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The association between lung cancer incidence and ambient air pollution in China: A spatiotemporal analysis

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ABSTRACT

Background: China is experiencing more and more days of serious air pollution recently, and has the highest lung cancer burden in the world.
Objectives: To examine the associations between lung cancer incidence and fine particles ($PM_{2.5}$) and ozone in China.
Methods: We used 75 communities' data of lung cancer incidence from the National Cancer Registration of China from 1990 to 2009. The annual concentrations of fine particles ($PM_{2.5}$) and ozone at $0.1° \times 0.1°$ spatial resolution were generated by combing remote sensing, global chemical transport models, and improvements in coverage of surface measurements. A spatial age-period-cohort model was used to examine the relative risks of lung cancer incidence associated with the air pollutants, after adjusting for impacts of age, period, and birth cohort, sex, and community type (rural and urban) as well as the spatial variation on lung cancer incidence.
Results: The relative risks of lung cancer incidence related to a 10 $\mu g/m^3$ increase in 2-year average $PM_{2.5}$ were 1.055 (95% confidence interval (CI): 1.038, 1.072) for men, 1.149 (1.120, 1.178) for women, 1.060 (1.044, 1.075) for an urban communities, 1.037 (0.998, 1.078) for a rural population, 1.074 (1.052, 1.096) for people aged 30–65 years, and 1.111 (1.077, 1.146) for those aged over 75 years. Ozone also had a significant association with lung cancer incidence.
Conclusions: The increased risks of lung cancer incidence were associated with $PM_{2.5}$ and ozone air pollution. Control measures to reduce air pollution would likely lower the future incidence of lung cancer.

1. Introduction

Lung cancer is now the most common cancer in the world, with the majority of the cases in developing countries (Ferlay et al., 2010; Jemal et al., 2011). China has the highest lung cancer burden in the world (Zhao et al., 2010). According to the latest Chinese cancer registration annual report, the world age-standardized incidence rate of lung cancer was 47.5 per 100,000 for men and 22.2 per 100,000 for women in 2009 (Chen et al., 2013), and these incidences are expected to rise (Chen et al., 2011).

Determining the risk factors associated with this high burden is crucial for cancer prevention and control. The established risk factors for lung cancer include smoking (Correa et al., 1983; Hackshaw et al., 1997; Hecht, 2002; Janerich et al., 1990) and air pollution (Cohen, 2000; Mumford et al., 1987; Pope et al., 2002; Vineis et al., 2004). In particular, ambient air pollution is the most widespread environmental carcinogen (Cohen, 2000; Vineis et al., 2004). Globally, it is estimated that 12.8% of lung cancer death can be attributed to exposure of the fine particulate matter air pollution alone (Evans et al., 2013; Fajersztajn et al., 2013). In 2010, an estimated 223,000 deaths from lung cancer worldwide were attributed to air pollution (Straif et al., 2013).

With the rapid economic growth and increased urbanization of rural areas, China is experiencing very high concentrations of air pollutants (Brauer et al., 2012). The average concentration of fine particulate matter in densely populated regions of China can exceed 100 $\mu g/m^3$ (Guo et al., 2013). However, studies on ambient air pollution and lung cancer have never been performed at the national level. In the present study, we investigated lung cancer

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incidence in relation to long-term exposure to two ambient air pollutants, fine particulate matter ($PM_{2.5}$) and ozone (O_3), using population-based national cancer registration data of China.

2. Methods

2.1. Study design and participants

The National Cancer Registration Center of China is responsible for the collection, evaluation and publication of cancer statistics from population-based cancer registries in China each year since 1970s. All data on cancer incidence are reported to population-based cancer registries from hospitals, community health centers or other departments, including centers of township medical insurance and the New-type Rural Cooperative Medical System. Based on the integrity and quality of lung cancer data, a total of 75 cancer registries out of 104 (72%) from the national cancer database were selected from 1990 to 2009 in this study (Fig. 1). ICD10 (International Classification of Disease for Oncology, version 10) was used to classify lung cancer cases. The detailed information on each case including year and age at diagnosis, gender and community type (rural or urban area) was used. Population data was collected for each community and year from local statistics bureaus. We limited analyses to persons at least 30 years old, because few cases occurred below this age. We stratified the lung cancer incidence into 12 age groups (30–34 years, 35–39 years, 40–44 years, 80–84 years, and 85+ years) for each community.

2.2. Exposure assessment

We used data on annual mean $PM_{2.5}$ and O_3 for the years 1990 and 2005 from a previous study (Brauer et al., 2012), which estimated the concentration of global air pollution to assess the global burden of disease attributable to outdoor air pollution. In brief, Ambient $PM_{2.5}$ and O_3 exposures for the Earth's entire human population were estimated, which allowed the inclusion of populations in smaller cities and rural areas to examine the disease burden related to air pollution. Remote sensing, global chemical-transport models, and improvements in coverage of surface measurements were combined to estimate the global estimates of annual average ambient concentrations of $PM_{2.5}$ and O_3 at $0.1° \times 0.1°$ spatial resolution for the years 1990 and 2005.

We spatially matched our study communities with the global air pollution data using latitude and longitude for the years 1990 and 2005. We then predicted the annual concentrations of $PM_{2.5}$ and O_3 during the years 1990–2009 for each community using a linear regression model, because the data for air pollution is only available for the years 1990 and 2005.

Lastly we linked the lung cancer incidence data and predicted annual concentrations of $PM_{2.5}$ and O_3 during the years 1990–2009 for each of the 75 communities.

2.3. Statistical analysis

Age-period-cohort models can separate the effects of age from the effects of risk factors in relation to calendar time and birth cohort effects (Robertson and Boyle, 1998). The incidence of lung cancer increases with age, and there were substantial birth cohort effect and period effect (Eilstein et al., 2008; Mdzinarishvili et al., 2009). In this study, we therefore included separate variables for age, period, and cohort effects, and gradually extended the model to include information on air pollution. Thus we examined the association between air pollution and lung cancer incidence after controlling for the effects of age, period, and birth cohort. As there might be spatial cluster in lung cancer incidence, we also included a spatial term in the analyses to control for the spatial distribution of lung cancer incidence (Mdzinarishvili et al., 2010).

We used an over-dispersed Poisson regression model to fit the spatial age-period-cohort model:

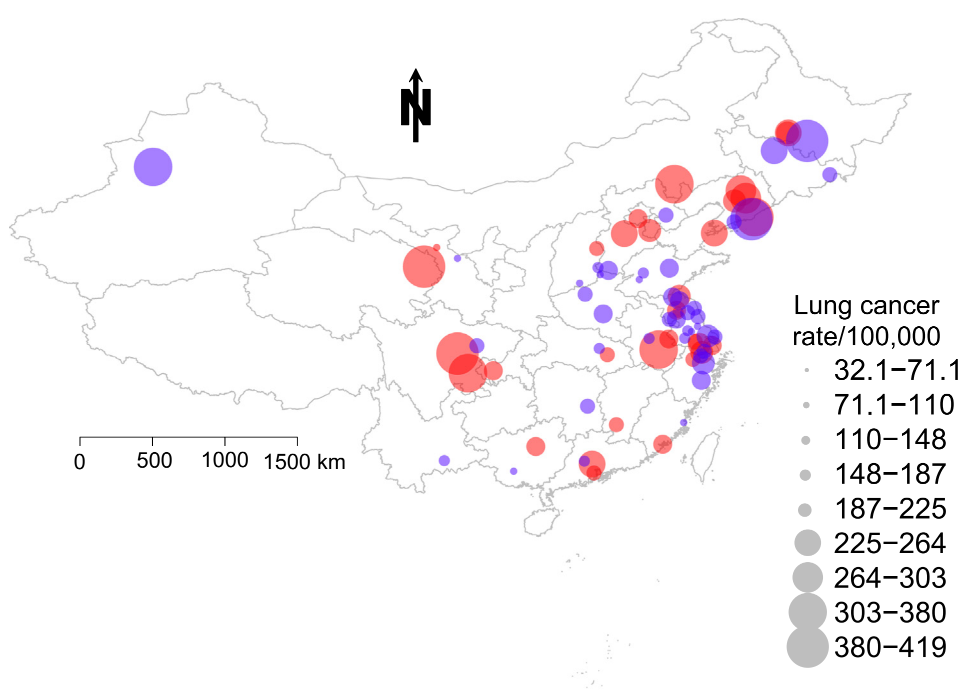

Fig. 1. The location of the 75 study communities and standardized lung cancer incidence rate for people aged >30 years in urban (red colour) and rural (purple colour) China, during 1990–2009. The rate was standardized by world Segi's population 1985. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)