnoses are
19
20 registered at discharge from the hospital, transfer to another hospital, and death in the
21
22 hospital. In a previous study (7), the outcomes were heart diseases ICD-10 codes: I20-I25,
23
24 I44-I50, ischemic heart diseases ICD-10 codes: I20-I25, cardiac arrhythmias and heart failure
25
26 ICD-10 codes: I44-I50, and atrial fibrillation ICD-10 I48 (7). In the present study, the
27
28 outcome analysed was cardiac arrest ICD-10 code I46. Emergency department visits and
29
30 urgent hospital admissions were combined and are called emergency hospital visits.
31
32
33
34
35
36
37

38 **Air pollutants and meteorological data**

39
40
41 Information on pollution was obtained from Grensas monitor station (GRE), operated by the
42
43 governmental institution Environment Agency of Iceland. GRE is in the centre of the
44
45 Reykjavik capital area near one of the busiest road intersections in the city. Other stations in
46
47 the city were not permanently located or were not continuously monitoring throughout the
48
49 study period and were therefore not used in the study. However, to test whether GRE was
50
51 reflective of the total capital area, Pearson's correlation was calculated for GRE
52
53 measurements and measurements from another station located in Dalsmari, Kopavogur
54
55 municipality, for the period 2014-2017. Results of Pearson's correlation coefficients between
56
57
58
59
60

1
2
3 these two measurement stations were for PM₁₀ 0.44, for NO₂ 0.78, for SO₂ 0.98, and for H₂S
4
5 0.84. PM_{2.5} was not measured in Dalsmari.

6
7
8 Pollutants measured at GRE were NO₂, particulate matter with aerodynamic diameter less
9
10 than 10 µm (PM₁₀), particulate matter with aerodynamic diameter less than 2.5 µm (PM_{2.5}),
11
12 sulphur dioxide (SO₂), and hydrogen sulphide (H₂S), all measured in µg/m³. The
13
14 meteorological data was obtained from the governmental institution Icelandic Meteorological
15
16 Office and included temperature (°C) and relative humidity (RH). PM₁₀ and PM_{2.5} were
17
18 measured with an Andersen EMS IR Thermo (model FH62 I-R), NO₂ with Horiba device
19
20 (model APNA 360E), and SO₂ and H₂S with the Horiba model APOA 360E. Every 6-12
21
22 months the devices are calibrated. Exposure data included 12 years or 4,383 days. Daily
23
24 averages (midnight to midnight the following day) were calculated from hourly
25
26 concentrations if at least 75% of one-hour data existed. Missing daily averages for NO₂, PM₁₀,
27
28 PM_{2.5}, SO₂, and H₂S were 383 days (8.7%), 165 days (3.8%), 923 days (21.1%), 200 days
29
30 (4.6%), and 284 days (6.5%), respectively. Data gaps were seen and can be attributed to
31
32 inactive measurement devices due to unknown causes, with the exception of 52 days of
33
34 missing H₂S measurements at the beginning of the study period, as H₂S measurements at GRE
35
36 started at the end of February 2006. For temperature and RH, 6 days (0.1%) and 6 days
37
38 (0.1%) were missing, respectively. Minor gaps in the curves were fitted by linear
39
40 interpolation.

41
42 Descriptive statistics were calculated and showed as daily concentration levels in µg/m³ of the
43
44 pollutants, as well as Spearman's correlation coefficient between pollutants and
45
46 meteorological factors.

47 48 **Patient and public involvement**

49
50 No patient involved.
51
52
53
54
55
56
57
58
59
60

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, H₂S, 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 $\mu\text{g}/\text{m}^3$ 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.

1
2
3 Although readmissions within 10 days with the same primary discharge diagnosis were
4 excluded, it is still possible that some patients first went to the emergency department and
5 were subsequently admitted that same day to in-hospital wards where they might have
6 received a different diagnosis than they were given at the emergency department. To test
7 whether this could distort the main result of the association between increased pollutant
8 concentration and the emergency hospital visits, a sensitivity analysis was done, in which data
9 was restricted to emergency department visits only.
10
11
12
13
14
15
16
17
18
19

20 Statistical analysis was done with R version 4.0.3 (<https://www.r-project.org/>). Statistical tests
21 used in this study were all two-tailed and we considered results statistically significant for $p <$
22 0.05.
23
24
25
26

27 The study was approved by the National Bioethics Committee (ref. no.
28 VSNb2018120011/03.01), the Data Protection Authority (ref. no. 10-050), and the Scientific
29 Committee of LUH.
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

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, H₂S, and meteorological variables are presented in Table 2. Missing daily average was highest for PM₁₀ but did not exceed 25% of the days of the study period. The concentrations of PM₁₀ 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 PM₁₀ 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 PM₁₀, as shown in Table A, Supplementary data. A positive association was observed between exposure to NO₂ 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 NO₂, as shown in Table A, Supplementary data.

In examining the daily lag exposure to PM₁₀ 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 PM₁₀ (Table 3). Significant associations were shown for exposure to NO₂ at lag 4 and for SO₂ at lag 0, and unstratified emergency

1
2
3 hospital visits for cardiac arrest; the increased risks were OR 1.096 (95% CI 1.008-1.192) and
4
5 OR 1.084 (95% CI 1.002-1.173) per 10 $\mu\text{g}/\text{m}^3$ increase of NO_2 and SO_2 , respectively (Table
6
7
8 3).

9
10 In the multivariate model significant associations were shown between exposure to PM_{10} at
11
12 lag 2 and at lag 0-2, lag 0-3, and lag 0-4, and increased risks of cardiac arrest (ICD-10 code
13
14 I46), in the age, gender, age and gender combined, and season strata, i.e., in all the strata
15
16 except in the stratum of young females (Table 3)(The season strata are shown in Table C,
17
18 Supplementary data). In Figure 1, OR and 95% CI of cardiac arrest per 10 $\mu\text{g}/\text{m}^3$ increase of
19
20 PM_{10} concentrations in multi-pollutant models are shown at lag 0 to lag 4 for different strata
21
22 and unstratified.
23
24
25

26
27 In the single pollutant analyses, positive associations were observed for exposure to PM_{10} at
28
29 lag 0-3, and lag 0-4, and emergency hospital visits for cardiac arrest with successful
30
31 resuscitation (ICD-10 codes: I46.0); the increased risks of cardiac arrest were OR 1.161 (95%
32
33 CI 1.014-1.329), and OR 1.177 (95% CI 1.013-1.368), respectively, per 10 $\mu\text{g}/\text{m}^3$ increase of
34
35 PM_{10} , as shown in Table B, Supplementary data. A positive association was observed for
36
37 exposure to $\text{PM}_{2.5}$ at lag 3, and lag 4, and the increased risk of cardiac arrest with successful
38
39 resuscitation; the increased risk was OR 1.090 (95% CI 1.008-1.178), and OR 1.101 (95% CI
40
41 1.006-1.204), per 10 $\mu\text{g}/\text{m}^3$ increase of $\text{PM}_{2.5}$, respectively, as shown in Table B,
42
43
44 Supplementary data. A positive association was observed for exposure to PM_{10} at lag 2, and
45
46 the increased risk of cardiac arrest without indication of successful resuscitation (ICD-10
47
48 codes: I46, I46.1, and I46.9); the increased risk was OR 1.079 (95% CI 1.008-1.155), as
49
50
51 shown in Table B, Supplementary data.
52
53
54

55
56 In the multivariate model a positive association was observed between exposure to PM_{10} and
57
58 emergency hospital visits for cardiac arrest with successful resuscitation (ICD-10 code:
59
60 I46.0); the increased risks of cardiac arrest were OR 1.104 (95% CI 1.002-1.216) at lag 2, OR

1
2
3 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
4
5 1.209 (95% CI 1.027-1.422) at lag 0-4, per 10 $\mu\text{g}/\text{m}^3$ increase of PM_{10} , as shown in Table 4. A
6
7 positive association was observed between exposure to $\text{PM}_{2.5}$ and the increased risk of cardiac
8
9 arrest with successful resuscitation; the increased risk was OR 1.088 (95% CI 1.001-1.182) at
10
11 lag 3, and OR 1.104 (95% CI 1.006-1.21) at lag 4, per 10 $\mu\text{g}/\text{m}^3$ increase of $\text{PM}_{2.5}$, as shown
12
13 in Table 4. A positive association was observed between exposure to PM_{10} and the increased
14
15 risk of cardiac arrest without indication of successful resuscitation (ICD-10 codes: I46, I46.1,
16
17 and I46.9); the increased risk was OR 1.090 (95% CI 1.013-1.173) at lag 2, as shown in Table
18
19 4. In Figure 2, OR and 95% CI of cardiac arrest per 10 $\mu\text{g}/\text{m}^3$ increase of PM_{10} concentrations
20
21 in multi-pollutant models are shown at lag 0 to lag 4 when stratified on season and whether
22
23 there is an indication of successful resuscitation or not.
24
25
26
27
28

29 In the sensitive analysis of the association between daily exposure to PM_{10} and emergency
30
31 hospital visits for cardiac arrest (ICD-10 code I46), when restricting the calculation to
32
33 emergency department visits only (353 visits), the results did not change substantially: in the
34
35 unstratified analysis, the increased risk of cardiac arrest was OR 1.099 (95% CI 1.028-1.175)
36
37 at lag 2 per 10 $\mu\text{g}/\text{m}^3$ increase of PM_{10} .
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

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 PM₁₀ and cardiac arrest at lag 2, lag 0-2, lag 0-3, and lag 0-4, so the 24 hours concentrations of PM₁₀ 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 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

1
2
3 hospitals or emergency departments. In addition, the Utstein definition recommends
4 registration of several time points and intervals important for the research and quality
5 assurance related to the resuscitation, but such time elements are not required in the hospital
6 discharge registries based on the ICD-10. Some studies have shown that the risks of OHCA
7 were associated with a short-term increase in exposure to particulate matter, sometimes $PM_{2.5}$,
8 or ultrafine particulate matter (11-14), and sometimes PM_{10} (15), with various associations
9 with O_3 , other caseous pollutants, and high temperature. An OHCA study conducted in
10 Stockholm, Sweden demonstrated a significant exposure-response association between
11 OHCA risk and O_3 , but no association for $PM_{2.5}$ or NO_2 , (24), while another OHCA study in
12 Lombardy, Italy, showed, with different methodology, that the concentrations of all the
13 pollutants in the study were significantly higher in days with high incidence of OHCA except
14 for O_3 (25). In these OHCA studies (11-15,24,25) no difference is made between those who
15 survive the event and those who do not survive. In the previously mentioned UK study (8) on
16 the association between air pollution and hospital admission for different cardiovascular
17 events, exposure to NO_2 was significant, while in the same publication some of the mortality
18 outcomes were associated with exposure to $PM_{2.5}$ but not to NO_2 (8), indicating the possibility
19 of different pathogenetic pathways for the outcomes, as has been discussed briefly in the case
20 of NO_2 (4), and in the comprehensive review of the causal role of particulate material (2). The
21 category cardiac arrest in the ICD-10 coding system represents a small group compared to
22 other CVD diagnoses and seems to be concealed within the larger summary group of cardiac
23 arrhythmias (10) or omitted from the analysis (8). In this respect, our recent study on the same
24 dataset is not an exception: increased risk of cardiac arrhythmias (ICD-10 codes I44 to I50)
25 was associated with an increase in NO_2 exposure (7), a finding that hides the association
26 between cardiac arrest (ICD-10 code I46) and exposure to PM_{10} as demonstrated in the
27 present study.
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 Among the strengths of this study is that it is population-based, as the hospital and emergency
4 department data were obtained from the only emergency health care institution, the LUH,
5 serving the population in the catchment area of the Reykjavik capital. The design of the study
6 is also a strength, as the bidirectional time-stratified case-crossover approach virtually
7 excludes confounding of individual characteristics and the matching adjusted for weekly
8 pattern and time trends. Another strength of the study is its use of the encrypted identification
9 number of each patient in the Register of hospital-treated patients, which ensures the correct
10 counting and identification of the cases and their admissions. Furthermore, it is noteworthy
11 that visits of the cases receiving the primary discharge diagnosis cardiac arrest (453 cases)
12 were evenly distributed over the study period (4383 days), so the distribution diminished the
13 risk of overlapping the sets of case and control days.
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28

29 That said, there are few limitations. First, the concentration of the pollutants derived from one
30 monitoring station in the Reykjavik capital area, and not from individual exposure
31 measurements. The results from these measurements did, however, correlate well with
32 measurements from another monitoring station located in the capital area during three years of
33 the study period. Another limitation is that only the primary discharge diagnosis was included
34 in the study, meaning that the cases may have underlying diseases that could modify the
35 result.
36
37
38
39
40
41
42
43
44
45

46 Furthermore, the quality of the routine discharge diagnosis at the LUH has not been
47 investigated in a separate study for accuracy or reliability, which is a weakness our study
48 shares with the many studies based on hospital records. The primary discharge diagnosis of
49 cardiac arrest (ICD-10 code I46) set at emergency admission to the hospital and emergency
50 department does not indicate whether the causes were cardiac- or trauma related, and there
51 may be doubt as to where the patient developed the cardiac arrest, i.e., whether the event
52
53
54
55
56
57
58
59
60

1
2
3 initially occurred outside or inside the hospital. The study population consisted of patients
4
5 aged 18 years and older, which limits the generalisability of the results to those under 18.
6
7

8 The present study concentrates on traffic related pollutants; however, emissions from the
9
10 volcanic eruptions occurring in Iceland during the study period may have confounded the
11
12 results. The Eyjafjallajökull eruption in 2010 was found to have minor health effect on the
13
14 local population, but not the population in the Reykjavik capital area (26). The Holuhraun
15
16 eruption in 2014 to 2015 emitted a massive amount of SO₂ and mature volcanic plume, and
17
18 the exposure to these was associated with an increase in the dispensing of asthma medication
19
20 and an increase in health care utilisation for respiratory diseases in the Reykjavik capital area
21
22 during four months in the year 2014 (27,28). The present study was not designed to catch the
23
24 possible effect of these emissions on the cardiovascular health of the population of the
25
26 Reykjavik capital area, and its role remains unknown with that respect.
27
28
29
30

31
32 We made several stratifications to explore the possible association between air pollutants and
33
34 emergency hospital visits for cardiac arrest in this study. Because of this, some concerns may
35
36 emerge about multiple comparisons; however, this has been dealt with in the literature (29).
37
38
39
40

41 **Conclusions**

42
43
44 This study was, to our knowledge, the first to utilise the new endpoint of cardiac arrest (ICD-
45
46 10 code I46) according to the hospital discharge registry. This outcome has in previous
47
48 epidemiological studies been included in larger groups of CVDs, and its special status may
49
50 have been overshadowed by the more common diagnosis of CVDs. Our results indicate a
51
52 positive association between short-term increase in PM₁₀ and emergency hospital visits for
53
54 cardiac arrest in the Reykjavik capital area, known for having low levels of traffic-related
55
56 pollution. The effects were found in most subgroups, and were highest among the elderly, and
57
58
59
60

1
2
3 in the winter season, and among those who were successfully resuscitated. Future ecological
4
5 studies of this type should perhaps concentrate more on precisely defined endpoints; however,
6
7 doing so will not replace the obvious lack of exact individual exposure measurements for each
8
9
10 of the cases.
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

For peer review only

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 ₂ S	Hydrogen sulphide
ICD-10	International Classification of Diseases 10th edition
IHD	Ischemic heart disease
km	Kilometre
LUH	Landspítali 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.

Acknowledgements

Not applicable.

References

1. Brook RD, Franklin B, Cascio W, Hong Y, Howard G, Lipsett M, et al. Air pollution and cardiovascular disease: a statement for healthcare professionals from the Expert Panel on Population and Prevention Science of the American Heart Association. *Circulation*. 2004;109(21):2655-71.
2. Brook RD, Rajagopalan S, Pope CA, 3rd, Brook JR, Bhatnagar A, Diez-Roux AV, et al. Particulate matter air pollution and cardiovascular disease: An update to the scientific statement from the American Heart Association. *Circulation*. 2010;121(21):2331-78.
3. Meng X, Liu C, Chen R, Sera F, Vicedo-Cabrera AM, Milojevic A, et al. Short term associations of ambient nitrogen dioxide with daily total, cardiovascular, and respiratory mortality: multilocation analysis in 398 cities. *BMJ*. 2021;372:n534.
4. Stieb DM, Zheng C, Salama D, Berjawi R, Emode M, Hocking R, et al. Systematic review and meta-analysis of case-crossover and time-series studies of short term outdoor nitrogen dioxide exposure and ischemic heart disease morbidity. *Environ Health*. 2020;19(1):47.
5. Belch JJ, Fitton C, Cox B, Chalmers JD. Associations between ambient air pollutants and hospital admissions: more needs to be done. *Environ. Sci. Pollut. Res*. 2021;28(43):61848-52.
6. Dahlquist M, Frykman V, Kemp-Gudmundsdottir K, Svennberg E, Wellenius GA, P LSL. Short-term associations between ambient air pollution and acute atrial fibrillation episodes. *Environ Int*. 2020;141:105765.
7. Halldorsdottir S, Finnbjornsdottir RG, Elvarsson BT, Gudmundsson G, Rafnsson V. Ambient nitrogen dioxide is associated with emergency hospital visits for atrial fibrillation: a population-based case-crossover study in Reykjavik, Iceland. *Environ Health*. 2022;21(1):2.
8. Milojevic A, Wilkinson P, Armstrong B, Bhaskaran K, Smeeth L, Hajat S. Short-term effects of air pollution on a range of cardiovascular events in England and Wales: case-crossover analysis of the MINAP database, hospital admissions and mortality. *Heart*. 2014;100(14):1093-8.
9. Talbott EO, Rager JR, Benson S, Brink LA, Bilonick RA, Wu C. A case-crossover analysis of the impact of PM(2.5) on cardiovascular disease hospitalizations for selected CDC tracking states. *Environ Res*. 2014;134:455-65.
10. Zheng Q, Liu H, Zhang J, Chen D. The effect of ambient particle matters on hospital admissions for cardiac arrhythmia: a multi-city case-crossover study in China. *Environ Health*. 2018;17(1):60.
11. Ensor KB, Raun LH, Persse D. A case-crossover analysis of out-of-hospital cardiac arrest and air pollution. *Circulation*. 2013;127(11):1192-9.
12. Rosenthal FS, Kuisma M, Lanki T, Hussein T, Boyd J, Halonen JJ, et al. Association of ozone and particulate air pollution with out-of-hospital cardiac arrest in Helsinki, Finland: evidence for two different etiologies. *J Expo Sci Environ Epidemiol*. 2013;23(3):281-8.
13. Xia R, Zhou G, Zhu T, Li X, Wang G. Ambient Air Pollution and Out-of-Hospital Cardiac Arrest in Beijing, China. *Int J Environ Res Public Health*. 2017;14(4).
14. Zhao B, Johnston FH, Salimi F, Kurabayashi M, Negishi K. Short-term exposure to ambient fine particulate matter and out-of-hospital cardiac arrest: a nationwide case-crossover study in Japan. *Lancet Planet. Health*. 2020;4(1):e15-e23.
15. Tobaldini E, Iodice S, Bonora R, Bonzini M, Brambilla A, Sesana G, et al. Out-of-hospital cardiac arrests in a large metropolitan area: synergistic effect of exposure to air particulates and high temperature. *Eur. J. Prev. Cardiol*. 2020;27(5):513-9.
16. Jacobs I, Nadkarni V, Bahr J, Berg RA, Billi JE, Bossaert L, Cassan P, Coovadia A, D'Este K, Finn J, Halperin H, Handley A, Herlitz J, Hickey R, Idris A, Kloeck W, Larkin GL, Mancini ME, Mason P, Mears G, Monsieurs K, Montgomery W, Morley P, Nichol G, Nolan J, Okada K, Perlman J, Shuster M, Steen PA, Sterz F, Tibballs J, Timerman S, Truitt T, Zideman D; International Liaison Committee on Resuscitation. Cardiac arrest and cardiopulmonary resuscitation outcome reports: update and simplification of the Utstein templates for resuscitation registries. A statement for healthcare professionals from a task force of the international liaison committee on resuscitation (American Heart Association, European Resuscitation Council, Australian Resuscitation Council, New Zealand

- Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Southern Africa) Resuscitation. 2004 Dec;63(3):233-49.
17. Perkins GD, Jacobs IG, Nadkarni VM, Berg RA, Bhanji F, Biarent D, Bossaert LL, Brett SJ, Chamberlain D, de Caen AR, Deakin CD, Finn JC, Gräsner JT, Hazinski MF, Iwami T, Koster RW, Lim SH, Ma MH, McNally BF, Morley PT, Morrison LJ, Monsieurs KG, Montgomery W, Nichol G, Okada K, Ong ME, Travers AH, Nolan JP; Utstein Collaborators. Cardiac Arrest and Cardiopulmonary Resuscitation Outcome Reports: Update of the Utstein Resuscitation Registry Templates for Out-of-Hospital Cardiac Arrest: A Statement for Healthcare Professionals From a Task Force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian and New Zealand Council on Resuscitation, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Southern Africa, Resuscitation Council of Asia); and the American Heart Association Emergency Cardiovascular Care Committee and the Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation. *Resuscitation*. 2015;96:328-40.
18. Carlsen HK, Forsberg B, Meister K, Gíslason T, Oudin A. Ozone is associated with cardiopulmonary and stroke emergency hospital visits in Reykjavík, Iceland 2003-2009. *Environ Health*. 2013;12:28.
19. Finnbjörnsdóttir RG, Zoëga H, Olafsson O, Thorsteinsson T, Rafnsson V. Association of air pollution and use of glyceryl trinitrate against angina pectoris: a population-based case-crossover study. *Environ Health*. 2013;12(1):38.
20. Statistics Iceland. Population by municipality, sex, citizenship and quarters 2011-2019. <https://hagstofa.is/talnaefni/ibuar/mannfjoldi/yfirlit/> (2020). Accessed 06 Feb 2020.
21. Levy D, Lumley T, Sheppard L, Kaufman J, Checkoway H. Referent selection in case-crossover analyses of acute health effects of air pollution. *Epidemiology*. 2001;12(2):186-92.
22. Maclure M. The case-crossover design: a method for studying transient effects on the risk of acute events. *Am J Epidemiol*. 1991;133(2):144-53.
23. Berdowski J, Berg RA, Tijssen JG, Koster RW. Global incidences of out-of-hospital cardiac arrest and survival rates: Systematic review of 67 prospective studies. *Resuscitation*. 2010;81(11):1479-87.
24. Raza A, Bellander T, Bero-Bedada G, Dahlquist M, Hollenberg J, Jonsson M, Lind T, Rosenqvist M, Svensson L, Ljungman PL. Short-term effects of air pollution on out-of-hospital cardiac arrest in Stockholm. *Eur Heart J*. 2014;35:861-8.
25. Gentile FR, Primi R, Baldi E, Compagnoni S, Mare C, Contri E, Reali F, Bussi D, Facchin F, Currao A, Bendotti S, Savastano S; Lombardia CARE researchers. Out-of-hospital cardiac arrest and ambient air pollution: A dose-effect relationship and an association with OHCA incidence. *PLoS One*. 2021;25;16(8):e0256526.
26. Carlsen HK, Hauksdóttir A, Valdimarsdóttir UA, Gíslason T, Einarsdóttir G, Runolfsson H, et al. Health effects following the Eyjafjallajökull volcanic eruption: a cohort study. *BMJ Open*. 2012;2(6).
27. Carlsen HK, Ilyinskaya E, Baxter PJ, Schmidt A, Thorsteinsson T, Pfeffer MA, et al. Increased respiratory morbidity associated with exposure to a mature volcanic plume from a large Icelandic fissure eruption. *Nat. Commun*. 2021;12(1):2161-.
28. Carlsen HK, Valdimarsdóttir U, Briem H, Dominici F, Finnbjörnsdóttir RG, Jóhannsson T, et al. Severe volcanic SO exposure and respiratory morbidity in the Icelandic population - a register study. *Environ. Health: Glob. Access Sci. Source*. 2021;20(1):23.
29. Rothman KJ. No Adjustments Are Needed for Multiple Comparisons. *Epidemiology*. 1990;1(1):43-6.

Table 1 Descriptive statistics of emergency hospital visits for cardiac arrest (ICD-10: I46) to Landspítali 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 (≥ 71 yr)	192 (42)	190
Younger (< 71 yr)	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 ($\mu\text{g}/\text{m}^3$) of pollutants and meteorological data in the Reykjavik 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 ₂ S	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
<i>Spearman's correlation</i>							
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 ₂ S	-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; H₂S: hydrogen sulphide; NO₂: nitrogen dioxide; PM₁₀: particulate matter $\leq 10\mu\text{m}$ in diameter; PM_{2,5}: particulate matter $\leq 2.5\mu\text{m}$ in diameter; RH: relative humidity; SO₂: 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 NO₂, PM₁₀, PM_{2.5}, SO₂ and H₂S, 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.

Categories/Visits (n)	Lag	NO ₂		PM ₁₀		PM _{2.5}		SO ₂		H ₂ S	
		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	0.879-1.107	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	0.900-1.070	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	0.929-1.212	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	0.099-1.665	1.270
1		1.029	0.860-1.231	1.006	0.928-1.091	0.895	0.764-1.049	0.740	0.271-2.316	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	0.091-1.582	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	0.096-2.132	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
	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	0.927-1.067	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	0.941-1.073	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	0.953-1.235	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	0.959-1.260	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	0.927-1.226	1.096
1		0.985	0.853-1.137	1.000	0.891-1.122	1.001	0.910-1.101	0.974	0.831-1.140	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	0.903-1.085	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	0.880-1.117	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	0.921-1.236	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	0.821-1.197	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	0.821-1.208	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
	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	0.919-1.105	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	0.958-1.214	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	0.926-1.091	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	0.901-1.353	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	0.910-1.445	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	0.009-1.342	2.088	0.734-5.942

Table 3 Continued

1	Older females (57)	0	1.394	1.036-1.876	0.926	0.750-1.142	0.772	0.523-1.140	0.420	0.000-7.404	0.847	0.418-1.713
2		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
3		2	1.228	0.926-1.628	1.177	1.010-1.371	0.983	0.840-1.151	0.150	0.000-4.657	0.534	0.182-1.565
4		3	1.002	0.778-1.291	1.039	0.945-1.144	0.966	0.781-1.194	0.630	0.167-3.918	1.074	0.633-1.823
5		4	1.128	0.908-1.401	0.925	0.772-1.108	0.935	0.761-1.148	3.684	0.477-32.751	0.736	0.351-1.545
6		0-1	1.330	0.907-1.950	0.967	0.753-1.242	0.861	0.653-1.136	0.470	0.000-7.870	0.994	0.472-2.093
7		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
8		0-3	1.364	0.879-2.115	1.167	0.916-1.486	0.931	0.726-1.194	0.174	0.000-5.284	0.951	0.338-2.669
9		0-4	1.401	0.924-2.124	1.116	0.847-1.469	0.918	0.701-1.201	0.421	0.000-10.137	0.727	0.217-2.434
10	Younger females (68)	0	1.131	0.873-1.465	1.052	0.864-1.281	0.930	0.776-1.113	0.184	0.000-2.013	2.148	1.038-4.446
11		1	1.074	0.853-1.350	1.013	0.926-1.109	0.857	0.649-1.130	0.896	0.200-3.212	0.958	0.509-1.800
12		2	0.853	0.661-1.100	1.186	0.976-1.440	0.901	0.714-1.137	0.481	0.000-3.209	1.194	0.638-2.232
13		3	1.062	0.815-1.384	1.037	0.879-1.224	0.999	0.834-1.197	0.097	0.000-1.338	1.248	0.608-2.560
14		4	1.186	0.910-1.546	0.880	0.693-1.118	1.197	0.964-1.486	0.187	0.000-1.544	1.137	0.603-2.146
15		0-1	1.149	0.828-1.595	1.044	0.900-1.211	0.892	0.696-1.142	0.363	0.000-2.893	1.624	0.711-3.711
16		0-2	1.001	0.687-1.459	1.124	0.921-1.371	0.866	0.653-1.150	0.277	0.000-2.883	1.763	0.701-4.434
17		0-3	1.013	0.652-1.573	1.167	0.910-1.496	0.896	0.674-1.192	0.105	0.000-1.872	2.165	0.764-6.133
18		0-4	1.162	0.720-1.874	1.133	0.856-1.499	0.951	0.708-1.277	0.047	0.000-1.342	2.088	0.734-5.942
19	Older males (135)	0	0.940	0.795-1.111	1.021	0.907-1.150	1.079	0.969-1.202	1.097	0.900-1.240	1.222	0.877-1.703
20		1	1.000	0.846-1.183	0.985	0.846-1.145	1.032	0.925-1.151	0.996	0.800-1.164	1.116	0.722-1.725
21		2	1.095	0.919-1.305	1.167	1.001-1.362	1.039	0.920-1.172	0.984	0.800-1.079	1.483	1.019-2.159
22		3	1.053	0.881-1.258	1.058	0.947-1.182	1.059	0.940-1.192	0.831	0.500-1.334	1.457	1.000-2.121
23		4	1.006	0.850-1.191	1.126	1.005-1.262	1.051	0.952-1.161	1.003	0.800-1.123	0.938	0.910-1.440
24		0-1	0.920	0.748-1.132	1.010	0.856-1.191	1.067	0.943-1.207	1.090	0.900-1.268	1.381	0.848-2.248
25		0-2	0.948	0.745-1.208	1.138	0.959-1.350	1.078	0.937-1.240	1.062	0.900-1.245	1.738	1.000-3.021
26		0-3	0.966	0.739-1.263	1.177	0.972-1.424	1.092	0.924-1.289	1.020	0.800-1.230	1.963	1.062-3.628
27		0-4	0.949	0.709-1.272	1.280	1.037-1.579	1.125	0.942-1.344	1.033	0.800-1.254	1.907	0.990-3.673
28	Younger males (193)	0	0.941	0.818-1.081	1.050	0.960-1.147	0.971	0.883-1.067	1.093	0.900-1.217	1.194	0.871-1.637
29		1	0.984	0.855-1.134	1.097	1.009-1.193	1.005	0.929-1.087	1.001	0.800-1.203	1.076	0.694-1.668
30		2	0.922	0.792-1.074	1.018	0.926-1.118	0.976	0.894-1.066	1.011	0.900-1.113	0.974	0.640-1.484
31		3	1.111	0.970-1.272	1.017	0.942-1.099	1.025	0.956-1.098	1.082	0.900-1.238	1.108	0.798-1.538
32		4	1.134	0.997-1.291	1.017	0.905-1.143	1.076	0.975-1.188	1.013	0.900-1.096	0.850	0.559-1.292
33		0-1	0.932	0.781-1.113	1.110	1.003-1.229	0.989	0.899-1.087	1.123	0.900-1.329	1.208	0.767-1.902
34		0-2	0.868	0.704-1.071	1.127	0.995-1.276	0.979	0.882-1.086	1.134	0.900-1.400	1.244	0.697-2.222
35		0-3	0.929	0.738-1.169	1.125	0.979-1.293	0.993	0.891-1.107	1.186	0.900-1.522	1.318	0.716-2.426
36		0-4	1.020	0.801-1.300	1.123	0.961-1.312	1.017	0.902-1.146	1.185	0.900-1.556	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 NO₂, PM₁₀, PM_{2.5}, SO₂, and H₂S, 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.

Categories/Visits (n)	Lag	NO ₂		PM ₁₀		PM _{2.5}		SO ₂		H ₂ S	
		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	0.883-1.301	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	0.064-1.010	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	0.958-1.462	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	0.921-1.520	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	0.886-1.132	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	0.924-1.067	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	0.827-1.190	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	0.928-1.152	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	0.885-1.185	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	0.925-1.286	1.283	0.813-2.027	

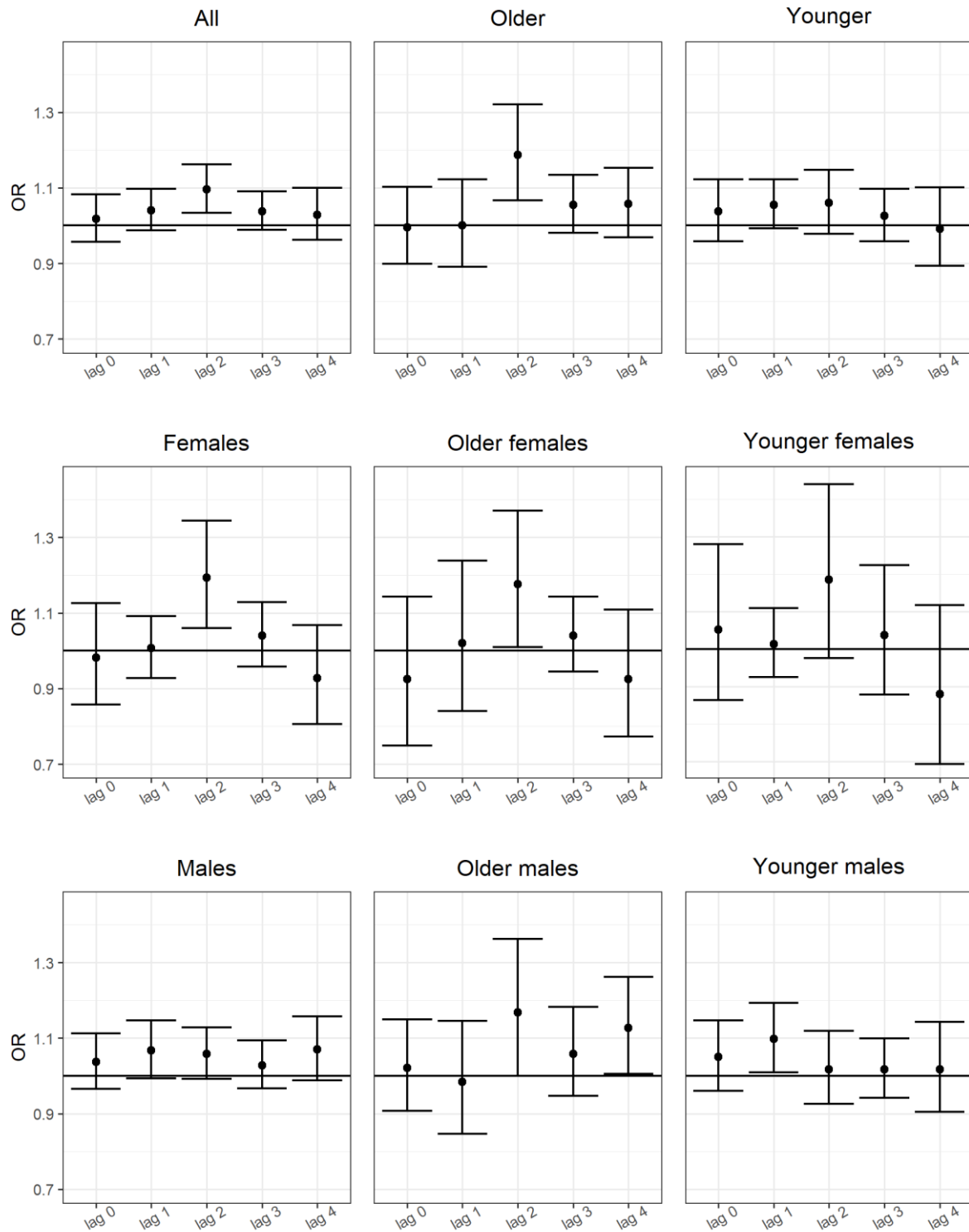


Figure 1. The odds ratio (OR) and bars showing 95% confidence intervals of cardiac arrest (ICD-10 code I46) per 10 µg/m³ increase in PM₁₀ concentrations in multiple-pollutant models at lag 0 to lag 4 for unstratified material and different strata.

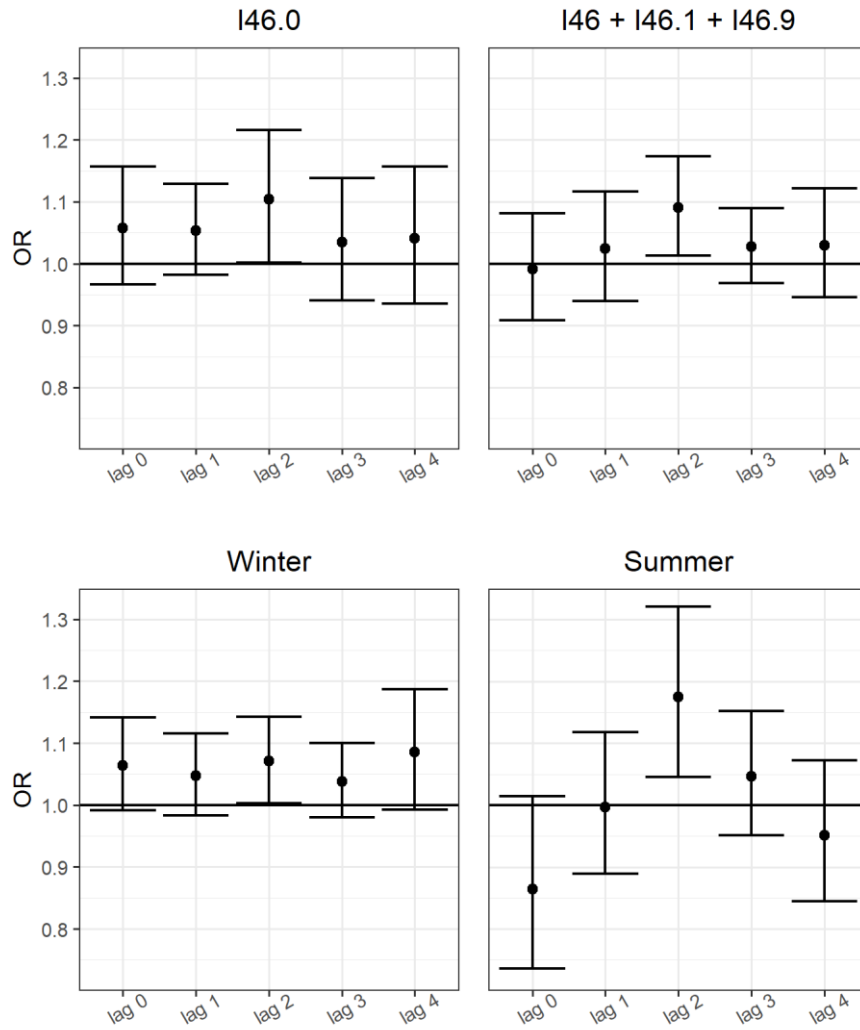


Figure 2. The odds ratio (OR) and bars showing 95% confidence intervals of cardiac arrest with successful resuscitation (ICD-10 code: I46.0) and other cardiac arrest categories grouped together (ICD-10 codes I46, I46.1 and I46.9), as well as cardiac arrest (ICD-10 code: I46) stratified to winter and summer, per 10 $\mu\text{g}/\text{m}^3$ 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 NO₂, PM₁₀, PM_{2.5}, SO₂, and H₂S, 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.

Categories/Visits (n)	Lag	NO ₂		PM ₁₀		PM _{2.5}		SO ₂		H ₂ S	
		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

6/bmjopen-2022-066743 on 15 May 2023. Downloaded from <http://bmjopen.bmj.com/> on April 27, 2024 by guest. Protected by copyright.

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 NO₂, PM₁₀, PM_{2.5}, SO₂, and H₂S, in single pollutant models, at lag 0 to lag 4, lag 0-1, lag 0-2, lag 0-3, and lag 0-4.

Categories/Visits (n)	Lag	NO ₂		PM ₁₀		PM _{2.5}		SO ₂		H ₂ S	
		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		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 µg/m³ increase in NO₂, PM₁₀, PM_{2.5}, SO₂ and H₂S, 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.

Categories/Visits (n)	Lag	NO ₂		PM ₁₀		PM _{2,5}		SO ₂		H ₂ S	
		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
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 (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	10, table 1 NA NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest	10, tables 1, 2 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 (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	11-13 NA 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.

1
2
3 Ambient air pollution and emergency department visits and
4 hospitalisation for cardiac arrest: a population-based case-crossover
5 study in Reykjavik, Iceland
6
7
8
9
10
11

12 Authors:

13
14 Solveig Halldorsdottir¹ solveighall@gmail.com

15
16 Ragnhildur Gudrun Finnbjornsdottir² ragnhildur.finnbjornsdottir@gmail.com

17
18 Bjarki Thor Elvarsson³ bjarki.elvarsson@gmail.com

19
20 Oddny Sigurborg Gunnarsdottir⁴ oddnygunn@gmail.com

21
22 Gunnar Gudmundsson^{5,6} ggudmund@landspitali.is

23
24 Vilhjalmur Rafnsson^{7*} vilraf@hi.is
25
26
27
28
29
30
31

32 ¹University of Iceland, Centre of Public Health Science, Reykjavik, Iceland

33
34 ²Environment Agency of Iceland, Reykjavik, Iceland

35
36 ³Marine and Freshwater Research Institute, Reykjavik, Iceland

37
38 ⁴Landspitali University Hospital, Reykjavik, Iceland

39
40 ⁵University of Iceland, Faculty of Medicine, Reykjavik, Iceland

41
42 ⁶Landspitali University Hospital, Department of Respiratory Medicine & Sleep, Reykjavik,
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
Iceland

⁷University of Iceland, Department of Preventive Medicine, Reykjavik, Iceland

*Corresponding author: Vilhjalmur Rafnsson vilraf@hi.is

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 Landspítali 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 NO₂, PM₁₀, PM_{2.5}, and SO₂ with adjustment for H₂S, temperature and relative humidity.

Main outcome measure Odds ratio (OR) and 95% confidence intervals (CI) per 10 µg/m³ increase in concentration of pollutants.

Results: The 24-h mean NO₂ was 20.7 µg/m³, mean PM₁₀ was 20.5 µg/m³, mean PM_{2.5} was 12.5 µg/m³, and mean SO₂ was 2.5 µg/m³. PM₁₀ level was positively associated with the number of emergency hospital visits (n=453) for cardiac arrest. Each 10 µg/m³ increase in PM₁₀ 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 PM₁₀ 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 PM₁₀ concentrations

1
2
3 was associated with cardiac arrest. Future ecological studies of this type and their related
4
5 discussions should perhaps concentrate more on precisely defined endpoints.
6
7

8 **Key words** Cardiac arrest, urgent hospital visits, successful resuscitation, multivariate
9
10 models, cardiovascular diseases
11
12

13 **Strength and limitations of this study**

14

- 15
16 • The study is population-based, relies on comprehensive population registries, and
17 include information of daily concentrations of the pollutants which cover more than
18 75% of the days in the study period.
19
- 20 • The methodology allows within-subject comparison while adjusting for various time
21 trends such as seasonality, and day of week.
22
- 23 • The concentration of the pollutants derived from one monitoring station, and not from
24 individual exposure measurements.
25
- 26 • The population is small, and therefore the total number of cases were few, resulting in
27 low statistical power.
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

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 NO₂ 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 NO₂ 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 NO₂ 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, NO₂, 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

1
2
3 for CVD, arrhythmias, atrial fibrillation, and heart failure was associated with an increased
4 concentration of NO₂; however, cardiac arrest was not included as an outcome in the study.
5
6
7 Cardiac arrest was mentioned in the aforementioned Chinese study (10) but was not analysed
8
9
10 separately.

11
12
13 There are several studies on the association of air pollution and out of hospital cardiac arrest
14 (OHCA) (11-15). The risk of OHCA were associated with a short-term increase in exposure
15 to particulate matter, sometimes PM_{2.5}, or ultrafine particulate matter (11-14), and sometimes
16 PM₁₀ (15), with various associations with O₃, other caseous pollutants, and high temperature.
17
18 The collection of cases in the OHCA studies use special registers as a source, regarding
19 Utstein definition (16,17) with the original purpose to provide a structured framework to
20 evaluate emergency medical service. The main criteria in the definition of the cases in the
21 OHCA studies are: 1) the cardiovascular collapse has occurred outside a hospital, and 2) the
22 event has elicited a resuscitation attempt. Neither of these conditions is required for the
23 physician given diagnosis of cardiac arrest according to the International Classification of
24 Diseases 10th edition (ICD-10) code I46 registered as discharge diagnosis at hospitals or
25 emergency departments.
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40

41 The comprehensive population and health registries in Iceland make this an optimal setting to
42 study the association between relatively low daily exposure to air pollution, and different
43 heart related conditions (7,18,19). The aim of the present study was to explore the association
44 between traffic-related pollutants, NO₂, PM₁₀, PM_{2.5}, and SO₂ in the Reykjavik capital area
45 and urgent hospital and emergency department visits for cardiac arrest, ICD-10 code I46, as
46 the primary discharge diagnosis, and to simultaneously adjust for meteorological variables
47 and geothermal-originated pollutants.
48
49
50
51
52
53
54
55
56
57
58
59
60

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 H₂S emission originates from the plants. Reykjavik's capital area spreads over 247.5 km² 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, Hafnarfjörður, 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 inpatient wards of Landspítali 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

1
2
3 identification numbers are widely used in Icelandic society and population registries,
4 including the SAGA register. We received the identification numbers in encrypted form,
5
6 which enabled us to identify repeated visits to LUH. Readmissions to LUH within 10 days
7
8 with the same ICD-10 primary discharge diagnosis were excluded. From the SAGA register
9
10 we received the following details: admission date, encrypted identification number, unique
11
12 number of the admission, age, gender, primary discharge diagnosis for certain codes
13
14 according to the International Classification of Diseases 10th edition (ICD-10). In this study,
15
16 both admission to the emergency department and formal admission to the hospital are
17
18 included, so there is no requirement that a patient stayed overnight. The diagnoses are
19
20 registered at discharge from the hospital, transfer to another hospital, and death in the
21
22 hospital. In a previous study (7), the outcomes were heart diseases ICD-10 codes: I20-I25,
23
24 I44-I50, ischemic heart diseases ICD-10 codes: I20-I25, cardiac arrhythmias and heart failure
25
26 ICD-10 codes: I44-I50, and atrial fibrillation ICD-10 I48 (7). In the present study, the
27
28 outcome analysed was cardiac arrest ICD-10 code I46. Emergency department visits and
29
30 urgent hospital admissions were combined and are called emergency hospital visits.
31
32
33
34
35
36
37

38 **Air pollutants and meteorological data**

39
40
41 Information on pollution was obtained from Grensas monitor station (GRE), operated by the
42
43 governmental institution Environment Agency of Iceland. GRE is in the centre of the
44
45 Reykjavik capital area near one of the busiest road intersections in the city. Other stations in
46
47 the city were not permanently located or were not continuously monitoring throughout the
48
49 study period and were therefore not used in the study. However, to test whether GRE was
50
51 reflective of the total capital area, Pearson's correlation was calculated for GRE
52
53 measurements and measurements from another station located in Dalasmari, Kopavogur
54
55 municipality, for the period 2014-2017. Results of Pearson's correlation coefficients between
56
57
58
59
60

1
2
3 these two measurement stations were for PM₁₀ 0.44, for NO₂ 0.78, for SO₂ 0.98, and for H₂S
4
5 0.84. PM_{2.5} was not measured in Dalsmari.
6
7

8
9 Pollutants measured at GRE were NO₂, particulate matter with aerodynamic diameter less
10
11 than 10 µm (PM₁₀), particulate matter with aerodynamic diameter less than 2.5 µm (PM_{2.5}),
12
13 sulphur dioxide (SO₂), and hydrogen sulphide (H₂S), all measured in µg/m³. The
14
15 meteorological data was obtained from the governmental institution Icelandic Meteorological
16
17 Office and included temperature (°C) and relative humidity (RH). PM₁₀ and PM_{2.5} were
18
19 measured with an Andersen EMS IR Thermo (model FH62 I-R), NO₂ with Horiba device
20
21 (model APNA 360E), and SO₂ and H₂S with the Horiba model APOA 360E. Every 6-12
22
23 months the devices are calibrated. Exposure data included 12 years or 4,383 days. Daily
24
25 averages (midnight to midnight the following day) were calculated from hourly
26
27 concentrations if at least 75% of one-hour data existed. Missing daily averages for NO₂, PM₁₀,
28
29 PM_{2.5}, SO₂, and H₂S were 383 days (8.7%), 165 days (3.8%), 923 days (21.1%), 200 days
30
31 (4.6%), and 284 days (6.5%), respectively. Data gaps were seen and can be attributed to
32
33 inactive measurement devices due to unknown causes, with the exception of 52 days of
34
35 missing H₂S measurements at the beginning of the study period, as H₂S measurements at GRE
36
37 started at the end of February 2006. For temperature and RH, 6 days (0.1%) and 6 days
38
39 (0.1%) were missing, respectively. Minor gaps in the curves were fitted by linear
40
41 interpolation.
42
43
44
45
46
47

48 Descriptive statistics were calculated and showed as daily concentration levels in µg/m³ of the
49
50 pollutants, as well as Spearman's correlation coefficient between pollutants and
51
52 meteorological factors.
53
54
55
56
57
58
59
60

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, H₂S, 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 $\mu\text{g}/\text{m}^3$ 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

1
2
3 were subsequently admitted that same day to in-hospital wards where they might have
4
5 received a different diagnosis than they were given at the emergency department. To test
6
7 whether this could distort the main result of the association between increased pollutant
8
9 concentration and the emergency hospital visits, a sensitivity analysis was done, in which data
10
11 was restricted to emergency department visits only.
12
13

14
15 Statistical analysis was done with R version 4.0.3 (<https://www.r-project.org/>). Statistical tests
16
17 used in this study were all two-tailed and we considered results statistically significant for $p <$
18
19 0.05.
20
21

22
23 The study was approved by the National Bioethics Committee (ref. no.
24
25 VSNb2018120011/03.01), the Data Protection Authority (ref. no. 10-050), and the Scientific
26
27 Committee of LUH.
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

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 ~~higest~~ 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, H₂S, and meteorological variables are presented in Table 2. Missing daily average was highest for PM₁₀ but did not exceed 25% of the days of the study period. The concentrations of PM₁₀ 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 PM₁₀ 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 PM₁₀, as shown in Table A, Supplementary data. A positive association was observed between exposure to NO₂ 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 NO₂, as shown in Table A, Supplementary data.

In examining the daily lag exposure to PM₁₀ 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 PM₁₀ (Table 3). Significant associations were shown for exposure to NO₂ at lag 4 and for SO₂ at lag 0, and unstratified emergency

1
2
3 hospital visits for cardiac arrest; the increased risks were OR 1.096 (95% CI 1.008-1.192) and
4
5 OR 1.084 (95% CI 1.002-1.173) per 10 $\mu\text{g}/\text{m}^3$ increase of NO_2 and SO_2 , respectively (Table
6
7
8 3).

9
10
11 ~~When applying the multivariate model in the stratified analyses of daily pollutants exposure~~
12 ~~and the association of emergency hospital visits for cardiac arrest (ICD-10 code I46), a~~
13 ~~discernible pattern emerges.~~ Significant In the multivariate model significant associations
14
15 were shown between exposure to PM_{10} at lag 2 and/or exposure to PM_{10} at lag 0-2, lag 0-3,
16
17 and lag 0-4, and increased risks of cardiac arrest (ICD-10 code I46), in the age, gender, age
18
19 and gender combined, and season strata, i.e., in all the strata except in the stratum of young
20
21 females (Table 3). In Figure 1, OR and 95% CI of cardiac arrest per 10 $\mu\text{g}/\text{m}^3$ increase of
22
23 PM_{10} concentrations in multi-pollutant models are shown at lag 0 to lag 4 for different strata
24
25 and unstratified.

26
27
28
29
30
31
32 In the single pollutant analyses, positive associations were observed for exposure to PM_{10} at
33
34 lag 0-3, and lag 0-4, and emergency hospital visits for cardiac arrest with successful
35
36 resuscitation (ICD-10 codes: I46.0); the increased risks of cardiac arrest were OR 1.161 (95%
37
38 CI 1.014-1.329), and OR 1.177 (95% CI 1.013-1.368), respectively, per 10 $\mu\text{g}/\text{m}^3$ increase of
39
40 PM_{10} , as shown in Table B, Supplementary data. A positive association was observed for
41
42 exposure to $\text{PM}_{2.5}$ at lag 3, and lag 4, and the increased risk of cardiac arrest with successful
43
44 resuscitation; the increased risk was OR 1.090 (95% CI 1.008-1.178), and OR 1.101 (95% CI
45
46 1.006-1.204), per 10 $\mu\text{g}/\text{m}^3$ increase of $\text{PM}_{2.5}$, respectively, as shown in Table B,
47
48 Supplementary data. A positive association was observed for exposure to PM_{10} at lag 2, and
49
50 the increased risk of cardiac arrest without indication of successful resuscitation (ICD-10
51
52 codes: I46, I46.1, and I46.9); the increased risk was OR 1.079 (95% CI 1.008-1.155), as
53
54 shown in Table B, Supplementary data.
55
56
57
58
59
60

1
2
3 ~~When we applied the multivariate model to the stratification of whether the cardiac arrests~~
4 ~~were indicated with successful resuscitation (ICD-10 code I46.0) or not (ICD-10 code I46,~~
5 ~~I46.1, and I46.9) and the association with daily pollutant exposure, a similar pattern emerges~~
6 ~~to that of the single pollutants analyses, shown in Table 4; however, the OR were somewhat~~
7 ~~higher and were observed at more lags and pollutants. A~~In the multivariate model a positive
8 association was observed between exposure to PM₁₀ and emergency hospital visits for cardiac
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

association was observed between exposure to PM₁₀ 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 PM₁₀, 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 for exposure to NO₂ 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 PM₁₀ 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 PM₁₀ 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 PM₁₀ 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

1
2
3 unstratified analysis, the increased risk of cardiac arrest was OR 1.099 (95% CI 1.028-1.175)
4
5 at lag 2 per 10 $\mu\text{g}/\text{m}^3$ increase of PM_{10} .
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

For peer review only

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 PM₁₀ and cardiac arrest at lag 2, lag 0-2, lag 0-3, and lag 0-4, so the 24 hours concentrations of PM₁₀ 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

1
2
3 I46, when this diagnosis is used at hospitals or emergency departments. In addition, the
4
5 Utstein definition recommends registration of several time points and intervals important for
6
7 the research and quality assurance related to the resuscitation, but such time elements are not
8
9 required in the hospital discharge registries based on the ICD-10. Some studies have shown
10
11 that the risks of OHCA were associated with a short-term increase in exposure to particulate
12
13 matter, sometimes PM_{2.5}, or ultrafine particulate matter (11-14), and sometimes PM₁₀ (15),
14
15 with various associations with O₃, other caseous pollutants, and high temperature. An OHCA
16
17 study conducted in Stockholm, Sweden demonstrated a significant exposure-response
18
19 association between OHCA risk and O₃, but no association for PM_{2.5} or NO₂, (24), while
20
21 another OHCA study in Lombardy, Italy, showed, with different methodology, that the
22
23 concentrations of all the pollutants in the study were significantly higher in days with high
24
25 incidence of OHCA except for O₃ (25). In these OHCA studies (11-15,24,25) no difference is
26
27 made between those who survive the event and those who do not survive. In the previously
28
29 mentioned UK study (8) on the association between air pollution and hospital admission for
30
31 different cardiovascular events, exposure to NO₂ was significant, while in the same
32
33 publication some of the mortality outcomes were associated with exposure to PM_{2.5} but not to
34
35 NO₂ (8), indicating the possibility of different pathogenetic pathways for the outcomes, as has
36
37 been discussed briefly in the case of NO₂ (4), and in the comprehensive review of the causal
38
39 role of particulate material (2). The category cardiac arrest in the ICD-10 coding system
40
41 represents a small group compared to other CVD diagnoses and seems to be concealed within
42
43 the larger summary group of cardiac arrhythmias (10) or omitted from the analysis (8). In this
44
45 respect, our recent study on the same dataset is not an exception: increased risk of cardiac
46
47 arrhythmias (ICD-10 codes I44 to I50) was associated with an increase in NO₂ exposure (7), a
48
49 finding that hides the association between cardiac arrest (ICD-10 code I46) and exposure to
50
51 PM₁₀ as demonstrated in the present study.
52
53
54
55
56
57
58
59
60

1
2
3 Among the strengths of this study is that it is population-based, as the hospital and emergency
4 department data were obtained from the only emergency health care institution, the LUH,
5 serving the population in the catchment area of the Reykjavik capital. The design of the study
6 is also a strength, as the bidirectional time-stratified case-crossover approach virtually
7 excludes confounding of individual characteristics and the matching adjusted for weekly
8 pattern and time trends. Another strength of the study is its use of the encrypted identification
9 number of each patient in the Register of hospital-treated patients, which ensures the correct
10 counting and identification of the cases and their admissions. Furthermore, it is noteworthy
11 that visits of the cases receiving the primary discharge diagnosis cardiac arrest (453 cases)
12 were evenly distributed over the study period (4383 days), so the distribution diminished the
13 risk of overlapping the sets of case and control days.
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28

29 That said, there are few limitations. First, the concentration of the pollutants derived from one
30 monitoring station in the Reykjavik capital area, and not from individual exposure
31 measurements. The results from these measurements did, however, correlate well with
32 measurements from another monitoring station located in the capital area during three years of
33 the study period. Another limitation is that only the primary discharge diagnosis was included
34 in the study, meaning that the cases may have underlying diseases that could modify the
35 result.
36
37
38
39
40
41
42
43
44
45

46 Furthermore, the quality of the routine discharge diagnosis at the LUH has not been
47 investigated in a separate study for accuracy or reliability, which is a weakness our study
48 shares with the many studies based on hospital records. The primary discharge diagnosis of
49 cardiac arrest (ICD-10 code I46) set at emergency admission to the hospital and emergency
50 department does not indicate whether the causes were cardiac- or trauma related, and there
51 may be doubt as to where the patient developed the cardiac arrest, i.e., whether the event
52
53
54
55
56
57
58
59
60

1
2
3 initially occurred outside or inside the hospital. The study population consisted of patients
4
5 aged 18 years and older, which limits the generalisability of the results to those under 18.
6
7

8
9 The present study concentrates on traffic related pollutants; however, emissions from the
10
11 volcanic eruptions occurring in Iceland during the study period may have confounded the
12
13 results. The Eyjafjallajökull eruption in 2010 was found to have minor health effect on the
14
15 local population, but not the population in the Reykjavik capital area (26). The Holuhraun
16
17 eruption in 2014 to 2015 emitted a massive amount of SO₂ and mature volcanic plume, and
18
19 the exposure to these was associated with an increase in the dispensing of asthma medication
20
21 and an increase in health care utilisation for respiratory diseases in the Reykjavik capital area
22
23 during four months in the year 2014 (27,28). The present study was not designed to catch the
24
25 possible effect of these emissions on the cardiovascular health of the population of the
26
27 Reykjavik capital area, and its role remains unknown with that respect.
28
29
30

31
32 We made several stratifications to explore the possible association between air pollutants and
33
34 emergency hospital visits for cardiac arrest in this study. Because of this, some concerns may
35
36 emerge about multiple comparisons; however, this has been dealt with in the literature (29).
37
38
39
40

41 **Conclusions**

42
43
44 This study was, to our knowledge, the first to utilise the new endpoint of cardiac arrest (ICD-
45
46 10 code I46) according to the hospital discharge registry. This outcome has in previous
47
48 epidemiological studies been included in larger groups of CVDs, and its special status may
49
50 have been overshadowed by the more common diagnosis of CVDs. Our results indicate a
51
52 positive association between short-term increase in PM₁₀ and emergency hospital visits for
53
54 cardiac arrest in the Reykjavik capital area, known for having low levels of traffic-related
55
56 pollution. The effects were found in most subgroups, and were highest among the elderly, and
57
58
59
60

1
2
3 in the winter season, and among those who were successfully resuscitated. Future ecological
4
5 studies of this type should perhaps concentrate more on precisely defined endpoints; however,
6
7 doing so will not replace the obvious lack of exact individual exposure measurements for each
8
9
10 of the cases.
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

For peer review only

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 ₂ S	Hydrogen sulphide
ICD-10	International Classification of Diseases 10th edition
IHD	Ischemic heart disease
km	Kilometre
LUH	Landspítali 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.

Acknowledgements

Not applicable.

References

1. Brook RD, Franklin B, Cascio W, Hong Y, Howard G, Lipsett M, et al. Air pollution and cardiovascular disease: a statement for healthcare professionals from the Expert Panel on Population and Prevention Science of the American Heart Association. *Circulation*. 2004;109(21):2655-71.
2. Brook RD, Rajagopalan S, Pope CA, 3rd, Brook JR, Bhatnagar A, Diez-Roux AV, et al. Particulate matter air pollution and cardiovascular disease: An update to the scientific statement from the American Heart Association. *Circulation*. 2010;121(21):2331-78.
3. Meng X, Liu C, Chen R, Sera F, Vicedo-Cabrera AM, Milojevic A, et al. Short term associations of ambient nitrogen dioxide with daily total, cardiovascular, and respiratory mortality: multilocation analysis in 398 cities. *BMJ*. 2021;372:n534.
4. Stieb DM, Zheng C, Salama D, Berjawi R, Emode M, Hocking R, et al. Systematic review and meta-analysis of case-crossover and time-series studies of short term outdoor nitrogen dioxide exposure and ischemic heart disease morbidity. *Environ Health*. 2020;19(1):47.
5. Belch JJ, Fitton C, Cox B, Chalmers JD. Associations between ambient air pollutants and hospital admissions: more needs to be done. *Environ. Sci. Pollut. Res*. 2021;28(43):61848-52.
6. Dahlquist M, Frykman V, Kemp-Gudmundsdottir K, Svennberg E, Wellenius GA, P LSL. Short-term associations between ambient air pollution and acute atrial fibrillation episodes. *Environ Int*. 2020;141:105765.
7. Halldorsdottir S, Finnbjornsdottir RG, Elvarsson BT, Gudmundsson G, Rafnsson V. Ambient nitrogen dioxide is associated with emergency hospital visits for atrial fibrillation: a population-based case-crossover study in Reykjavik, Iceland. *Environ Health*. 2022;21(1):2.
8. Milojevic A, Wilkinson P, Armstrong B, Bhaskaran K, Smeeth L, Hajat S. Short-term effects of air pollution on a range of cardiovascular events in England and Wales: case-crossover analysis of the MINAP database, hospital admissions and mortality. *Heart*. 2014;100(14):1093-8.
9. Talbott EO, Rager JR, Benson S, Brink LA, Bilonick RA, Wu C. A case-crossover analysis of the impact of PM(2.5) on cardiovascular disease hospitalizations for selected CDC tracking states. *Environ Res*. 2014;134:455-65.
10. Zheng Q, Liu H, Zhang J, Chen D. The effect of ambient particle matters on hospital admissions for cardiac arrhythmia: a multi-city case-crossover study in China. *Environ Health*. 2018;17(1):60.
11. Ensor KB, Raun LH, Persse D. A case-crossover analysis of out-of-hospital cardiac arrest and air pollution. *Circulation*. 2013;127(11):1192-9.
11. Rosenthal FS, Kuisma M, Lanki T, Hussein T, Boyd J, Halonen JJ, et al. Association of ozone and particulate air pollution with out-of-hospital cardiac arrest in Helsinki, Finland: evidence for two different etiologies. *J Expo Sci Environ Epidemiol*. 2013;23(3):281-8.
13. Xia R, Zhou G, Zhu T, Li X, Wang G. Ambient Air Pollution and Out-of-Hospital Cardiac Arrest in Beijing, China. *Int J Environ Res Public Health*. 2017;14(4).
14. Zhao B, Johnston FH, Salimi F, Kurabayashi M, Negishi K. Short-term exposure to ambient fine particulate matter and out-of-hospital cardiac arrest: a nationwide case-crossover study in Japan. *Lancet Planet. Health*. 2020;4(1):e15-e23.
15. Tobaldini E, Iodice S, Bonora R, Bonzini M, Brambilla A, Sesana G, et al. Out-of-hospital cardiac arrests in a large metropolitan area: synergistic effect of exposure to air particulates and high temperature. *Eur. J. Prev. Cardiol*. 2020;27(5):513-9.
16. Jacobs I, Nadkarni V, Bahr J, Berg RA, Billi JE, Bossaert L, Cassan P, Coovadia A, D'Este K, Finn J, Halperin H, Handley A, Herlitz J, Hickey R, Idris A, Kloeck W, Larkin GL, Mancini ME, Mason P, Mears G, Monsieurs K, Montgomery W, Morley P, Nichol G, Nolan J, Okada K, Perlman J, Shuster M, Steen PA, Sterz F, Tibballs J, Timerman S, Truitt T, Zideman D; International Liaison Committee on Resuscitation. Cardiac arrest and cardiopulmonary resuscitation outcome reports: update and simplification of the Utstein templates for resuscitation registries. A statement for healthcare professionals from a task force of the international liaison committee on resuscitation (American Heart Association, European Resuscitation Council, Australian Resuscitation Council, New Zealand

- Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Southern Africa) Resuscitation. 2004 Dec;63(3):233-49.
17. Perkins GD, Jacobs IG, Nadkarni VM, Berg RA, Bhanji F, Biarent D, Bossaert LL, Brett SJ, Chamberlain D, de Caen AR, Deakin CD, Finn JC, Gräsner JT, Hazinski MF, Iwami T, Koster RW, Lim SH, Ma MH, McNally BF, Morley PT, Morrison LJ, Monsieurs KG, Montgomery W, Nichol G, Okada K, Ong ME, Travers AH, Nolan JP; Utstein Collaborators. Cardiac Arrest and Cardiopulmonary Resuscitation Outcome Reports: Update of the Utstein Resuscitation Registry Templates for Out-of-Hospital Cardiac Arrest: A Statement for Healthcare Professionals From a Task Force of the International Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council, Australian and New Zealand Council on Resuscitation, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation, Resuscitation Council of Southern Africa, Resuscitation Council of Asia); and the American Heart Association Emergency Cardiovascular Care Committee and the Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation. Resuscitation. 2015;96:328-40.
18. Carlsen HK, Forsberg B, Meister K, Gíslason T, Oudin A. Ozone is associated with cardiopulmonary and stroke emergency hospital visits in Reykjavík, Iceland 2003-2009. Environ Health. 2013;12:28.
19. Finnbjörnsdóttir RG, Zoëga H, Olafsson O, Thorsteinsson T, Rafnsson V. Association of air pollution and use of glyceryl trinitrate against angina pectoris: a population-based case-crossover study. Environ Health. 2013;12(1):38.
20. Statistics Iceland. Population by municipality, sex, citizenship and quarters 2011-2019. <https://hagstofa.is/talnaefni/ibuar/mannfjoldi/yfirlit/> (2020). Accessed 06 Feb 2020.
21. Levy D, Lumley T, Sheppard L, Kaufman J, Checkoway H. Referent selection in case-crossover analyses of acute health effects of air pollution. Epidemiology. 2001;12(2):186-92.
22. Maclure M. The case-crossover design: a method for studying transient effects on the risk of acute events. Am J Epidemiol. 1991;133(2):144-53.
23. Berdowski J, Berg RA, Tijssen JG, Koster RW. Global incidences of out-of-hospital cardiac arrest and survival rates: Systematic review of 67 prospective studies. Resuscitation. 2010;81(11):1479-87.
24. Raza A, Bellander T, Bero-Bedada G, Dahlquist M, Hollenberg J, Jonsson M, Lind T, Rosenqvist M, Svensson L, Ljungman PL. Short-term effects of air pollution on out-of-hospital cardiac arrest in Stockholm. Eur Heart J. 2014;35:861-8.
25. Gentile FR, Primi R, Baldi E, Compagnoni S, Mare C, Contri E, Reali F, Bussi D, Facchin F, Currao A, Bendotti S, Savastano S; Lombardia CARE researchers. Out-of-hospital cardiac arrest and ambient air pollution: A dose-effect relationship and an association with OHCA incidence. PLoS One. 2021;25;16(8):e0256526.
26. Carlsen HK, Hauksdóttir A, Valdimarsdóttir UA, Gíslason T, Einarsdóttir G, Runolfsson H, et al. Health effects following the Eyjafjallajökull volcanic eruption: a cohort study. BMJ Open. 2012;2(6).
27. Carlsen HK, Ilyinskaya E, Baxter PJ, Schmidt A, Thorsteinsson T, Pfeffer MA, et al. Increased respiratory morbidity associated with exposure to a mature volcanic plume from a large Icelandic fissure eruption. Nat. Commun. 2021;12(1):2161-.
28. Carlsen HK, Valdimarsdóttir U, Briem H, Dominici F, Finnbjörnsdóttir RG, Jóhannsson T, et al. Severe volcanic SO₂ exposure and respiratory morbidity in the Icelandic population - a register study. Environ. Health: Glob. Access Sci. Source. 2021;20(1):23.
29. Rothman KJ. No Adjustments Are Needed for Multiple Comparisons. Epidemiology. 1990;1(1):43-6.

Table 1. Descriptive statistics of emergency hospital visits for cardiac arrest (ICD-10: I46) to Landspítali 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 (≥ 71 yr)	192 (42)	190
Younger (< 71 yr)	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 ($\mu\text{g}/\text{m}^3$) 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 ₂ S	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
<i>Spearman's correlation</i>							
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 ₂ S	-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; H₂S: hydrogen sulphide; NO₂: nitrogen dioxide; PM₁₀: particulate matter $\leq 10\mu\text{m}$ in diameter; PM_{2,5}: particulate matter $\leq 2.5\mu\text{m}$ in diameter; RH: relative humidity; SO₂: 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 NO₂, PM₁₀, PM_{2.5}, SO₂ and H₂S, 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.

Categories/Visits (n)	Lag	NO ₂		PM ₁₀		PM _{2.5}		SO ₂		H ₂ S	
		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	0.987-1.166	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

6/bmjopen-2022-015143 on 13 May 2023. Downloaded from http://bmjopen.bmj.com/ on April 27, 2024 by guest. Protected by copyright.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46

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

For peer review only

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	0.926	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	0.927	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

bmjopen-2022-066743 on 15 May 2023. Downloaded from <http://bmjopen.bmj.com/> on April 27, 2024 by guest. Protected by copyright.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46

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

For peer review only

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 NO₂, PM₁₀, PM_{2.5}, SO₂, and H₂S, 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.

Categories/Visits (n)	Lag	NO ₂		PM ₁₀		PM _{2.5}		SO ₂		H ₂ S	
		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
I46, I46.1, I46.9 (259)	0	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
	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	

6/bmjopen-2022-015729 on 15 May 2023. Downloaded from <http://bmjopen.bmj.com/> on April 27, 2024 by guest. Protected by copyright.

BMJ Open

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

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2022-066743.R2
Article Type:	Original research
Date Submitted by the Author:	07-Apr-2023
Complete List of Authors:	Halldorsdottir, Solveig; Centre of Public Health Science Finnbjornsdottir, Ragnhildur Gudrun; Environment Agency of Iceland Elvarsson, Bjarki; Marine and Freshwater Research Institute Gunnarsdottir, Oddny Sigurborg; Landspítali University Hospital Gudmundsson, Gunnar; University of Iceland Rafnsson, Vilhjalmur; University of Iceland, Department of Preventive Medicine
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Public health
Keywords:	EPIDEMIOLOGY, Adult cardiology < CARDIOLOGY, REGISTRIES

SCHOLARONE™
Manuscripts



I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our [licence](#).

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which [Creative Commons](#) licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

1
2
3 Ambient air pollution and emergency department visits and
4 hospitalisation for cardiac arrest: a population-based case-crossover
5 study in Reykjavik, Iceland
6
7
8
9
10
11

12 Authors:

13
14 Solveig Halldorsdottir¹ solveighall@gmail.com

15
16 Ragnhildur Gudrun Finnbjornsdottir² ragnhildur.finnbjornsdottir@gmail.com

17
18 Bjarki Thor Elvarsson³ bjarki.elvarsson@gmail.com

19
20 Oddny Sigurborg Gunnarsdottir⁴ oddnygunn@gmail.com

21
22 Gunnar Gudmundsson^{5,6} ggudmund@landspitali.is

23
24 Vilhjalmur Rafnsson^{7*} vilraf@hi.is
25
26
27
28
29
30
31

32 ¹University of Iceland, Centre of Public Health Science, Reykjavik, Iceland

33
34 ²Environment Agency of Iceland, Reykjavik, Iceland

35
36 ³Marine and Freshwater Research Institute, Reykjavik, Iceland

37
38 ⁴Landspitali University Hospital, Reykjavik, Iceland

39
40 ⁵University of Iceland, Faculty of Medicine, Reykjavik, Iceland

41
42 ⁶Landspitali University Hospital, Department of Respiratory Medicine & Sleep, Reykjavik,
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
Iceland

⁷University of Iceland, Department of Preventive Medicine, Reykjavik, Iceland

*Corresponding author: Vilhjalmur Rafnsson vilraf@hi.is

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 Landspítali 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 NO₂, PM₁₀, PM_{2.5}, and SO₂ with adjustment for H₂S, temperature and relative humidity.

Main outcome measure Odds ratio (OR) and 95% confidence intervals (CI) per 10 µg/m³ increase in concentration of pollutants.

Results: The 24-h mean NO₂ was 20.7 µg/m³, mean PM₁₀ was 20.5 µg/m³, mean PM_{2.5} was 12.5 µg/m³, and mean SO₂ was 2.5 µg/m³. PM₁₀ level was positively associated with the number of emergency hospital visits (n=453) for cardiac arrest. Each 10 µg/m³ increase in PM₁₀ 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 PM₁₀ 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 PM₁₀ concentrations

1
2
3 was associated with cardiac arrest. Future ecological studies of this type and their related
4
5 discussions should perhaps concentrate more on precisely defined endpoints.
6
7

8 **Key words** Cardiac arrest, urgent hospital visits, successful resuscitation, multivariate
9
10 models, cardiovascular diseases
11
12

13 **Strengths and limitations of this study**

14

- 15
16 • The study is population-based, relies on comprehensive population registries, and
17 includes information on daily concentrations of the pollutants which cover more than
18 75% of the days in the study period.
19
- 20 • The methodology allows within-subject comparison while adjusting for various time
21 trends such as seasonality, and day of week.
22
- 23 • The concentration of the pollutants derived from one monitoring station, and not from
24 individual exposure measurements.
25
- 26 • The population is small, and therefore the total number of cases were few, resulting in
27 low statistical power.
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

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 NO₂ 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 NO₂ 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 NO₂ 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, NO₂, 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

1
2
3 admissions for CVD, arrhythmias, atrial fibrillation, and heart failure was associated with an
4 increased concentration of NO₂; however, cardiac arrest was not included as an outcome in
5
6 the study. Cardiac arrest was mentioned in the aforementioned Chinese study (10) but was not
7
8 analysed separately.
9
10

11
12
13 There are several studies on the association between air pollution and out-of-hospital cardiac
14
15 arrest (OHCA) (11-15). The risk of OHCA was associated with a short-term increase in
16
17 exposure to particulate matter, sometimes PM_{2.5}, or ultrafine particulate matter (11-14), and
18
19 sometimes PM₁₀ (15), with various associations with O₃, other gaseous pollutants, and high
20
21 temperature. The collection of cases in the OHCA studies use special registers as a source,
22
23 regarding Utstein definition (16,17) with the original purpose to provide a structured
24
25 framework to evaluate emergency medical service. The main criteria in the definition of the
26
27 cases in the OHCA studies are: 1) the cardiovascular collapse has occurred outside a hospital,
28
29 and 2) the event has elicited a resuscitation attempt. Neither of these conditions is required for
30
31 the physician given diagnosis of cardiac arrest according to the International Classification of
32
33 Diseases 10th edition (ICD-10) code I46 registered as discharge diagnosis at hospitals or
34
35 emergency departments.
36
37
38
39
40

41
42 The comprehensive population and health registries in Iceland make this an optimal setting to
43
44 study the association between relatively low daily exposure to air pollution, and different
45
46 heart-related conditions (7,18,19). The aim of the present study was to explore the association
47
48 between traffic-related pollutants, NO₂, PM₁₀, PM_{2.5}, and SO₂ in the Reykjavik capital area
49
50 and urgent hospital and emergency department visits for cardiac arrest, ICD-10 code I46, as
51
52 the primary discharge diagnosis, and to simultaneously adjust for meteorological variables
53
54 and geothermal-originated pollutants.
55
56
57
58
59
60

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 H₂S emissions originate from the plants. Reykjavik's capital area spreads over 247.5 km² 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, Hafnarfjörður, 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 inpatient wards of Landspítali 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

1
2
3 identification numbers are widely used in Icelandic society and population registries,
4 including the SAGA register. We received the identification numbers in encrypted form,
5
6 which enabled us to identify repeated visits to LUH. Readmissions to LUH within 10 days
7
8 with the same ICD-10 primary discharge diagnosis were excluded. From the SAGA register
9
10 we received the following details: admission date, encrypted identification number, unique
11
12 number of the admission, age, gender, and primary discharge diagnosis for certain codes
13
14 according to the International Classification of Diseases 10th edition (ICD-10). In this study,
15
16 both admission to the emergency department and formal admission to the hospital are
17
18 included, so there is no requirement that a patient stayed overnight. The diagnoses are
19
20 registered at discharge from the hospital, transfer to another hospital, and death in the
21
22 hospital. In a previous study (7), the outcomes were heart diseases ICD-10 codes: I20-I25,
23
24 I44-I50, ischemic heart diseases ICD-10 codes: I20-I25, cardiac arrhythmias and heart failure
25
26 ICD-10 codes: I44-I50, and atrial fibrillation ICD-10 I48 (7). In the present study, the
27
28 outcome analysed was cardiac arrest ICD-10 code I46. Emergency department visits and
29
30 urgent hospital admissions were combined and are called emergency hospital visits.
31
32
33
34
35
36
37

38 **Air pollutants and meteorological data**

39
40
41 Information on pollution was obtained from Grensas monitor station (GRE), operated by the
42
43 governmental institution Environment Agency of Iceland. GRE is in the centre of the
44
45 Reykjavik capital area near one of the busiest road intersections in the city. Other stations in
46
47 the city were not permanently located or were not continuously monitoring throughout the
48
49 study period and were therefore not used in the study. However, to test whether GRE was
50
51 reflective of the total capital area, Pearson's correlation was calculated for GRE
52
53 measurements and measurements from another station located in Dalsmari, Kopavogur
54
55 municipality, for the period 2014-2017. Results of Pearson's correlation coefficients between
56
57
58
59
60

1
2
3 these two measurement stations were for PM₁₀ 0.44, for NO₂ 0.78, for SO₂ 0.98, and for H₂S
4
5 0.84. PM_{2.5} was not measured in Dalsmari.
6
7

8
9 Pollutants measured at GRE were NO₂, particulate matter with aerodynamic diameter less
10
11 than 10 µm (PM₁₀), particulate matter with aerodynamic diameter less than 2.5 µm (PM_{2.5}),
12
13 sulphur dioxide (SO₂), and hydrogen sulphide (H₂S), all measured in µg/m³. The
14
15 meteorological data was obtained from the governmental institution Icelandic Meteorological
16
17 Office and included temperature (°C) and relative humidity (RH). PM₁₀ and PM_{2.5} were
18
19 measured with an Andersen EMS IR Thermo (model FH62 I-R), NO₂ with Horiba device
20
21 (model APNA 360E), and SO₂ and H₂S with the Horiba model APOA 360E. Every 6-12
22
23 months the devices are calibrated. Exposure data included 12 years or 4,383 days. Daily
24
25 averages (midnight to midnight the following day) were calculated from hourly
26
27 concentrations if at least 75% of one-hour data existed. Missing daily averages for NO₂, PM₁₀,
28
29 PM_{2.5}, SO₂, and H₂S were 383 days (8.7%), 165 days (3.8%), 923 days (21.1%), 200 days
30
31 (4.6%), and 284 days (6.5%), respectively. Data gaps were seen and can be attributed to
32
33 inactive measurement devices due to unknown causes, with the exception of 52 days of
34
35 missing H₂S measurements at the beginning of the study period, as H₂S measurements at GRE
36
37 started at the end of February 2006. For temperature and RH, 6 days (0.1%) and 6 days
38
39 (0.1%) were missing, respectively. Minor gaps in the curves were fitted by linear
40
41 interpolation.
42
43
44
45
46
47

48 Descriptive statistics were calculated and showed as daily concentration levels in µg/m³ of the
49
50 pollutants, as well as Spearman's correlation coefficient between pollutants and
51
52 meteorological factors.
53
54

55 **Patient and public involvement**

56

57
58 No patient was involved.
59
60

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, H₂S, 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 $\mu\text{g}/\text{m}^3$ 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)

1
2
3 were employed in the analyses to explore the temporal association between pollutants and
4 cardiac arrest. The results of the multivariate models with all lag structures are presented in
5 the article, and other results are shown as Supplementary data.
6
7
8
9

10 Although readmissions within 10 days with the same primary discharge diagnosis were
11 excluded, it is still possible that some patients first went to the emergency department and
12 were subsequently admitted that same day to in-hospital wards where they might have
13 received a different diagnosis than they were given at the emergency department. To test
14 whether this could distort the main result of the association between increased pollutant
15 concentration and emergency hospital visits, a sensitivity analysis was done, in which data
16 was restricted to emergency department visits only.
17
18
19
20
21
22
23
24
25
26

27 Statistical analysis was done with R version 4.0.3 (<https://www.r-project.org/>). Statistical tests
28 used in this study were all two-tailed and we considered results statistically significant for $p <$
29 0.05.
30
31
32
33
34

35 The study was approved by the National Bioethics Committee (ref. no.
36 VSNb2018120011/03.01), the Data Protection Authority (ref. no. 10-050), and the Scientific
37 Committee of LUH.
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

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, H₂S, 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 PM₁₀ 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 PM₁₀ 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 PM₁₀, as shown in Table A, Supplementary data. A positive association was observed between exposure to NO₂ 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 NO₂, as shown in Table A, Supplementary data.

In examining the daily lag exposure to PM₁₀ 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 PM₁₀ (Table 3). Significant associations were shown for exposure to NO₂ at lag 4 and for SO₂ at lag 0, and unstratified emergency

1
2
3 hospital visits for cardiac arrest; the increased risks were OR 1.096 (95% CI 1.008-1.192) and
4
5 OR 1.084 (95% CI 1.002-1.173) per 10 $\mu\text{g}/\text{m}^3$ increase of NO_2 and SO_2 , respectively (Table
6
7
8 3).

9
10 In the multivariate model significant associations were shown between exposure to PM_{10} at
11
12 lag 2 and at lag 0-2, lag 0-3, and lag 0-4, and increased risks of cardiac arrest (ICD-10 code
13
14 I46), in the age, gender, age and gender combined, and season strata, i.e., in all the strata
15
16 except in the stratum of young females as shown in Table B, and Table C, Supplementary
17
18 data. In Figure 1, OR and 95% CI of cardiac arrest per 10 $\mu\text{g}/\text{m}^3$ increase of PM_{10}
19
20 concentrations in multi-pollutant models are shown at lag 0 to lag 4 for different strata and
21
22 unstratified.
23
24
25

26
27 In the single pollutant analyses, positive associations were observed for exposure to PM_{10} at
28
29 lag 0-3, and lag 0-4, and emergency hospital visits for cardiac arrest with successful
30
31 resuscitation (ICD-10 codes: I46.0); the increased risks of cardiac arrest were OR 1.161 (95%
32
33 CI 1.014-1.329), and OR 1.177 (95% CI 1.013-1.368), respectively, per 10 $\mu\text{g}/\text{m}^3$ increase of
34
35 PM_{10} , as shown in Table D, Supplementary data. A positive association was observed for
36
37 exposure to $\text{PM}_{2.5}$ at lag 3, and lag 4, and the increased risk of cardiac arrest with successful
38
39 resuscitation; the increased risk was OR 1.090 (95% CI 1.008-1.178), and OR 1.101 (95% CI
40
41 1.006-1.204), per 10 $\mu\text{g}/\text{m}^3$ increase of $\text{PM}_{2.5}$, respectively, as shown in Table D,
42
43
44
45 Supplementary data. A positive association was observed for exposure to PM_{10} at lag 2, and
46
47 the increased risk of cardiac arrest without indication of successful resuscitation (ICD-10
48
49 codes: I46, I46.1, and I46.9); the increased risk was OR 1.079 (95% CI 1.008-1.155), as
50
51 shown in Table D, Supplementary data.
52
53
54

55
56 In the multivariate model a positive association was observed between exposure to PM_{10} and
57
58 emergency hospital visits for cardiac arrest with successful resuscitation (ICD-10 code:
59
60 I46.0); the increased risks of cardiac arrest were OR 1.104 (95% CI 1.002-1.216) at lag 2, OR

1
2
3 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
4
5 1.209 (95% CI 1.027-1.422) at lag 0-4, per 10 $\mu\text{g}/\text{m}^3$ increase of PM_{10} , as shown in Table 4. A
6
7 positive association was observed between exposure to $\text{PM}_{2.5}$ and the increased risk of cardiac
8
9 arrest with successful resuscitation; the increased risk was OR 1.088 (95% CI 1.001-1.182) at
10
11 lag 3, and OR 1.104 (95% CI 1.006-1.21) at lag 4, per 10 $\mu\text{g}/\text{m}^3$ increase of $\text{PM}_{2.5}$, as shown
12
13 in Table 4. A positive association was observed between exposure to PM_{10} and the increased
14
15 risk of cardiac arrest without indication of successful resuscitation (ICD-10 codes: I46, I46.1,
16
17 and I46.9); the increased risk was OR 1.090 (95% CI 1.013-1.173) at lag 2, as shown in Table
18
19 4. In Figure 2, OR and 95% CI of cardiac arrest per 10 $\mu\text{g}/\text{m}^3$ increase of PM_{10} concentrations
20
21 in multi-pollutant models are shown at lag 0 to lag 4 when stratified on season and whether
22
23 there is an indication of successful resuscitation or not.
24
25
26
27
28

29 In the sensitive analysis of the association between daily exposure to PM_{10} and emergency
30
31 hospital visits for cardiac arrest (ICD-10 code I46), when restricting the calculation to
32
33 emergency department visits only (353 visits), the results did not change substantially: in the
34
35 unstratified analysis, the increased risk of cardiac arrest was OR 1.099 (95% CI 1.028-1.175)
36
37 at lag 2 per 10 $\mu\text{g}/\text{m}^3$ increase of PM_{10} .
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

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 PM₁₀ and cardiac arrest at lag 2, lag 0-2, lag 0-3, and lag 0-4, so the 24-hour concentrations of PM₁₀ 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

1
2
3 departments. In addition, the Utstein definition recommends registration of several time points
4
5 and intervals important for the research and quality assurance related to the resuscitation, but
6
7 such time elements are not required in the hospital discharge registries based on the ICD-10.
8
9
10 Some studies have shown that the risks of OHCA were associated with a short-term increase
11
12 in exposure to particulate matter, sometimes PM_{2.5}, or ultrafine particulate matter (11-14), and
13
14 sometimes PM₁₀ (15), with various associations with O₃, other gaseous pollutants, and high
15
16 temperature. An OHCA study conducted in Stockholm, Sweden demonstrated a significant
17
18 exposure-response association between OHCA risk and O₃, but no association for PM_{2.5} or
19
20 NO₂, (24), while another OHCA study in Lombardy, Italy, showed, with a different
21
22 methodology, that the concentrations of all the pollutants in the study were significantly
23
24 higher in days with high incidence of OHCA except for O₃ (25). In these OHCA studies (11-
25
26 15,24,25) no difference is made between those who survive the event and those who do not
27
28 survive. In the previously mentioned UK study (8) on the association between air pollution
29
30 and hospital admission for different cardiovascular events, exposure to NO₂ was significant,
31
32 while in the same publication some of the mortality outcomes were associated with exposure
33
34 to PM_{2.5} but not to NO₂ (8), indicating the possibility of different pathogenetic pathways for
35
36 the outcomes, as has been discussed briefly in the case of NO₂ (4), and in the comprehensive
37
38 review of the causal role of particulate material (2). The category cardiac arrest in the ICD-10
39
40 coding system represents a small group compared to other CVD diagnoses and seems to be
41
42 concealed within the larger summary group of cardiac arrhythmias (10) or omitted from the
43
44 analysis (8). In this respect, our recent study on the same dataset is not an exception:
45
46 increased risk of cardiac arrhythmias (ICD-10 codes I44 to I50) was associated with an
47
48 increase in NO₂ exposure (7), a finding that hides the association between cardiac arrest (ICD-
49
50 10 code I46) and exposure to PM₁₀ as demonstrated in the present study.
51
52
53
54
55
56
57
58
59
60

1
2
3 Among the strengths of this study is that it is population-based, as the hospital and emergency
4 department data were obtained from the only emergency healthcare institution, the LUH,
5 serving the population in the catchment area of the Reykjavik capital. The design of the study
6 is also a strength, as the bidirectional time-stratified case-crossover approach virtually
7 excludes confounding of individual characteristics and the matching adjusted for weekly
8 pattern and time trends. Another strength of the study is its use of the encrypted identification
9 number of each patient in the Register of hospital-treated patients, which ensures the correct
10 counting and identification of the cases and their admissions. Furthermore, it is noteworthy
11 that visits of the cases receiving the primary discharge diagnosis of cardiac arrest (453 cases)
12 were evenly distributed over the study period (4383 days), so the distribution diminished the
13 risk of overlapping the sets of case and control days.
14
15

16
17 That said, there are few limitations. First, the concentration of the pollutants derived from one
18 monitoring station in the Reykjavik capital area, and not from individual exposure
19 measurements. The results from these measurements did, however, correlate well with
20 measurements from another monitoring station located in the capital area during three years of
21 the study period. Another limitation is that only the primary discharge diagnosis was included
22 in the study, meaning that the cases may have underlying diseases that could modify the
23 result.
24
25

26
27 Furthermore, the quality of the routine discharge diagnosis at the LUH has not been
28 investigated in a separate study for accuracy or reliability, which is a weakness our study
29 shares with the many studies based on hospital records. The primary discharge diagnosis of
30 cardiac arrest (ICD-10 code I46) set at emergency admission to the hospital and emergency
31 department does not indicate whether the causes were cardiac- or trauma related, and there
32 may be doubt as to where the patient developed the cardiac arrest, i.e., whether the event
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 initially occurred outside or inside the hospital. The study population consisted of patients
4
5 aged 18 years and older, which limits the generalisability of the results to those under 18.
6
7

8
9 The present study concentrates on traffic-related pollutants; however, emissions from the
10
11 volcanic eruptions occurring in Iceland during the study period may have confounded the
12
13 results. The Eyjafjallajökull eruption in 2010 was found to have minor health effect on the
14
15 local population, but not the population in the Reykjavik capital area (26). The Holuhraun
16
17 eruption in 2014 to 2015 emitted a massive amount of SO₂ and mature volcanic plume, and
18
19 the exposure to these was associated with an increase in the dispensing of asthma medication
20
21 and an increase in healthcare utilisation for respiratory diseases in the Reykjavik capital area
22
23 during four months in the year 2014 (27,28). The present study was not designed to catch the
24
25 possible effect of these emissions on the cardiovascular health of the population of the
26
27 Reykjavik capital area, and its role remains unknown in that respect.
28
29
30

31
32 We made several stratifications to explore the possible association between air pollutants and
33
34 emergency hospital visits for cardiac arrest in this study. Because of this, some concerns may
35
36 emerge about multiple comparisons; however, this has been dealt with in the literature (29).
37
38
39
40

41 **Conclusions**

42
43
44 This study was, to our knowledge, the first to utilise the new endpoint of cardiac arrest (ICD-
45
46 10 code I46) according to the hospital discharge registry. This outcome has in previous
47
48 epidemiological studies been included in larger groups of CVDs, and its special status may
49
50 have been overshadowed by the more common diagnosis of CVDs. Our results indicate a
51
52 positive association between short-term increase in PM₁₀ and emergency hospital visits for
53
54 cardiac arrest in the Reykjavik capital area, known for having low levels of traffic-related
55
56 pollution. The effects were found in most subgroups, and were highest among the elderly, in
57
58
59
60

1
2
3 the winter season, and among those who were successfully resuscitated. Future ecological
4
5 studies of this type should perhaps concentrate more on precisely defined endpoints; however,
6
7 doing so will not replace the obvious lack of exact individual exposure measurements for each
8
9 of the cases.
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

For peer review only

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 ₂ S	Hydrogen sulphide
ICD-10	International Classification of Diseases 10th edition
IHD	Ischemic heart disease
km	Kilometre
LUH	Landspítali 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.

Acknowledgements

Not applicable.

References

1. Brook RD, Franklin B, Cascio W, Hong Y, Howard G, Lipsett M, et al. Air pollution and cardiovascular disease: a statement for healthcare professionals from the Expert Panel on Population and Prevention Science of the American Heart Association. *Circulation*. 2004;109(21):2655-71.
2. Brook RD, Rajagopalan S, Pope CA, 3rd, Brook JR, Bhatnagar A, Diez-Roux AV, et al. Particulate matter air pollution and cardiovascular disease: An update to the scientific statement from the American Heart Association. *Circulation*. 2010;121(21):2331-78.
3. Meng X, Liu C, Chen R, Sera F, Vicedo-Cabrera AM, Milojevic A, et al. Short term associations of ambient nitrogen dioxide with daily total, cardiovascular, and respiratory mortality: multilocation analysis in 398 cities. *BMJ*. 2021;372:n534.
4. Stieb DM, Zheng C, Salama D, Berjawi R, Emode M, Hocking R, et al. Systematic review and meta-analysis of case-crossover and time-series studies of short term outdoor nitrogen dioxide exposure and ischemic heart disease morbidity. *Environ Health*. 2020;19(1):47.
5. Belch JJ, Fitton C, Cox B, Chalmers JD. Associations between ambient air pollutants and hospital admissions: more needs to be done. *Environ. Sci. Pollut. Res*. 2021;28(43):61848-52.
6. Dahlquist M, Frykman V, Kemp-Gudmundsdottir K, Svennberg E, Wellenius GA, P LSL. Short-term associations between ambient air pollution and acute atrial fibrillation episodes. *Environ Int*. 2020;141:105765.
7. Halldorsdottir S, Finnbjornsdottir RG, Elvarsson BT, Gudmundsson G, Rafnsson V. Ambient nitrogen dioxide is associated with emergency hospital visits for atrial fibrillation: a population-based case-crossover study in Reykjavik, Iceland. *Environ Health*. 2022;21(1):2.
8. Milojevic A, Wilkinson P, Armstrong B, Bhaskaran K, Smeeth L, Hajat S. Short-term effects of air pollution on a range of cardiovascular events in England and Wales: case-crossover analysis of the MINAP database, hospital admissions and mortality. *Heart*. 2014;100(14):1093-8.
9. Talbott EO, Rager JR, Benson S, Brink LA, Bilonick RA, Wu C. A case-crossover analysis of the impact of PM(2.5) on cardiovascular disease hospitalizations for selected CDC tracking states. *Environ Res*. 2014;134:455-65.
10. Zheng Q, Liu H, Zhang J, Chen D. The effect of ambient particle matters on hospital admissions for cardiac arrhythmia: a multi-city case-crossover study in China. *Environ Health*. 2018;17(1):60.
11. Ensor KB, Raun LH, Persse D. A case-crossover analysis of out-of-hospital cardiac arrest and air pollution. *Circulation*. 2013;127(11):1192-9.
12. Rosenthal FS, Kuisma M, Lanki T, Hussein T, Boyd J, Halonen JJ, et al. Association of ozone and particulate air pollution with out-of-hospital cardiac arrest in Helsinki, Finland: evidence for two different etiologies. *J Expo Sci Environ Epidemiol*. 2013;23(3):281-8.
13. Xia R, Zhou G, Zhu T, Li X, Wang G. Ambient Air Pollution and Out-of-Hospital Cardiac Arrest in Beijing, China. *Int J Environ Res Public Health*. 2017;14(4).
14. Zhao B, Johnston FH, Salimi F, Kurabayashi M, Negishi K. Short-term exposure to ambient fine particulate matter and out-of-hospital cardiac arrest: a nationwide case-crossover study in Japan. *Lancet Planet. Health*. 2020;4(1):e15-e23.
15. Tobaldini E, Iodice S, Bonora R, Bonzini M, Brambilla A, Sesana G, et al. Out-of-hospital cardiac arrests in a large metropolitan area: synergistic effect of exposure to air particulates and high temperature. *Eur. J. Prev. Cardiol*. 2020;27(5):513-9.
16. Jacobs I, Nadkarni V, Bahr J, Berg RA, Billi JE, Bossaert L, Cassan P, Coovadia A, D'Este K, Finn J, Halperin H, Handley A, Herlitz J, Hickey R, Idris A, Kloeck W, Larkin GL, Mancini ME, Mason P, Mears G, Monsieurs K, Montgomery W, Morley P, Nichol G, Nolan J, Okada K, Perlman J, Shuster M, Steen PA, Sterz F, Tibballs J, Timerman S, Truitt T, Zideman D; International Liaison Committee on Resuscitation. Cardiac arrest and cardiopulmonary resuscitation outcome reports: update and simplification of the Utstein templates for resuscitation registries. A statement for healthcare professionals from a task force of the international liaison committee on resuscitation (American Heart Association, European Resuscitation Council, Australian Resuscitation Council, New Zealand

- 1
2
3 Resuscitation Council, Heart and Stroke Foundation of Canada, InterAmerican Heart Foundation,
4 Resuscitation Council of Southern Africa) Resuscitation. 2004 Dec;63(3):233-49.
- 5 17. Perkins GD, Jacobs IG, Nadkarni VM, Berg RA, Bhanji F, Biarent D, Bossaert LL, Brett SJ,
6 Chamberlain D, de Caen AR, Deakin CD, Finn JC, Gräsner JT, Hazinski MF, Iwami T, Koster RW, Lim SH,
7 Ma MH, McNally BF, Morley PT, Morrison LJ, Monsieurs KG, Montgomery W, Nichol G, Okada K, Ong
8 ME, Travers AH, Nolan JP; Utstein Collaborators. Cardiac Arrest and Cardiopulmonary Resuscitation
9 Outcome Reports: Update of the Utstein Resuscitation Registry Templates for Out-of-Hospital
10 Cardiac Arrest: A Statement for Healthcare Professionals From a Task Force of the International
11 Liaison Committee on Resuscitation (American Heart Association, European Resuscitation Council,
12 Australian and New Zealand Council on Resuscitation, Heart and Stroke Foundation of Canada,
13 InterAmerican Heart Foundation, Resuscitation Council of Southern Africa, Resuscitation Council of
14 Asia); and the American Heart Association Emergency Cardiovascular Care Committee and the
15 Council on Cardiopulmonary, Critical Care, Perioperative and Resuscitation. Resuscitation.
16 2015;96:328-40.
- 17 18. Carlsen HK, Forsberg B, Meister K, Gíslason T, Oudin A. Ozone is associated with
18 cardiopulmonary and stroke emergency hospital visits in Reykjavík, Iceland 2003-2009. Environ
19 Health. 2013;12:28.
- 20 19. Finnbjörnsdóttir RG, Zoëga H, Olafsson O, Thorsteinsson T, Rafnsson V. Association of air
21 pollution and use of glyceryl trinitrate against angina pectoris: a population-based case-crossover
22 study. Environ Health. 2013;12(1):38.
- 23 20. Statistics Iceland. Population by municipality, sex, citizenship and quarters 2011-2019.
24 <https://hagstofa.is/talnaefni/ibuar/mannfjoldi/yfirlit/> (2020). Accessed 06 Feb 2020.
- 25 21. Levy D, Lumley T, Sheppard L, Kaufman J, Checkoway H. Referent selection in case-crossover
26 analyses of acute health effects of air pollution. Epidemiology. 2001;12(2):186-92.
- 27 22. Maclure M. The case-crossover design: a method for studying transient effects on the risk of
28 acute events. Am J Epidemiol. 1991;133(2):144-53.
- 29 23. Berdowski J, Berg RA, Tijssen JG, Koster RW. Global incidences of out-of-hospital cardiac
30 arrest and survival rates: Systematic review of 67 prospective studies. Resuscitation.
31 2010;81(11):1479-87.
- 32 24. Raza A, Bellander T, Bero-Bedada G, Dahlquist M, Hollenberg J, Jonsson M, Lind T, Rosenqvist
33 M, Svensson L, Ljungman PL. Short-term effects of air pollution on out-of-hospital cardiac arrest in
34 Stockholm. Eur Heart J. 2014;35:861-8.
- 35 25. Gentile FR, Primi R, Baldi E, Compagnoni S, Mare C, Contri E, Reali F, Bussi D, Facchin F,
36 Currao A, Bendotti S, Savastano S; Lombardia CARE researchers. Out-of-hospital cardiac arrest and
37 ambient air pollution: A dose-effect relationship and an association with OHCA incidence. PLoS One.
38 2021;25;16(8):e0256526.
- 39 26. Carlsen HK, Hauksdóttir A, Valdimarsdóttir UA, Gíslason T, Einarsdóttir G, Runolfsson H, et al.
40 Health effects following the Eyjafjallajökull volcanic eruption: a cohort study. BMJ Open. 2012;2(6).
- 41 27. Carlsen HK, Ilyinskaya E, Baxter PJ, Schmidt A, Thorsteinsson T, Pfeffer MA, et al. Increased
42 respiratory morbidity associated with exposure to a mature volcanic plume from a large Icelandic
43 fissure eruption. Nat. Commun. 2021;12(1):2161-.
- 44 28. Carlsen HK, Valdimarsdóttir U, Briem H, Dominici F, Finnbjörnsdóttir RG, Jóhannsson T, et al.
45 Severe volcanic SO exposure and respiratory morbidity in the Icelandic population - a register study.
46 Environ. Health: Glob. Access Sci. Source. 2021;20(1):23.
- 47 29. Rothman KJ. No Adjustments Are Needed for Multiple Comparisons. Epidemiology.
48 1990;1(1):43-6.
- 49
50
51
52
53
54
55
56
57
58
59
60

1
2
3 Figure 1. The odds ratio (OR) and bars showing 95% confidence intervals of cardiac arrest
4 (ICD10 code I46) per 10 $\mu\text{g}/\text{m}^3$
5
6
7
8 increase in PM10 concentrations in multiple-pollutant models
9
10
11 at lag 0 to lag 4 for unstratified material and different strata.
12
13
14
15
16
17
18
19

20 Figure 2. The odds ratio (OR) and bars showing 95% confidence intervals of cardiac arrest
21 with
22
23 successful resuscitation (ICD-10 code: I46.0) and other cardiac arrest categories
24
25 grouped together (ICD-10 codes I46, I46.1 and I46.9), as well as cardiac arrest (ICD-10
26
27 code: I46) stratified to winter and summer, per 10 $\mu\text{g}/\text{m}^3$
28
29 increase in PM10
30
31 concentrations in multiple-pollutant models at lag 0 to lag 4.
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Table 1 Descriptive statistics of emergency hospital visits for cardiac arrest (ICD-10: I46) to Landspítali 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 (≥ 71 yr)	192 (42)	190
Younger (< 71 yr)	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 ($\mu\text{g}/\text{m}^3$) of pollutants and meteorological data in the Reykjavik 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 ₂ S	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
<i>Spearman's correlation</i>							
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 ₂ S	-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; H₂S: hydrogen sulphide; NO₂: nitrogen dioxide; PM₁₀: particulate matter $\leq 10\mu\text{m}$ in diameter; PM_{2,5}: particulate matter $\leq 2.5\mu\text{m}$ in diameter; RH: relative humidity; SO₂: 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 NO₂, PM₁₀, PM_{2.5}, SO₂ and H₂S, 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 ₂ S
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 (0.936-1.074)	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 (0.972-1.211)	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 (0.965-1.212)	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 NO₂, PM₁₀, PM_{2.5}, SO₂, and H₂S, 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.

Categories/Visits (n)	Lag	NO ₂	PM ₁₀	PM _{2.5}	SO ₂	H ₂ S
		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 (0.895-1.301)	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 (0.982-1.462)	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		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 (0.889-1.190)	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 (0.889-1.227)	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)

bmjopen-2022-06-11-2024 by guest. Protected by copyright.

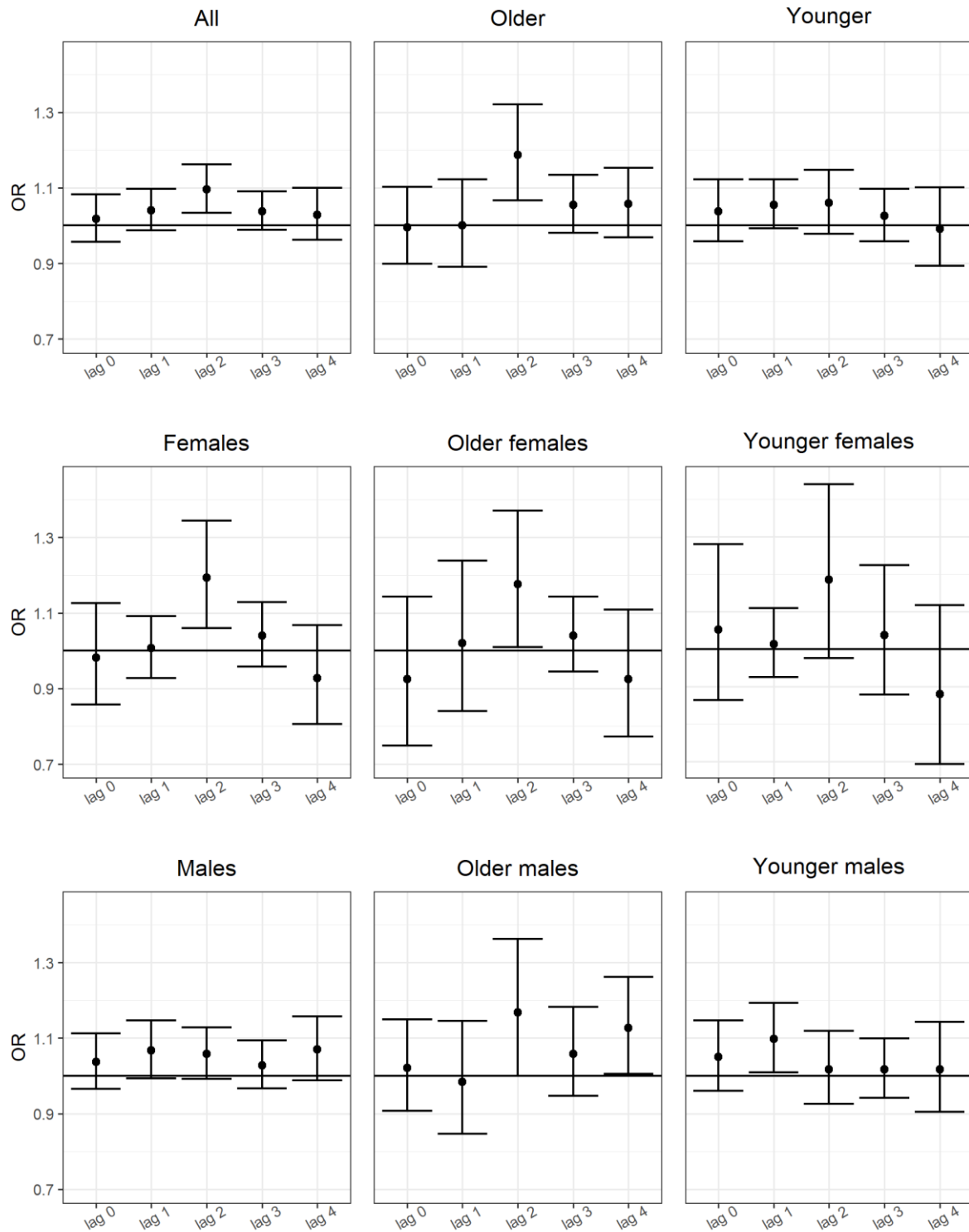


Figure 1. The odds ratio (OR) and bars showing 95% confidence intervals of cardiac arrest (ICD-10 code I46) per 10 µg/m³ increase in PM₁₀ concentrations in multiple-pollutant models at lag 0 to lag 4 for unstratified material and different strata.

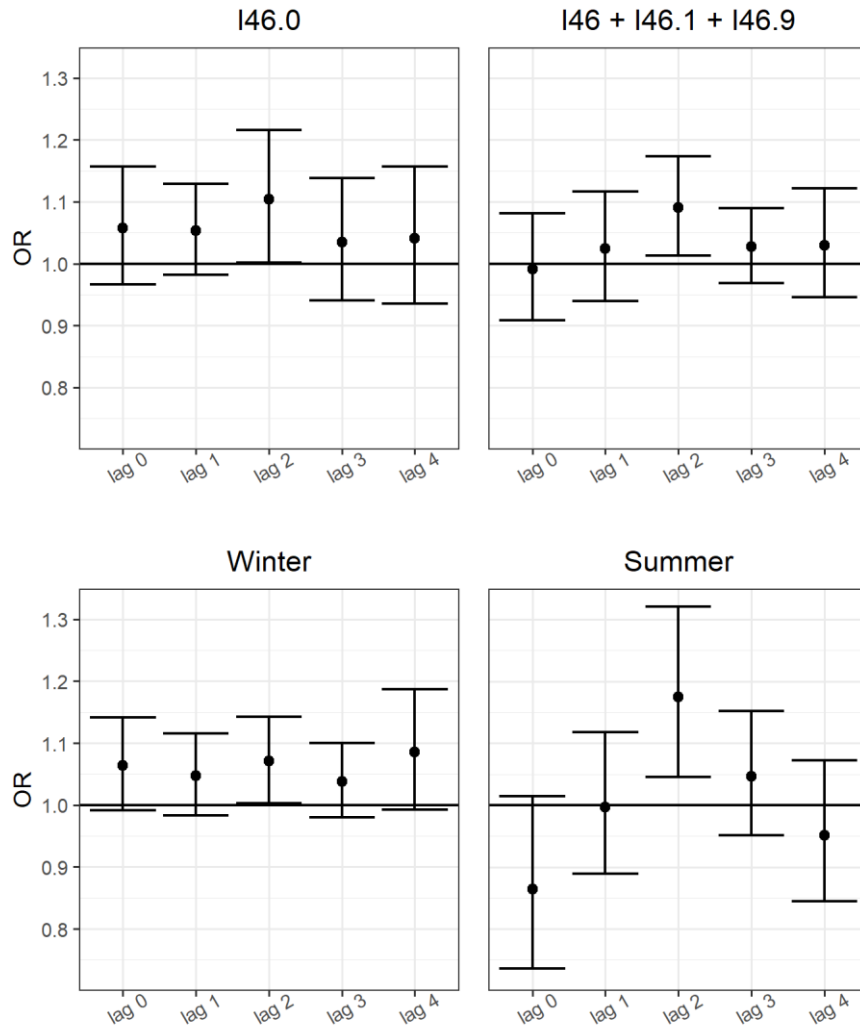


Figure 2. The odds ratio (OR) and bars showing 95% confidence intervals of cardiac arrest with successful resuscitation (ICD-10 code: I46.0) and other cardiac arrest categories grouped together (ICD-10 codes I46, I46.1 and I46.9), as well as cardiac arrest (ICD-10 code: I46) stratified to winter and summer, per 10 $\mu\text{g}/\text{m}^3$ 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 NO₂, PM₁₀, PM_{2.5}, SO₂, and H₂S, 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.

Categories/Visits (n)	Lag	NO ₂		PM ₁₀		PM _{2.5}		SO ₂		H ₂ S	
		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

6/bmjopen-2022-066743 on 15 May 2023. Downloaded from <http://bmjopen.bmj.com/> on April 27, 2024 by guest. Protected by copyright.

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 NO₂, PM₁₀, PM_{2.5}, SO₂ and H₂S, 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.

Categories/Visits (n)	Lag	NO ₂		PM ₁₀		PM _{2.5}		SO ₂		H ₂ S	
		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		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
	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
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	

6/bmjopen-2022-066743 on 15 May 2023. Downloaded from http://bmjopen.bmj.com/ On April 27, 2024 by guest. Protected by copyright.

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 NO₂, PM₁₀, PM_{2.5}, SO₂ and H₂S, 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.

Categories/Visits (n)	Lag	NO ₂		PM ₁₀		PM _{2.5}		SO ₂		H ₂ S	
		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 NO₂, PM₁₀, PM_{2.5}, SO₂, and H₂S, in single pollutant models, at lag 0 to lag 4, lag 0-1, lag 0-2, lag 0-3, and lag 0-4.

Categories/Visits (n)	Lag	NO ₂		PM ₁₀		PM _{2.5}		SO ₂		H ₂ S	
		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		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 (b) Give reasons for non-participation at each stage (c) Consider use of a flow diagram	10, table 1 NA NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders (b) Indicate number of participants with missing data for each variable of interest	10, tables 1, 2 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 (b) Report category boundaries when continuous variables were categorized (c) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	11-13 NA 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.