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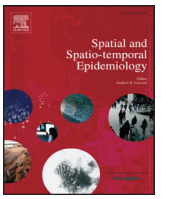

Air pollution and stroke – an overview of the evidence base

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ABSTRACT

Air pollution is being increasingly recognized as a significant risk factor for stroke. There are numerous sources of air pollution including industry, road transport and domestic use of biomass and solid fuels. Early reports of the association between air pollution and stroke come from studies investigating health effects of severe pollution episodes. Several daily time series and case-crossover studies have reported associations with stroke. There is also evidence linking chronic air pollution exposure with stroke and with reduced survival after stroke. A conceptual framework linking air pollution exposure and stroke is proposed. It links acute and chronic exposure to air pollution with pathways to acute and chronic effects on stroke risk. Current evidence regarding potential mechanisms mainly relate to particulate air pollution. Whilst further evidence would be useful, there is already sufficient evidence to support consideration of reduction in air pollution as a preventative measure to reduce the stroke burden globally.

1. Introduction

There is increasing interest in the link between air pollution and stroke and an increasing number of studies have been published on this subject. Both air pollution and stroke are common, making the link between these two topics of major public health importance and relevance worldwide. In estimates released in 2014, the World Health Organization (WHO) estimated that seven million deaths annually worldwide were attributable to the combined effects of outdoor and indoor air pollution (WHO, 2014a). Of particular note is the breakdown of deaths attributed to specific diseases. The WHO estimated that stroke accounted for 40% of all deaths attributable to outdoor air pollution, making stroke the joint leading cause of death attributable to this exposure, along with ischemic heart disease, which was also estimated to account for 40% of all outdoor air pollution related deaths. With regard to deaths attributable to indoor air pollution, stroke was the leading cause of death, accounting for 34%, followed by ischemic heart disease at 26% and chronic obstructive pulmonary disease at 22%.

In this article, a brief overview of air pollution sources and trends in pollution levels is described followed by an outline of the classification and subtypes of stroke. A conceptual model linking air pollution and stroke is presented followed by an outline of epidemiological study designs that may be used to investigate the association between air pollution and stroke. The article then examines the link between air pollution and stroke, focusing on pollution episodes, studies examining daily time series data, studies examining chronic exposure and also the effects of outdoor air pollution on survival following stroke. Potential mechanisms underlying the link between air pollution and stroke are then considered. The article ends with a consideration of the implications for further research and policy.

2. Air pollution – sources and trends

Air pollution has been defined as any undesirable modification of air by substances that are toxic or may have

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adverse effects on health or that are offensive though not necessarily harmful to health (Last, 1995). These substances may be solids, liquids or gases and not infrequently are a mix of these components. Air pollutants include a wide range of substances including particulate matter, nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), volatile organic compounds and several other pollutants. The main air pollutants that have been investigated in relation to stroke are particulate matter, NO_2, SO_2, CO and O_3.

Particulate matter is a heterogeneous mix of substances, both in terms of size and shape and in terms of chemical composition. Particulate matter less than 10 μm in diameter (PM_{10}) comprises respirable particles because these particles can reach the alveoli when inhaled. Within this category, particles are further sub-classified into coarse particles which range from 2.5 to 10 μm in diameter, and fine particles which are less than 2.5 μm in diameter ($PM_{2.5}$). A subcategory of the latter is ultrafine particles which are less than 0.1 μm in diameter. In terms of mass, $PM_{2.5}$ generally accounts for approximately 50–70% of PM_{10}. Combustion of fossil fuels is one of the major sources of particulate air pollution. Other sources include dust storms, resuspension of road dust by moving vehicles, sea salt and volcanic eruptions.

Oxides of nitrogen, including NO_2, are principally formed when fuel is burned at high temperatures. Combustion of carbon fuels, particularly in conditions with a limited oxygen supply or at high temperatures, is a major source of CO. Motor vehicles are the major contributor to outdoor CO concentrations. SO_2 is principally formed by combustion of fossil fuel, with power stations being the major source of outdoor SO_2. Ground level O_3 is classified as a secondary pollutant and is formed by a photochemical reaction involving NO_2 and volatile organic compounds.

In high income countries, road transport and industry are the main sources of outdoor air pollution, although domestic combustion and agriculture also make significant contributions. In the UK, for example, the government estimated that industry accounted for 46% of NO_2 and 36% of PM_{10} emissions, while road transport accounted for 30% of NO_2 and 18% of PM_{10} emissions (House of Commons Environmental Audit Committee, 2010). In low and middle income countries, burning of biomass and solid fuels indoors is a significant source of exposure to air pollution and in poorly ventilated areas, very high levels of exposure may be encountered. Industry and road transport are also major contributors to air pollution in an increasing number of low and middle income countries. Other sources include clearance of forests using forest fires which can result in large areas being affected by the pollution haze produced.

With regard to trends in pollution levels, there has been a striking decline in outdoor pollution levels over the last four decades in several high income countries. Fig. 1, for example, illustrates the fall in black smoke levels between the 1960s and the 1980s in London, UK using data from a central monitoring station. The decline in outdoor pollution levels have, however, plateaued off in recent years in the UK, which is struggling to meet some European Union air quality standards, especially in London (King's College London, 2015). In the USA, there have been similar decreases in air pollution concentrations over recent decades (United States Environmental Protection Agency, 2015).

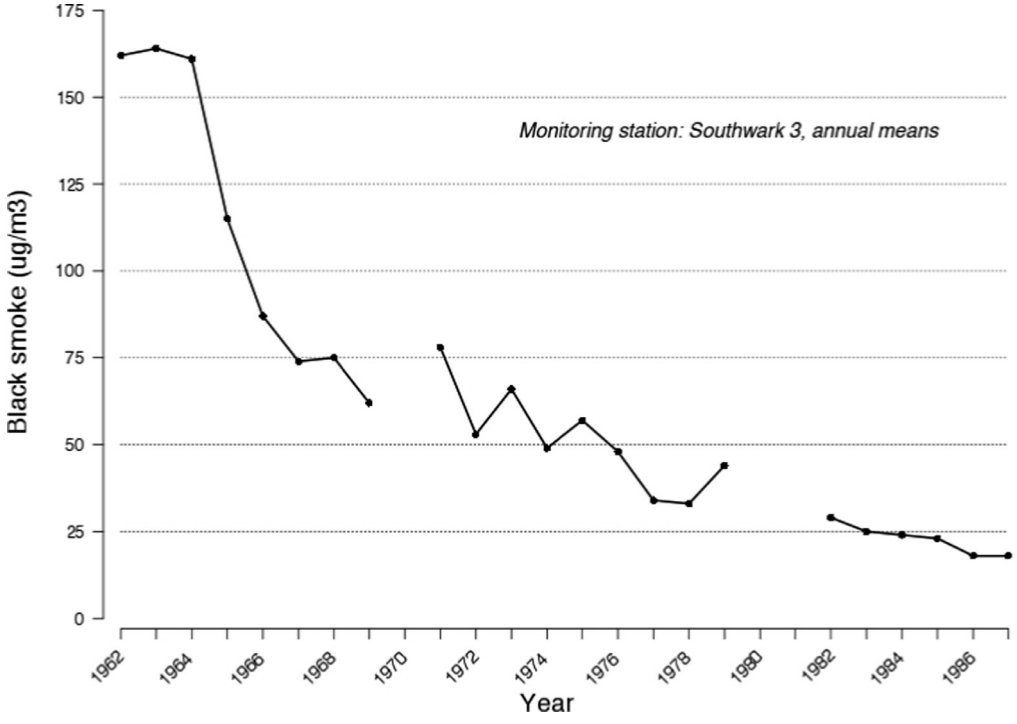

Fig. 1. Black smoke concentrations (annual means, in ug/m^3) from a background monitoring station in London, UK. 1962–1987.