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Costs of coronary heart disease and mortality associated with near-roadway air pollution

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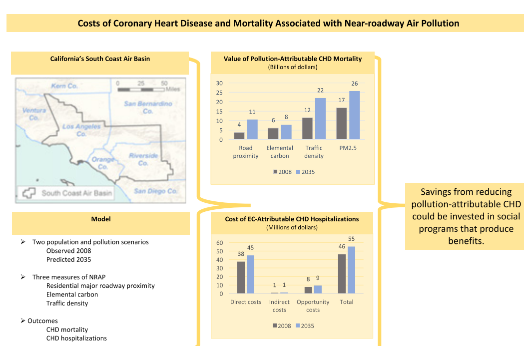
HIGHLIGHTS

- In Southern California in 2008, coronary heart disease mortality due to near-roadway airpollution cost \$4 - \$12 billion.
- Near-roadway-attributable hospitalization for heart disease cost \$48.6 million in 2008.
- The cost of NRAP-attributable heart disease is projected to increase markedly by 2035, duelargely to an aging population.

GRAPHICAL ABSTRACT



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ABSTRACT

Background: Emerging evidence indicates that the near-roadway air pollution (NRAP) mixture contributes to CHD, yet few studies have evaluated the associated costs.
Objective: We integrated an assessment of NRAP-attributable CHD in Southern California with new methods to value the associated mortality and hospitalizations.
Methods: Based on population-weighted residential exposure to NRAP (traffic density, proximity to a major roadway and elemental carbon), we estimated the inflation-adjusted value of NRAP-attributable mortality and costs of hospitalizations that occurred in 2008. We also estimated anticipated costs in 2035 based on projected changes in population and in NRAP exposure associated with California's plans to reduce greenhouse gas emissions. For comparison, we estimated the value of CHD mortality attributable to PM less than 2.5 μm in diameter ($PM_{2.5}$) in both 2008 and 2035.
Results: The value of CHD mortality attributable to NRAP in 2008 was between \$3.8 and \$11.5 billion, 23% (major roadway proximity) to 68% (traffic density) of the \$16.8 billion attributable to regulated regional $PM_{2.5}$. NRAP-attributable costs were projected to increase to \$10.6 to \$22 billion in 2035, depending on the NRAP metric. Cost of NRAP-attributable hospitalizations for CHD in 2008 was \$48.6 million and was projected to increase to \$51.4 million in 2035.

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Conclusions: We developed an economic framework that can be used to estimate the benefits of regulations to improve air quality. CHD attributable to NRAP has a large economic impact that is expected to increase by 2035, largely due to an aging population. $PM_{2.5}$-attributable costs may underestimate total value of air pollution-attributable CHD.

1. Introduction

Coronary heart disease (CHD) caused around one in six deaths in the United States in 2010 (Go et al., 2014). In the same year direct medical costs of CHD were $35.7 billion and are projected to almost triple, to $106.4 billion by 2030 (Heidenreich et al., 2011). Thus, policies that reduce the burden of CHD have potentially large economic benefits.

Globally, ambient particulate matter less than 2.5 μm in aerodynamic diameter ($PM_{2.5}$) is the second leading environmental contribution to the global burden of disease, accounting for 3.1 million deaths in 2010 (Lim, 2012). In 2012 there were an estimated 1.2 million deaths from coronary heart disease attributable to $PM_{2.5}$ (World Health Organization, n.d.). Emerging evidence indicates that the mixture of near roadway air pollution (NRAP) also causes CHD (Brook et al., 2010; Gan et al., 2011; Gan et al., 2010; Kan et al., 2008). However, there have been few studies examining the population burden and cost of NRAP.

We recently estimated the number of cases of NRAP- and $PM_{2.5}$-attributable CHD mortality and NRAP-attributable hospitalizations in California's South Coast Air Basin for 2008 and the burden of CHD expected in 2035 in an aging population (Ghosh et al., 2015). The year 2035 was used to demonstrate the potential effects of the Southern California Regional Transportation Plan which is likely to increase the number of people living near busy roads. The transportation plan is in response to landmark Californian legislation (Senate Bill 375) to reduce greenhouse gas emissions in the state. Because a third of greenhouse gases are from cars and trucks, the plan aims to reduce vehicle miles traveled through compact urban development and high density housing along public transportation corridors (SCAG, 2012). These corridors often have heavy vehicular traffic (SCAG, 2012). We showed that the usual approach to estimating air pollution-attributable CHD burden of disease based on population exposure to $PM_{2.5}$, which ignores the contribution of NRAP, may substantially underestimate the total burden of pollution-attributable CHD. Knowing the total costs of pollution-attributable CHD is essential to evaluating alternative strategies to reduce greenhouse gases.

The U.S. Environmental Protection Agency (EPA) developed an approach to valuing cardiovascular costs of $PM_{2.5}$ in the U.S. (US EPA, 2011). Value of mortality was based on the value of a statistical life (VSL). The EPA used a cost-of-illness approach for a myocardial infarction. The EPA's COI includes direct costs, primarily the cost of hospitalization, plus indirect costs, measured as lost earnings over a five-year period subsequent to the acute illness.

We expanded on the EPA's approach by assigning costs to a more complete estimate of the CHD burden attributable to air pollution, one that includes the effects of both $PM_{2.5}$ and NRAP. We estimated this burden for California's South Coast Air Basin (SoCAB) in 2008 and 2035. We applied an improved framework for estimating the costs of hospitalization, which reflects recent advances in medical technology for non-fatal myocardial infarction that have increased the role of medical management and decreased use of expensive coronary artery bypass grafts. We defined the indirect cost to the individual as lost income above what is covered by short-term disability insurance. We accounted for recent reductions in the median duration of lost work after CHD hospitalization. Finally, we estimated opportunity costs associated with the value of time that could have been spent on activities if not for the CHD.

2. Methods

We used previous estimates of the number of CHD deaths and hospitalizations attributable to NRAP in the SoCAB (Ghosh et al., 2015), as described below and in the Online supplement. SoCAB includes the densely populated southern part of Los Angeles County, western urbanized portions of Riverside and San Bernardino counties and all of Orange County. This region has heavy vehicular traffic corridors and has among the highest concentrations of $PM_{2.5}$ in the U.S. We adjusted all cost estimates from primary and secondary sources to 2014 U.S. dollars using the consumer price index (United States department of Labor, 2015a).

2.1. Air pollution-attributable CHD burden

Detailed methods used to estimate the population-weighted exposure, the pollution-attributable fraction and number of CHD hospitalizations and deaths in 2008 have been described previously (Ghosh et al., 2015). Those estimates were projected for 2035 under a compact development scenario from the Southern California Regional Transportation Plan (Ghosh et al., 2015). In summary, mortality and hospitalizations attributable to NRAP in SoCAB were estimated for an at-risk population of 3.32 million individuals aged 45 years and older in 2008 (35% of the total population of 15.5 million in SoCAB in 2008), and for the projected 8.0 million individuals aged 45 and older (43% of the total population of 18.5 million) in 2035. In order to distinguish the effect of the aging population on the 2035 attributable estimate from the effect of air pollution, we also estimated the hypothetical attributable burden of CHD in a 2035 population with the same age structure as in 2008.

We chose concentration-response functions appropriate for the study population (Ghosh et al., 2015) (see Table S1 in Online supplement). We estimated mortality attributable to NRAP and $PM_{2.5}$ in each county in SoCAB and SoCAB overall in 2008 and 2035. We used three measures of NRAP: parcel proximity to a major roadway (a dichotomous indicator of whether the center of each residential plot is within 150 m of a freeway or expressway or within 50 m of a major arterial), elemental carbon (a continuous measure which is a marker in southern California for diesel exhaust particulate exposure) (Geller et al., 2005), and traffic density within 300 m of each SoCAB parcel (a continuous measure defined as the distance-decayed annual average daily volume of traffic surrounding each plot). NRAP-attributable hospitalization concentration-response functions for CHD were available for elemental carbon (EC) only.

We used the population-weighted prevalence of near-roadway proximity and mean traffic density, and the mean EC and $PM_{2.5}$ concentration exceeding background levels of 0.12 and 5.6 $\mu g/m^3$, respectively. We estimated NRAP-related elemental carbon (EC) using a line source dispersion model and assigned a regional component of EC in a 4×4 km grid. Traffic density was adjusted downward in 2035 for anticipated reductions in fleet-average $PM_{2.5}$ emissions. Annual average $PM_{2.5}$ mass concentrations in each 4×4 km grid were assigned to all parcels in the grid in 2008 and in projected plots in 2035, accounting for anticipated changes in fleet emissions and vehicular mix.

CHD-mortality was based on ICD-10 codes I20–I25 and CHD-related hospitalizations were based on ICD-9 codes 410–414 and 429.2. These codes correspond to the concentration-response functions used to estimate the burden of disease (Table S1 in Online supplement). The baseline hospital discharge rates were limited to non-fatal events. The CHD-