Perspective

Identifying exposure disparities in air pollution epidemiology specific to adverse birth outcomes

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Abstract
More than 147 million people in the US live in areas where pollutant levels are above regulatory limits and pose a risk to health. Most of the vast network of air pollutant monitors in the US are located in places with higher pollution levels and a higher density of pollutant sources (e.g., point sources from industrial pollution). Vulnerable populations are more likely to live closer to pollutant sources, and thus closer to pollutant monitors. These differential exposures have an impact on maternal and child health; maternal air pollutant exposures have been linked to adverse outcomes such as preterm birth and infant low birth weight. Several studies are highlighted that address methodological approaches in the study of air pollution and health disparities.

1. Exposure disparities

A large segment of the US population lives in the vicinity of significant air pollution sources. It has been hypothesized that air pollution exposure is differentially distributed to lower socioeconomic status (SES) populations, backed by evidence from several recent studies [1–5]. For example in a nationwide study by Clark et al (2014), low-income non-white children and elderly were disproportionately exposed to NO2 [4]. Vulnerable populations are more likely to reside near air pollutant sources, and thus near pollutant monitors placed in higher pollution level zones. Such differential exposures have an impact on health, specifically, on the maternal and reproductive health status of minorities who are already at risk for adverse birth outcomes such as preterm birth and low birth weight.

Women from lower SES groups may be more susceptible to the effects of air pollution during pregnancy. During pregnancy, women may have disproportionate burdens from air pollution caused by increased susceptibility to effects of pollutants due to psychosocial stressors [6], lower baseline health status, poor access to health and social resources during pregnancy, and behaviors that lead to increased susceptibility (e.g., increased use of drugs and alcohol, and inadequate weight gain during pregnancy) [7].

Evidence suggests that contextual, area-level factors contribute significantly to health burden [8]. Specific area-level or neighborhood-level factors that set up for disproportionate air pollution exposure to socioeconomically disadvantaged populations include proximity to traffic and roads, crowding, poor infrastructure, hindered access to transportation and services (e.g., supermarkets and health care), and aspects of the social environment such as neighborhood crime level and lack of social support [8]. Land use decisions can result in the placement of polluting facilities near lower SES neighborhoods, contributing further to exposure.
Morello-Frosch et al (2006) present a framework of the added burden of place-based psychosocial stressors that can compromise and even exacerbate the ability of host defense, enhancing susceptibility to added toxic insult above the stressors of everyday life [9]. This concept of ‘double jeopardy’, introduced by the Institute of Medicine in 1999, applies to the disproportionate burden of air pollution exposure that specifically impacts people of color and of low SES [10].

2. Issues and approaches in methodology

In large epidemiologic studies linking air pollution from stationary monitors with health outcomes, it is especially important to accurately classify maternal pollutant exposure status. If methods of estimation lump women from large geographic regions into a single exposure category, then the ability to detect associations with health outcomes is compromised by exposure misclassification, thus taking away the ability to identify true health disparities experienced by vulnerable populations.

The validity of an exposure estimate based on ambient air pollutant monitoring data depends on the characteristics of the pollutant and how it can best be measured. Exposure estimates from a pollutant monitor too far away from an individual’s residence will result in large error. For example, particulate matter (PM) is thought to be fairly spatially homogeneous, while NO₂ demonstrates greater spatial heterogeneity, and thus the latter has a greater dependency on distance to roadways and temporal changes in traffic density. Methods chosen to assess exposure will in this case affect study results [11].

In a recent approach to examining exposure inequities, Bell and Ebisu [3] assessed exposure to the air pollutant PM with aerodynamic diameter ≤ 2.5 μm (PM_{2.5}) and its chemical components, and found that non-Hispanic blacks had the highest pollutant exposures to 13 out of 14 PM_{2.5} components measured [3]. Some of these components of PM_{2.5} were more closely associated with lower birth weight [12]. These results demonstrate that certain populations may be at higher risk than others based on race/ethnicity. However, census tracts with monitors had more non-Hispanic blacks than census tracts without monitors [3]. Thus, there is the potential for measurement bias. These types of analyses must be repeated by region, as chemical components of pollution and other population characteristics may differ [12].

Recently, more sophisticated approaches to exposure measurement have been developed. Methods such as spatial autocorrelation have been used to detect spatial clusters of air pollution exposure inequities specific to benzene exposure. These methods employ logistic regression analyzes and spatial autocorrelation based cluster analysis to document patterns of disproportionate exposures based on race and SES [5].

Another measurement consideration is the distance of the individual study participant from pollutant monitors, encompassing the issue of selection of buffer size. Ebisu et al (2014) explored differences in effects estimates for adverse birth outcomes based on air pollutant estimates using differing buffer sizes [12]. Associations varied by buffer size, indicating that there is a tradeoff between smaller buffer zone yielding smaller sample size (that may be more representative of the higher exposed portion of the population) and lack of associations, versus larger buffer yielding significant results but possibly masking the association for specific vulnerable populations that experience adverse birth outcomes. For example, the percentage of the population in poverty, with low levels of education and unemployed were highest in the smallest buffer zone. For these types of studies relying on ambient air pollutant monitors, selection of exposure assessment method comes with tradeoffs in accurate exposure classification, sample size, and population characteristics, ultimately impacting the generalizability of the study.
results [12]. With acknowledgement and consideration of these issues in study design, researchers can move towards improving the ability to uncover true disparities in exposure and effect.

3. Implications and future directions

Improved methodological approaches, such as those described above, can help more specifically identify areas with disproportionately high exposure levels that lead to health inequities [4]. Once these differences in exposure are more accurately identified, strategies such as community awareness campaigns and targeted allocation of funds to improve air quality in air-pollution hotspots can be implemented to alleviate pollution-related health burdens [13].

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