Effect of Exhaust- and Nonexhaust-Related Components of Particulate Matter on Long-Term Survival After Stroke

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Background and Purpose—Outdoor air pollution represents a potentially modifiable risk factor for stroke. We examined the link between ambient pollution and mortality up to 5 years poststroke, especially for pollutants associated with vehicle exhaust.

Methods—Data from the South London Stroke Register, a population-based register covering an urban, multiethnic population, were used. Hazard ratios (HR) for a 1 interquartile range increase in particulate matter <2.5 μm diameter ($PM_{2.5}$) and PM <10 μm (PM_{10}) were estimated poststroke using Cox regression, overall and broken down into exhaust and nonexhaust components. Analysis was stratified for ischemic and hemorrhagic strokes and was further broken down by Oxford Community Stroke Project classification.

Results—The hazard of death associated with $PM_{2.5}$ up to 5 years after stroke was significantly elevated (P=0.006) for all strokes (HR=1.28; 95% confidence interval [CI], 1.08–1.53) and ischemic strokes (HR, 1.32; 95% CI, 1.08–1.62). Within ischemic subtypes, $PM_{2.5}$ pollution increased mortality risk for total anterior circulation infarcts by 2-fold (HR, 2.01; 95% CI, 1.17–3.48; P=0.012) and by 78% for lacunar infarcts (HR, 1.78; 95% CI, 1.18–2.66; P=0.006). PM_{10} pollution was associated with 45% increased mortality risk for lacunar infarct strokes (HR, 1.45; 95% CI, 1.06–2.00; P=0.022). Separating $PM_{2.5}$ and PM_{10} into exhaust and nonexhaust components did not show increased mortality.

Conclusions—Exposure to certain outdoor PM pollution, particularly $PM_{2.5}$, increased mortality risk poststroke up to 5 years after the initial stroke. **(*Stroke*. 2016;47:2916-2922. DOI: 10.1161/STROKEAHA.116.014242.)**

Key Words: air pollution ■ mortality ■ particulate matter ■ stroke ■ survival analysis

Accounting for ≈9% of all deaths around the world, stroke is a major cause of mortality worldwide.[1] For the patients who survive, stroke continues to be associated with a higher risk of death for years after the event.[1–4] Outdoor air pollution, a well-known hazard to human health,[5,6] may be particularly harmful to people susceptible to stroke[7] and for survival after stroke.[8]

Mortality 1 month after stroke is ≈25%, after 6 months is ≈33%, and after 1 year is ≈50%.[1] Survivors of a first-ever stroke exhibit an >2-fold higher annual mortality rate than people from the general population, even several years after their initial stroke.[2,3] In 1 prospective study, 80% of those with first-ever stroke did not survive 10 years later.[4]

Several associative studies suggest that the effects of outdoor air pollution may act as a potentially modifiable risk factor on survival rates after having a stroke. The onset of stroke has been linked to nitrogen dioxide,[9,10] and acute stroke mortality has been linked to ozone,[11] nitrogen dioxide,[11] sulfur dioxide,[11] and carbon monoxide.[11,12] Long-term poststroke mortality has been linked to nitrogen dioxide.[8] However, the strongest evidence supporting a link between air pollution and mortality risks in a poststroke population comes from studies on particulate matter (PM).

There seems to be a causal link between PM air pollution and an increased risk of morbidity and mortality in humans.[13,14] Smaller PM below 2.5 μm in diameter ($PM_{2.5}$) may be especially hazardous to human health,[13] and PM levels <10 μm (PM_{10}) have also been implicated. Fewer studies have focused on the association between long-term PM exposures (ie, concentrations averaged over months or years) and adverse health conditions. There is no evidence to suggest a safe exposure level or threshold to short- or long-term PM air pollution.[13] A study conducted in France, Austria, and Switzerland attributed 6% of annual deaths, or an estimated 40 000 deaths per year, to PM_{10} air pollution.[14] One particular concern is how to identify PM sources that may contribute to this link; traffic-related sources are considered a prime candidate.[14] The growing ability of urban air pollution models

Received June 3, 2016; final revision received September 9, 2016; accepted September 28, 2016.

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The views expressed are those of the authors and not necessarily those of the NHS, the NIHR or the Department of Health.

Published in abstract form for the 2015 UK Stroke Conference (*Int J Stroke*. 2015;10[S5]:61–62).

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Stroke **is available at http://stroke.ahajournals.org** **DOI: 10.1161/STROKEAHA.116.014242**

to separate PM into source-related components[7,15] may prove useful in this regard.

The risk of death associated with air pollution may be unevenly spread throughout the population. There is evidence to suggest that people with a history of myocardial infarction or cardiovascular disease are susceptible to increased mortality risks with higher PM exposure levels.[16–19] Links between mortality and PM exposure have also been found in diabetics[13,16] and people with respiratory diseases.[18,19] Taken together, this evidence suggests that long-term exposure to PM air pollution may be associated with a higher risk of mortality in populations with preexisting health conditions. However, few studies have examined the long-term effects of PM exposure in a poststroke population.

This study combines a stroke register in South London with a high-resolution air quality model to investigate associations between long-term exposure to air pollution and survival after incident stroke.

Methods

Subjects

Patients in this study come from the South London Stroke Register, a population-based register of incident strokes set up in 1995 among an urban population living in a 2 boroughs of South London. The study had approval from the Ethics Committee of Guy's and St Thomas' Hospital Trust, King's College Hospital, and the subjects gave informed consent. The South London Stroke Register source population consists of 357 308 individuals, of whom 56% were white, 25% were black, 6% were Asian, and 12% were other ethnic group (census 2011). Stroke survival >5 years was examined from 2005 to 2012. Hemorrhagic strokes consisted of primary intracerebral hemorrhage and subarachnoid hemorrhage. Ischemic strokes were subdivided using the Oxford Community Stroke Project classification[10] as total anterior circulation infarct (TACI), partial anterior circulation infarct (PACI), posterior circulation infarct (POCI), and lacunar infarct (LACI).

Data Collection

Data collection methods have been described before.[20] Trained fieldworkers collected data as soon as possible after the time of first stroke and a clinician verified the diagnosis of stroke. This study utilized particular data on age, sex, ethnicity (black, white, and other), year of stroke, deprivation, transient ischemic attacks before stroke, and stroke severity. Deprivation was measured by the Index of Multiple Deprivation, and stroke severity was measured by National Institutes of Health Stroke Scale score. Patients with stroke were followed up at 3 months and yearly. Official notification of deaths and death certificates were obtained from the Health and Social Care Information Centre.[20]

Air Pollution

Pollution exposure was represented by averaged annual concentrations related to residential postcode at time of initial stroke (Table 1). The pollutants considered were nitric oxide (NO), nitrogen dioxide (NO_2), nitrogen oxides (NO_x), ozone (O_3), total oxidants ($Ox–O_3+NO_2$), and PM. PM was subdivided into $PM_{2.5}$ and PM_{10}, and the contribution of traffic exhaust and nonexhaust was examined.

Air pollution concentrations were derived using the KCLurban model developed at King's College London as part of the NERC/MRC/SRC/DEFRA/DoH Traffic Pollution and Health in London project (Traffic). The KCLurban model has been previously described[7] and has been well established in public health research.[21–23] The model provided annual mean concentrations for the pollutants at the geographical center of each postcode. Traffic exhaust and nontraffic exhaust sources were considered separately for $PM_{2.5}$ and PM_{10}.

Table 1. Average Pollutant Concentrations

	Mean (SD) μg/m^3	Median (IQR), μg/m^{-3}
NO	34.39 (7.15)	33.40 (29.54–38.40)
NO_2	44.59 (4.29)	44.05 (41.83–46.87)
NO_x	78.98 (11.41)	77.42 (71.42–85.41)
O_3	36.68 (3.08)	36.98 (34.35–38.90)
Ox	81.27 (2.45)	81.13 (79.66–82.38)
PM_{10}	24.84 (1.50)	24.91 (23.63–25.84)
PM_{10} exhaust	0.90 (0.29)	0.86 (0.71–1.07)
PM_{10} nonexhaust	3.18 (0.62)	3.06 (2.77–3.44)
$PM_{2.5}$	15.35 (1.13)	15.26 (14.45–16.31)
$PM_{2.5}$ exhaust	0.80 (0.26)	0.77 (0.63–0.95)
$PM_{2.5}$ nonexhaust	0.92 (0.17)	0.89 (0.81–1.00)
PM coarse	9.49 (0.69)	9.48 (8.92–9.94)

IQR indicates interquartile range; NO, nitric oxide; NO_2, nitrogen dioxide; NO_x, nitrogen oxides; O_3, ozone; Ox, oxidant; PM_{10}, particulate matter <10 μm; and $PM_{2.5}$, particulate matter <2.5 μm.

Inventory exhaust emissions factors were combined with UK-specific roadside measurements,[24] whereas nonexhaust emissions were based on the work of Harrison et al.[25] Pollution concentrations were then weighted by population counts at each postcode using 2011 census data and averaged across the years of the study period. This provided an estimated average pollution level that could be linked to the South London Stroke Register participants' place of residence at the time of initial stroke.

Statistical Analysis

Survival time was defined as time between stroke onset and death. Patients who were still alive were censored on December 31, 2012. Hazard ratios (HR) with 95% confidence intervals (CIs) were estimated for a 1 interquartile range (IQR) increase in each pollutant up to 5 years after initial stroke using a Cox regression model for all-cause mortality. Each pollutant was included separately in the models during the analyses. The analysis was stratified by overall stroke and subtypes (ischemic and hemorrhagic) and then by ischemic subtypes (TACI, PACI, POCI, and LACI). Models controlled for the following confounders: age, sex, ethnicity, year of stroke, deprivation (Index of Multiple Deprivation rank subdivided into quarters), transient ischemic attacks before stroke, and stroke severity (National Institutes of Health Stroke Scale total). Fewer deaths occurred in ischemic subtypes than in all strokes; to avoid overfitting the model, the number of confounders for ischemic subtypes was reduced to the following: age, sex, ethnicity, year of stroke, and stroke severity (National Institutes of Health Stroke Scale total). This reduced model was also applied to the data on all strokes, ischemic and hemorrhagic strokes. Estimate HRs for pollutants were similar in the reduced and main models (data not shown). Further models were also fitted in which an interaction term between particulate pollutants and subtype (ischemic or hemorrhagic or within ischemic subtypes) were included. Kaplan–Meier curves were plotted to assess survival probability and $PM_{2.5}$ exposure for ischemic, TACI, and LACI strokes up to 5 years; $PM_{2.5}$ exposure was divided into tertiles (low, middle, and high). The analysis was conducted using STATA version 13MP.

Results

Demographics of the Study Population

In total, 1800 strokes were recorded between 2005 and 2012. The average age was 68.8 years, with 26% of the individuals aged 75

to 84 years, and roughly half (52.3%) were men (Table 2). In the population, 74.3% of strokes were ischemic (n=1338), 14.5% were hemorrhagic (n=261), and 11.2% were unknown or undefined (n=201). Of the ischemic strokes, 10.5% of strokes were TACI, 29.6% were PACI, 10.9% were POCI, 23.2% were LACI, and 0.2% were unspecified ischemic infarcts. Hemorrhagic strokes consisted of primary intracerebral hemorrhage (11.3%) and subarachnoid hemorrhage (3.2%) strokes.

HRs for Incident Strokes, Including Subtype Analysis

HRs for all stroke types and separately for ischemic and hemorrhagic strokes are presented in Table 3. Five years after an initial stroke, $PM_{2.5}$ was associated with reduced survival rates by 28% per IQR increase for all strokes (HR, 1.28; 95% CI, 1.08–1.53; *P*=0.006; see also Figure [A]) and with reduced survival rates by 32% for ischemic strokes (HR, 1.32; 95% CI, 1.08–1.62; *P*=0.006). No significances were observed for hemorrhagic strokes. Significant interactions between type of stroke (ischemic or hemorrhagic) and PM_{10} (*P*=0.0077) and $PM_{2.5}$ (*P*=0.0095) further suggest that the pollutants may be associated with a higher mortality risk for ischemic strokes than for hemorrhagic strokes.

Within ischemic subtypes (Table 4), $PM_{2.5}$ was associated with a 2-fold reduced survival rate for TACI strokes per IQR increase (HR, 2.01;95% CI, 1.17–3.48; *P*=0.012; see also Figure [B]). For LACI strokes, higher mortality rates were observed for PM_{10} (HR, 1.45; 95% CI, 1.06–2.00; *P*=0.022) and $PM_{2.5}$ (HR, 1.78; 95% CI, 1.18–2.66; *P*=0.006; see also Figure [B]), reducing survival rates by 45% and 78%, respectively. No significances were observed for PACI and POCI ischemic strokes. Separating $PM_{2.5}$ and PM_{10} into exhaust and nonexhaust components did not show increased mortality in either analysis. Interactions between ischemic subtypes and PM_{10} (*P*=0.3985) and $PM_{2.5}$ (*P*=0.4128) were not statistically significant.

Discussion

Long-term annual exposure to the pollutant $PM_{2.5}$ is associated with an increase in the long-term morality rate in a post-stroke population, especially for ischemic strokes. Although the difference between subtypes was not statistically significant, there was also some indication that $PM_{2.5}$ exposure may increase risk of TACI and LACI more than POCI and PACI. For every IQR increase in $PM_{2.5}$, the risk of death after 5 years increased by 28%; for patients with ischemic stroke, the risk of death increased by 32%. Certain subtypes of ischemic strokes had particularly high mortality rates associated with $PM_{2.5}$ exposure; the risk of death for patients with TACI stroke increased by 2-fold for every IQR increase in $PM_{2.5}$.

Table 2. Incident Stroke Cases From 2005 to 2012 by Age, Sex, and Stroke Subtype

	No. of Strokes (%)	No. of Deaths	Cumulative Survival, % (95% CI)	*P* Value
Total	1800	729	87.1 (86.2–88.0)	
Age, mean (SD)	68.8 (15.8)	…	…	
Age, y				<0.0001
<55	364 (20.2)	52	83.9 (79.1–87.7)	
55–64	300 (16.7)	53	77.8 (71.6–82.9)	
65–74	396 (22.0)	149	55.2 (49.2–60.8)	
75–84	465 (25.8)	264	31.1 (25.9–36.5)	
>85	275 (15.3)	211	9.5 (5.4–15.0)	
Sex				<0.0001
Men	942 (52.3)	336	56.2 (52.2–60.0)	
Women	858 (47.7)	393	45.6 (41.5–49.6)	
Subtype				<0.0001
TACI	189 (10.5)	105	39.3 (31.3–47.2)	
PACI	532 (29.6)	241	45.7 (40.5–50.7)	
POCI	196 (10.9)	70	53.9 (44.8–62.1)	
LACI	417 (23.2)	134	59.3 (53.4–64.7)	
Infarction unspecified	4 (0.2)	2	50.0 (5.8–84.5)	
PICH	204 (11.3)	98	50.5 (42.6–57.9)	
SAH	57 (3.2)	16	71.2 (57.3–81.3)	
Unknown/undefined	201 (11.2)	63	49.7 (38.3–60.0)	

Number of incident strokes and deaths by age, sex, and stroke subtype. Cumulative survival at 5 years was calculated and compared across groups using the log-rank test. CI indicates confidence interval; LACI, lacunar infarct; PACI, partial anterior circulation infarct; PICH, primary intracerebral hemorrhage; POCI, posterior circulation infarct; SAH, subarachnoid hemorrhage; and TACI, total anterior circulation infarct.

Table 3. Associations Between Pollutants and HR Up To 5-Year Survival After Stroke (All Stroke, Ischemic Stroke, and Hemorrhagic Stroke)

	All Stroke (n=1800)		Ischemic (n=1338)		Hemorrhagic (n=261)	
	HR (95% CI)	*P* Value	HR (95% CI)	*P* Value	HR (95% CI)	*P* Value
NO	0.96 (0.85–1.08)	0.466	1.00 (0.88–1.15)	0.952	0.75 (0.53–1.06)	0.105
NO_2	0.97 (0.87–1.08)	0.556	1.01 (0.89–1.14)	0.929	0.80 (0.59–1.10)	0.173
NO_x	0.96 (0.85–1.08)	0.498	1.00 (0.88–1.15)	0.942	0.77 (0.55–1.08)	0.127
O_3	1.07 (0.87–1.33)	0.517	0.99 (0.78–1.27)	0.962	1.55 (0.86–2.80)	0.147
Ox	0.97 (0.88–1.08)	0.614	1.01 (0.90–1.13)	0.907	0.82 (0.61–1.12)	0.223
PM_{10}	1.12 (0.98–1.29)	0.102	1.16 (0.99–1.36)	0.069	0.77 (0.51–1.18)	0.239
PM_{10} exhaust	0.98 (0.84–1.15)	0.804	1.05 (0.89–1.25)	0.564	0.73 (0.46–1.16)	0.181
PM_{10} nonexhaust	0.95 (0.86–1.04)	0.262	0.98 (0.88–1.09)	0.697	0.80 (0.59–1.07)	0.131
$PM_{2.5}$	1.28 (1.08–1.53)*	0.006*	1.32 (1.08–1.62)*	0.006*	0.89 (0.53–1.49)	0.667
$PM_{2.5}$ exhaust	0.98 (0.84–1.14)	0.791	1.05 (0.89–1.25)	0.573	0.72 (0.45–1.15)	0.173
$PM_{2.5}$ nonexhaust	0.94 (0.85–1.03)	0.190	0.97 (0.87–1.08)	0.571	0.79 (0.57–1.07)	0.124
PM coarse	0.98 (0.87–1.10)	0.694	1.00 (0.87–1.14)	0.952	0.73 (0.51–1.06)	0.102

Confounders: age, sex, ethnicity (black, white, and other), National Institutes of Health Stroke Scale, deprivation score, previous transient ischemic attack, and year of stroke. CI indicates confidence interval; NO, nitric oxide; NO_2, nitrogen dioxide; NO_x, nitrogen oxides; O_3, ozone; O_x, oxidant; PM_{10}, particulate matter <10 μm; and $PM_{2.5}$, particulate matter <2.5 μm.

*$P<0.05$.

For patients with LACI stroke, 1 IQR increase in $PM_{2.5}$ was associated with a 78% increase in the risk of death; for PM_{10}, the associated increased risk of death was 45%.

The link between air pollution and stroke as a cause of death has been studied before[11,12,26,27]; however, the association of air pollution and the risk of death in a stroke population is less well known. To our knowledge, only 2 long-term studies have examined whether patients with stroke residing in areas with higher levels of outdoor air pollution have an increased risk of death. Similar to our study, the study by Maheswaran et al[8] used the South London Stroke Register and reported reduced survival for patients with stroke living in areas with higher levels of nitrogen dioxide and PM_{10}. A 10-μg/m^3 increase in PM_{10} was associated with a 52% increase in risk of death.[8] Wilker et al[28] used proximity to high-traffic roadways as a proxy for air pollution in the greater Boston area. People who had an ischemic stroke and were living <100 m from high-traffic roadways had a 20% higher mortality rate when compared with poststroke patients living >400 m.[28]

Our study suggests that people who have previously had an ischemic stroke, but not a hemorrhagic stroke, may be more vulnerable and at a higher risk of death to chronic, long-term exposure of PM. Several studies support the assertion that air pollution risks may be exacerbated in certain stroke subtypes. Ischemic but not hemorrhagic strokes have been associated with greater pollution-associated risks for stroke incidence,[7,9,10] acute stroke mortality,[11,12] and poststroke mortality[28] but not in all studies.[11] Only a few studies have looked at the link between specific stroke subtypes and air pollutants. Of the 2 studies that we could find on stroke and air pollution that examined specific subtypes, the onset of TACI and LACI strokes seemed to be associated with PM pollution.[7,29] This corresponds with our observations of increased mortality linked to higher PM pollution levels for TACI and LACI strokes.

Other evidence corroborates a link between air pollution and stroke. Higher levels of PM air pollution have been linked with acute stroke mortality on nationalized death records in Seoul, Korea,[11] and Helsinki, Finland.[12] There is also evidence to support an association with stroke incidence for PM_{10} and $PM_{2.5}$[7,9,10,30] although this is not supported in all studies.[26] One study by Zeka et al,[27] examining the effects of PM_{10} on daily mortality of the general population in 20 US cities, assessed whether a diagnosis of stroke would act as an individual effect modifier for mortality. They found that subjects with diagnoses of stroke had more than double the PM_{10}-associated risk of death for both all-cause mortality and for respiratory-related mortality.[27]

Possible Mechanisms

The adverse health effects of PM have been well documented.[13] The data demonstrating PM's effect on the cardiovascular system are especially strong, and ischemic stroke and cardiovascular disease share many risk factors, features, and pathophysiological mechanisms.[18] However, unlike cardiovascular disease, the health effects of PM exposure on cerebrovascular diseases like stroke are more uncertain and the mechanisms that may lead to them are less well understood.

PM is thought to contribute to cardiovascular and cerebrovascular disease by the mechanisms of systemic inflammation, direct and indirect coagulation activation, and direct translocation into systemic circulation.[18] O'Donnell et al[26] theorized that the health effects of PM and the onset of ischemic stroke likely differ depending on stroke cause and that risk may be greater for noncardioembolic than for cardioembolic strokes. It is possible that the physiological mechanisms that define

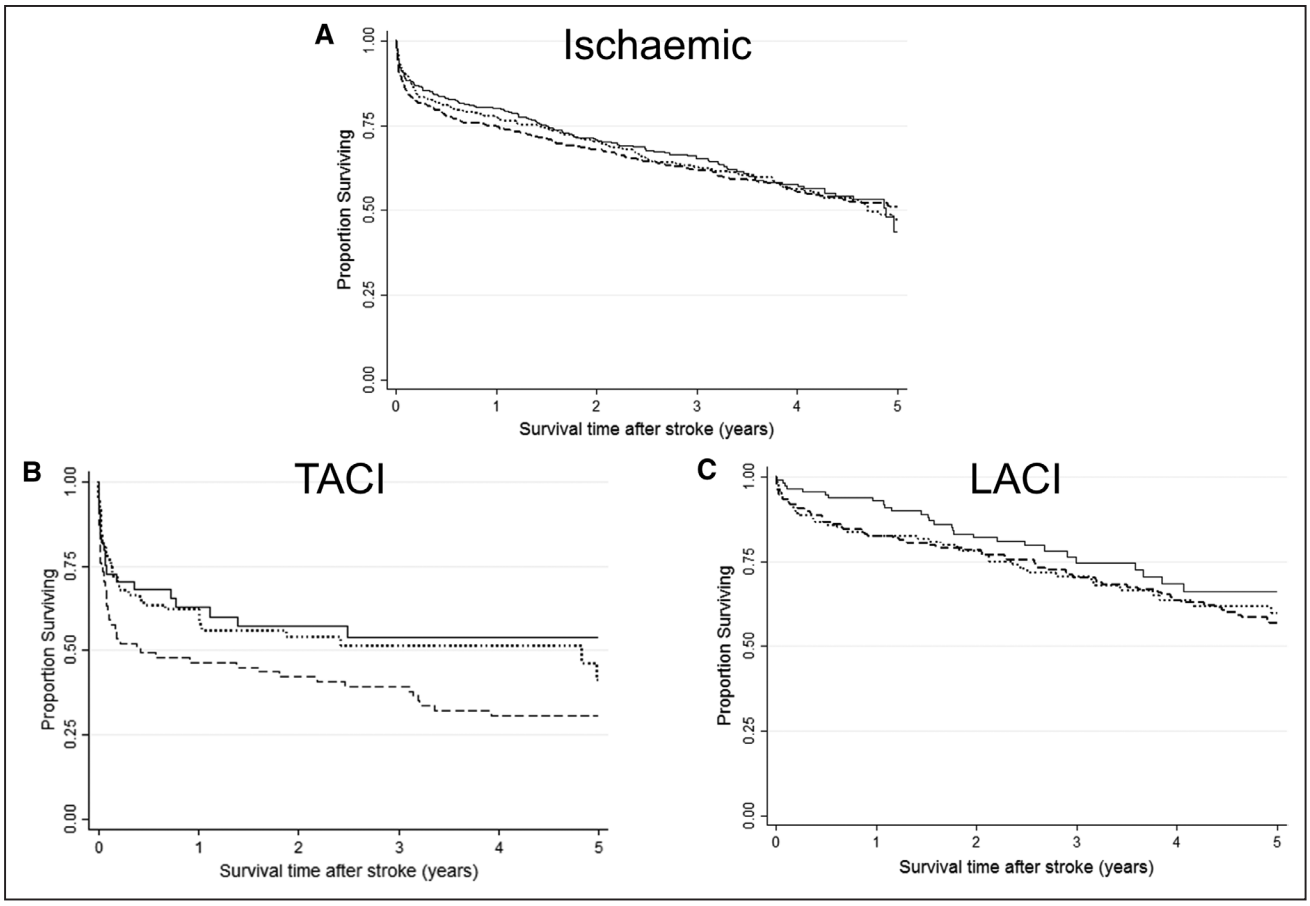

Figure. Kaplan–Meier curves of survival rates for ischemic, total anterior circulation infarct (TACI), and lacunar infarct (LACI), strokes by particulate matter <2.5-µm diameter ($PM_{2.5}$) exposure levels. Proportion of survival >5 y for ischemic strokes (**A**), and 2 ischemic subtypes, TACI (**B**), and LACI (**C**). $PM_{2.5}$ exposure levels adjusted by interquartile range were divided into thirds (——— low, ····· middle, – – – – high) for the Kaplan–Meier curve.

stroke cause onset may also play a role in the mechanisms that influence the risk of death in a poststroke population to the long-term exposure of PM.

Strengths and Limitations

This is the first study that has measured long-term annual pollution exposure and its association with survival rates in a poststroke population with the following factors: (1) examining overall, exhaust, and nonexhaust source contributions for $PM_{2.5}$ and PM_{10} and (2) breaking down incident stroke into specific causal subtypes. One of the positives of our study was that it was carefully controlled and attempted to reduce the influence of factors associated with stroke deaths such as previous transient ischemic attacks, stroke severity, age, sex, stroke ethnicity, and deprivation status.

One limitation of our study is that we did not quantify individual pollution exposure but used pollution levels at residential postcode addresses as a proxy for individual exposure to pollutants. Modeled pollution exposure estimates were assigned to the geographical centers of postcodes and then averaged across the years of the study. Information on how long the participant stayed in their residence, how far away their residence was located from the postcode centroid, and what the day-to-day activities of the participants were as they relate to pollutant exposure levels was not available.

Another potential point of criticism is that we only measured associations between long-term annual pollution exposure and mortality, and therefore it is hard to make a definitive statement of whether reducing air pollution would reduce mortality in a poststroke population. Previous studies, although, have found that air pollution reduction reduces the risk of death in the general population. Clancy et al[6] examined the health effects 6 years before and after a ban on coal sales in 1990 in Dublin, Ireland. The associated drop of deaths after the ban was stark; 116 fewer respiratory deaths and 243 fewer cardiovascular deaths occurred in Dublin after the coal ban. This indicates that air pollution reduction has the ability to reduce deaths. By identifying the groups that are particularly vulnerable to air pollution–associated mortality (eg, survivors of ischemic stroke and, in particular, TACI and LACI stroke), our study may have implications for wider health policies.

Sources of Funding

The research was funded/supported by the National Institute for Health Research (NIHR) Biomedical Research Centre based at Guy's and St Thomas' National Health Service (NHS) Foundation Trust and

Table 4. Associations Between Pollutants and HR Up To 5-Y Survival After Stroke, Broken Down by Ischemic Causal Subtype

	TACI (n=189)		PACI (n=532)		POCI (n=196)		LACI (n=417)	
	HR (95% CI)	*P* Value	HR (95% CI)	*P* Value	HR (95% CI)	*P* Value	HR (95% CI)	*P* Value
NO	0.86 (0.63–1.18)	0.360	0.96 (0.77–1.19)	0.696	0.90 (0.62–1.29)	0.554	1.19 (0.93–1.53)	0.172
NO_2	0.88 (0.66–1.18)	0.397	0.98 (0.79–1.21)	0.840	0.90 (0.64–1.27)	0.561	1.13 (0.90–1.43)	0.289
NO_x	0.87 (0.64–1.18)	0.373	0.96 (0.78–1.20)	0.748	0.90 (0.63–1.29)	0.555	1.17 (0.92–1.49)	0.211
O_3	1.15 (0.66–2.01)	0.622	1.16 (0.77–1.74)	0.475	1.20 (0.61–2.35)	0.600	0.70 (0.43–1.13)	0.149
Ox	0.85 (0.64–1.14)	0.279	1.02 (0.84–1.24)	0.817	0.91 (0.65–1.26)	0.551	1.08 (0.87–1.33)	0.482
PM_{10}	1.33 (0.89–1.99)	0.168	1.01 (0.80–1.28)	0.927	1.00 (0.61–1.64)	0.991	1.45 (1.06–2.00)*	0.022*
PM_{10} exhaust	0.92 (0.61–1.37)	0.676	1.02 (0.78–1.32)	0.907	0.85 (0.50–1.44)	0.545	1.28 (0.91–1.80)	0.151
PM_{10} nonexhaust	0.89 (0.69–1.15)	0.380	0.96 (0.80–1.14)	0.632	0.80 (0.57–1.12)	0.187	1.11 (0.91–1.36)	0.302
$PM_{2.5}$	2.01 (1.17–3.48)*	0.012*	0.95 (0.71–1.28)	0.751	1.40 (0.76–2.59)	0.286	1.78 (1.18–2.66)*	0.006*
$PM_{2.5}$ exhaust	0.92 (0.62–1.37)	0.683	1.01 (0.78–1.32)	0.916	0.85 (0.50–1.44)	0.535	1.28 (0.91–1.80)	0.150
$PM_{2.5}$ nonexhaust	0.88 (0.68–1.14)	0.321	0.95 (0.80–1.14)	0.608	0.77 (0.54–1.09)	0.137	1.11 (0.90–1.36)	0.333
PM coarse	0.93 (0.67–1.28)	0.635	1.06 (0.87–1.30)	0.562	0.79 (0.54–1.16)	0.225	1.11 (0.83–1.46)	0.485

Confounders: age, sex, ethnicity (black, white, and other), National Institutes of Health Stroke Scale, and year of stroke. CI indicates confidence interval; HR, hazard ratio; NO, nitric oxide; NO_2, nitrogen dioxide; NO_x, nitrogen oxides; O_3, ozone; O_x, oxidant; PM_{10}, particulate matter <10 μm; and $PM_{2.5}$, particulate matter below 2.5 μm.
*$P<0.05$.

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Disclosures

None.

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