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Impact of community disadvantage and air pollution burden on geographic disparities of ovarian cancer survival in California

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ABSTRACT

Ovarian cancer survival varies geographically throughout California. The objective of this study is to determine the impact of living in disadvantaged communities on spatial patterns of survival disparities. Including a bivariate spatial smooth of geographic location within the Cox proportional hazard models is an effective approach for spatial analyses of cancer survival. Women diagnosed with advanced Stage IIIC/IV epithelial ovarian cancer (1996–2006) were identified from the California Cancer Registry. The impact of living in disadvantaged communities, as measured by the California Office of Environmental Health Hazard Assessment cumulative CalEnviroScreen 2.0 score, on geographic disparities in survival was assessed while controlling for age, tumor characteristics, quality of care, and race. Community-level air quality indicators and socioeconomic status (SES) were also independently examined in secondary analyses. The Cox proportional hazard spatial methods are available in the MapGAM package implemented in R. An increase in the community disadvantage from the 5th (less disadvantage) to the 95th percentile (more disadvantage) was significantly associated with poorer ovarian cancer survival (hazard ratio [HR], 1.16; 95% confidence interval [CI], 1.07–1.26). Ozone levels and SES were the most influential indicators on geographic disparities that warrant further investigation. The use of a bivariate smoother of location within the survival model allows for more advanced spatial analyses for exploring potential air quality-related predictors of geographic disparities.

1. Introduction

Each year, an estimated 22,280 women in the United States are diagnosed with ovarian cancer (Siegel et al., 2016). Accounting for over 14,000 cancer-related deaths annually, ovarian cancer is the most fatal of the gynecological cancers (SEER Cancer Statistics Factsheets: Ovary Cancer, 2016; Moyer, 2012). Despite the high case fatality, survival rates among women in the general U.S. population have gradually increased throughout the years. As of 2011, 46% of American women diagnosed with this malignancy survive at least 5 years, a significant improvement from the 36% observed 40 years ago (SEER Cancer Statistics Factsheets: Ovary Cancer, 2016). However, improved survival is not equitable across all populations. Disparities in ovarian cancer outcomes have been linked to race (Zeng et al., 2015; Bristow et al., 2013, 2014; Jelovac and Armstrong, 2011; Terplan et al., 2012; Brewer et al., 2015), insurance (Harlan et al., 2003) and socioeconomic status (SES) (Bristow et al., 2013), access to quality ovarian cancer care (Bristow et al., 2013, 2014; Farley et al., 2009; Peterson et al., 2015), and characteristics of treatment center and physician (Bristow et al., 2009, 2010). Receiving appropriate disease-specific care that is adherent to the National Comprehensive Cancer Network (NCCN) treatment guidelines has prevailed as a significant prognostic factor of disease mortality (Bristow et al., 2013, 2014). However, many studies have reported that women of Black race, of lower SES and those living in disadvantaged communities are significantly less likely to receive standard cancer-specific care (Brewer et al., 2015; Peterson et al., 2015; Long et al., 2014; Bristow et al., 2015). Geographic location has been independently linked to disease-specific survival, and regional differences can only be partially explained by discrepancies in practice patterns and treatment paradigm (Bristow et al., 2014, 2015; Dehaeck et al., 2013; Fairfield et al., 2010; Lope et al., 2008).

Many factors can contribute to community disadvantage including environmental conditions. Limited research has explored the impact of pollution burden on ovarian cancer survival. In Spain, Lope et al.

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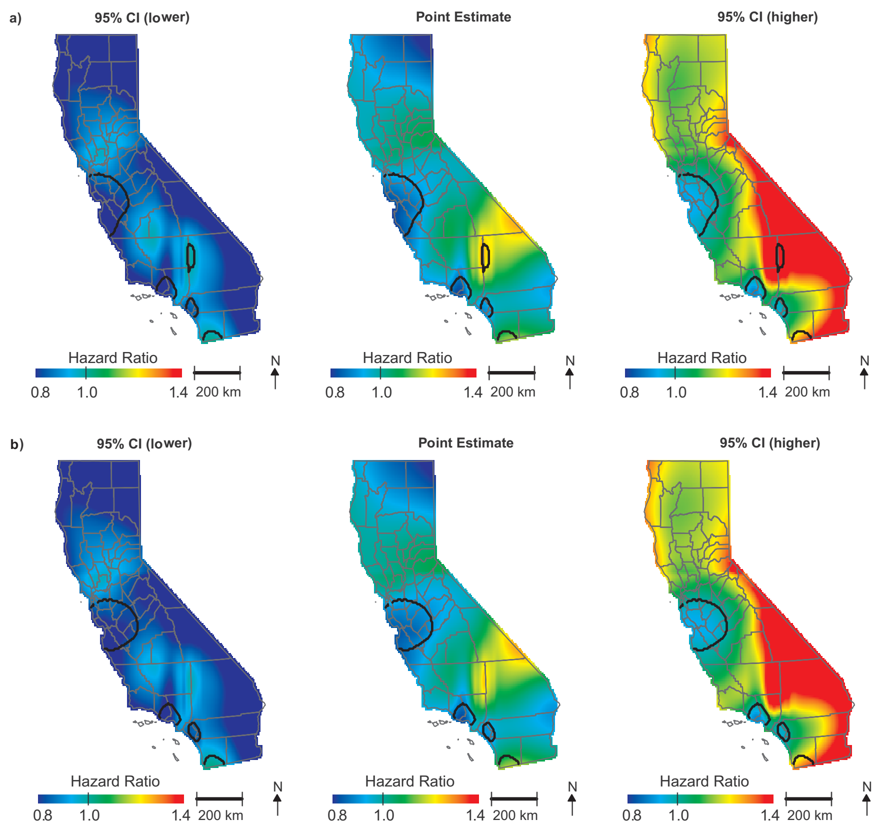

Fig. 1. Geographic patterns of ovarian cancer survival adjusted for patient, tumor, and treatment characteristics (a) and further adjusted for community disadvantage (b). Black lines indicate where hazard ratios exclude one.

identified significant disease-specific mortality differences by municipality, which remained independently predictive of survival even after controlling for demographic and treatment variables (Lope et al., 2008). The authors proposed occupational and environmental exposures as viable explanations of the disparity in mortality distribution observed. A Taiwanese ecological study examining whether an association existed between overall ambient air quality and ovarian cancer mortality revealed a significant relationship between exposure to particulate matter less than 2.5 µm ($PM_{2.5}$) and increased risk of death from ovarian cancer (Hung et al., 2012). Furthermore, the recent findings of significantly shortened lung cancer survival related to air pollutants exposure affirm the need for additional research examining air pollution burden as a possible determinant in ovarian cancer survival (Eckel et al., 2016).

Given that regional variations have previously been noted in California and survival disparities were not completely explained by individual-level multifactorial determinants (Bristow et al., 2015), studying the potential role of the community environment is a critical next step. The objective of the present study is to examine geographic disparities in ovarian cancer survival in California using a Cox proportional hazards additive models, which is an extension of the generalized additive model (GAM) that can systematically determine predictors of the spatial patterns. Our primary aim is to identify whether geographic disparities in survival are related to overall community disadvantage, as measured by the California Office of Environmental Health Hazard Assessment (OEHHA) cumulative CalEnviroScreen (CES) score.

The CES score is comprised of nineteen population and environmental indicators, including community-level air pollution indicators for ozone, $PM_{2.5}$, and diesel particulate matter. If results of our analyses suggest community disadvantage is associated with geographic survival disparities, secondary analyses will explore the contributions of these air pollution components to the overall impact of CES score. We selected ozone, $PM_{2.5}$, and diesel particulate matter for further investigation if warranted based on the existing literature that predominantly identifies air pollutants as potential risk factors for ovarian cancer survival which are known to affect communities disproportionately. These spatial analyses are a useful tool for exploring potential air quality-related predictors of geographic disparities and generating new hypotheses that would warrant future research in relation to cancer survival.

2. Materials and methods

2.1. Study population

We investigated the relationship between location at diagnosis, community disadvantage and air pollution burden, and survival among women diagnosed with International Federation of Gynecology and Obstetrics (FIGO) stage IIIC/IV ovarian cancer using data from the California Cancer Registry in a retrospective population-based spatial analysis. Registry case reporting throughout the state is nearly complete (99%) and over 95% of the cases are successfully followed (Bristow et al., 2014). Cases ≥18 years of age were ascertained from January 1996 through December 2006 for the entire state. At the time of diagnosis, the median age for the 11,765 study participants was 65.0 years and 7216 women (61.3%) had stage IIIC disease. Only 5342 women (45.4%) received care adherent to NCCN treatment guidelines. Study participants have been described in detail elsewhere (Bristow et al., 2014). The outcome of interest is ovarian cancer–specific survival, defined as the time between diagnosis and death from ovarian cancer or the date of last follow-up. Cases were followed through the end of 2007. The registry collects demographic and tumor characteristics including age at diagnosis, tumor characteristics, insurance type, race, SES, and the latitude and longitude of each subject's location, represented by the centroid of the address census block.

Community disadvantage and air pollution burden data were