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Review article

Lung cancer and particulate pollution: A critical review of spatial and temporal analysis evidence

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ABSTRACT

Background: Particulate matter (PM) has been recognized as one of the key risk factors of lung cancer. However, spatial and temporal patterns of this association remain unclear. Spatiotemporal analyses incorporate the spatial and temporal structure of the data within random effects models, generating more accurate evaluations of PM-lung cancer associations at a scale that can better inform lung cancer prevention programs.

Methods: We conducted a critical review of spatial and temporal analyses of PM and lung cancer. The databases of PubMed, Web of Science and Scopus were searched for potential articles published until September 30, 2017. We included studies that applied spatial and temporal analyses to evaluate the associations of $PM_{2.5}$ (inhalable particles with diameters that are 2.5 μm and smaller) and PM_{10} (inhalable particles with diameters that are 10 μm and smaller) with lung cancer.

Results: We identified 17 articles eligible for the review. Of these, 11 focused on $PM_{2.5}$, five on PM_{10}, and one on both. These studies suggested a significant positive association between $PM_{2.5}$ exposure and the risk of lung cancer. Relative risks of lung cancer mortality ranged from 1.08 (95% confidence interval (CI): 1.07–1.09) to 1.60 (95%CI: 1.09–2.33) for 10 μg/m^3 increase in $PM_{2.5}$ exposure. The association between PM_{10} and lung cancer had been less well researched and the results were not consistent. In terms of the analysis methods, 16 papers undertook spatial analysis and one paper employed temporal analysis. No paper included spatial and temporal analyses simultaneously and considered spatiotemporal uncertainty into model predictions. Among the 16 papers with spatial analyses, thirteen studies presented maps, while only five and 11 studies utilized spatial exploration and modeling methods, respectively.

Conclusions: Advanced spatial and temporal epidemiological methods were seldom applied to PM-lung cancer associations. Further research is urgently needed to develop and employ robust and comprehensive spatio-temporal analysis methods for the evaluation of PM-lung cancer associations and the support of lung cancer prevention strategies.

1. Introduction

Lung cancer is one of the most common causes of cancer morbidity and mortality worldwide. The Global Burden of Disease Study (GBD), the most current appraisal of the distribution of world cancer, reported 2.02 million new cases of lung cancer and 1.72 million lung cancer-related deaths in 2015 (Global Burden of Disease Cancer et al., 2017). Geographic and temporal differences in lung cancer incidence and mortality have been reported at global, regional and country levels (Chen et al., 2016; Ferlay et al., 2015; Y. Liu et al., 2016; Mokdad et al., 2017). Cigarette smoking, which is the most predominant risk factor for lung cancer, has been deemed as a major contributor to these spatial variations and time trends (Chen et al., 2016; Mokdad et al., 2017). However, other environmental factors are also important (Ferlay et al., 2015).

Particulate matter (PM) has been implicated as one of the causes of

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lung cancer by International Agency for Research of Cancer (IARC), based on a considerable body of research evidence (Loomis et al., 2013). Large geographic variations in $PM_{2.5}$ (inhalable particles with diameters that are 2.5 µm and smaller) and PM_{10} (inhalable particles with diameters that are 10 µm and smaller) concentrations have been reported, with Asian region having the highest level globally (Supplemental material, Fig. S1) (van Donkelaar et al., 2016). There is also substantial variation at regional and local scales and over time (Xu et al., 2017; Eeftens et al., 2012; Shi et al., 2017).

Spatial and temporal epidemiology is an emerging research method that has been widely used in the study of spatial and temporal patterns of cancer (Lewis et al., 2014; Pickle et al., 2007; Zurriaga et al., 2008). Spatial epidemiology commonly involves three general types of approaches, namely visualization, exploration and modeling, taking into account spatial and/or temporal autocorrelation. For example, Bayesian spatiotemporal conditional autoregressive (CAR) models using Markov Chain Monte Carlo (MCMC) methods have been developed to estimate spatial variation between spatially aggregated units, and associated uncertainty (Hu et al., 2010). A major advantage of this approach is that it compensates for residual variability resulting from spatial variation in parameters that were not included in models. Traditional analysis methods which ignore these autocorrelations can lead to less accurate results (Jiang et al., 2011). Despite the obvious appeal and applicability of these methods for evaluating PM-lung cancer associations at more detailed scales, few studies have done this and to date, PM-lung cancer associations computed from spatial and temporal epidemiological analyses have not been reviewed.

In this article, we aimed to systematically review published studies which have applied spatial and temporal epidemiology to evaluate the associations between PM exposures and lung cancer risk, critically appraise the utilization of the spatial and temporal epidemiological analyses and make recommendations for future studies.

2. Material and methods

2.1. Search strategy

This review (PROSPERO registration number: CRD42017082234) was conducted according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Supplemental material, Table S1). We identified potentially relevant studies published up to September 30, 2017 by searching PubMed, Web of Science and Scopus databases. The search terms were (lung cancer) AND ($PM_{2.5}$ OR PM_{10} OR particulate air OR particulate matter OR air pollution) AND (spatial OR space OR spatio* OR time series OR temporal) and the results were restricted to journal articles on human studies published in English. Titles and abstracts of articles obtained by electronic search were inspected by two reviewers independently (NW and WH). The references of identified original papers and review articles were scanned manually to try to include more appropriate studies.

2.2. Inclusion and exclusion criteria

Eligible articles included epidemiological studies which applied spatial and temporal analyses (i.e. spatial, time series or spatiotemporal analyses) to evaluate the associations between $PM_{2.5}$ or PM_{10} and lung cancer incidence, mortality or other disease burden measurements (e.g. disability-adjusted life years (DALYs)). Articles which calculated the odds ratio (OR), relative risk (RR), hazard ratio (HR) or attributable fraction (AF), or analyzed the spatial and temporal correlations between lung cancer and PM were considered for inclusion. Experimental studies, reviews and duplicated publications were excluded from the potential articles.

2.3. Quality assessment and data analysis

The modified criteria recommended by BioMed Central for study assessment (Supplemental material, Table S2) (Phung et al., 2016) was employed to undertake the quality assessment for the eligible studies. These criteria rank the quality of individual studies based on several domains, including exposure definition, control of confounding factors and so on. The maximum score was 23 and we classified the eligible studies as low, moderate and high quality based on the tertile of the scores. Two reviewers (NW and WH) conducted the quality assessment independently. Any inconsistencies between the two reviewers were discussed for agreement on final report.

All eligible articles were involved in the review to minimize bias. The following information was abstracted from eligible articles: First author, journal, site, study period, health outcomes (e.g. incidence, mortality or AF), estimation of PM exposure, study design, spatial approach, spatiotemporal methods, confounders, time lag between exposure and disease, and main findings. Due to different study designs and statistical methods across these studies, we were unable to perform meta-analysis over these papers. Instead, we conducted a narrative synthesis and critical review on the eligible studies.

3. Results

3.1. Literature search

Initially 626 articles were identified from PubMed (110), Web of Science (483) and Scopus (33) by key words (restricted to human studies and English language). In total, 510 papers remained after the removal of duplicate papers. After screening on titles and abstracts, 65 relevant papers underwent full text inspection. Seventeen papers which fulfilled the inclusion criteria were identified (Fig. 1). All the seventeen eligible articles met the high and moderate criteria of quality assessment with the score ranging from 12 to 22 (Supplemental material, Table S3). All studies reported the long-term effect of PM on lung cancer. Among them, 11 (65%, n = 11/17) and 5 (29%, n = 5/17) studies employing spatial analysis assessed the effect of $PM_{2.5}$ and PM_{10}, respectively. One study conducted time series analysis and included $PM_{2.5}$ and PM_{10} simultaneously.

3.2. Study characteristics

All of the 17 selected studies were published after 2005 (Fig. 2) and nine (53%, n = 9/17) papers were published in 2016 and 2017 (Cohen et al., 2017; Guo et al., 2016, 2017; Han et al., 2017; J. Liu et al., 2016; Liu et al., 2017; Pun et al., 2017; Song et al., 2017; Yoon et al., 2016). Six (67%, n = 6/9) of these studies were from China (Guo et al., 2016, 2017; Han et al., 2017; J. Liu et al., 2016; Liu et al., 2017; Song et al., 2017), all providing the influence of $PM_{2.5}$ exposure (Fig. 3). Without exception, these six papers analyzed the association at the scale of the whole country.

In addition to China, there were five studies (29%, n = 5/17) from the United States (Chalbot et al., 2014; Jerrett et al., 2005; Pun et al., 2017; Sloan et al., 2012; Yoon et al., 2016), one (6%, n = 1/17) from Canada (Hystad et al., 2013), two (n = 12%, 2/17) from Italy (Biggeri et al., 2005; Parodi et al., 2005), one (6%, n = 1/17) from Spain (Barcelo et al., 2009), one (6%, n = 1/17) from Israel (Eitan et al., 2010), and one (6%, n = 1/17) international contribution from the GBD study which explored the burden of disease attributed to $PM_{2.5}$ at global, regional and country levels (Cohen et al., 2017) (Fig. 3). In comparison to the Chinese studies, most of studies from other countries only concentrated on a certain location such as one or two states (Chalbot et al., 2014; Sloan et al., 2012), one region (Biggeri et al., 2005), one city (Jerrett et al., 2005; Barcelo et al., 2009; Eitan et al., 2010) or the area around an industry (Parodi et al., 2005) (Table 1).