Published in final edited form as:
Cancer Epidemiol Biomarkers Prev. 2017 April ; 26(4): 472–475. doi:10.1158/1055-9965.EPI-17-0104.

Geospatial Approaches to Cancer Control and Population Sciences

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Cancer incidence and mortality display strong geographic patterns worldwide and in the United States (1,2). The environment where individuals live, work, and play is increasingly being recognized as important across the cancer control continuum, including the risk of cancer development, detection, diagnosis, treatment, mortality and survivorship (3–5). At the same time, emergent technological capacity in Geographic information systems (GIS) and mapping, along with increasing sophistication in applied spatial methods, has resulted in a growing research community developing and applying geospatial approaches in health research (6). Through collaborative, transdisciplinary efforts, and continued data collection efforts there is great potential to apply these emerging geospatial approaches to various

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aspects of cancer prevention and control in order to inform etiology and target interventions and implementation of efficacious risk reducing strategies.

Motivated by national initiatives

The application of geospatial approaches across the cancer control continuum is closely tied to several efforts at the national level. This is exemplified by recent initiatives, such as personalized or precision medicine (7). The Precision Medicine Initiative is a comprehensive effort to better understand which treatments work for which individuals and under which conditions (8). Because health is shaped by factors beyond genetic susceptibility and clinical care, harnessing environmental exposures through geospatial approaches will allow for a much better risk-stratification of the population (9). Some have called the community-based corollary “precision public health”(10). In addition, achieving “health equity” and “creating social and physical environments that promote good health for all” are two of the four Healthy People 2020 goals that provide the impetus to examine geographically-based disparities related to adverse neighborhood conditions (11). To address these two goals, NCI has had long standing interests in geospatial approaches across the cancer control continuum, including efforts to develop and improve maps of cancer incidence and mortality (12) as well as support for resources and research concerning spatial and environmental aspects of cancer etiology and behavioral risk factors (13). NCI also strongly supports efforts to address health disparities via better understanding the relationships between place and health, a goal that cuts across multiple institutes at NIH (14). Geographical disparities and spatial considerations in cancer control were recently included in the 21st Century Cures Act, which supports accelerating research on cancer treatment and control, “... goes a long way to help us … enhancing prevention and detection efforts in every community regardless of zip code…”(15). NCI is increasing focus on cancer center catchment areas via award of administrative supplements to 15 cancer centers and new language in the Cancer Center Funding Opportunity Announcement (16). This includes an emphasis on using geospatial tools to define catchment areas and their population and environmental characteristics as well as a focus on community outreach and engagement.

Important methodological issues

Fulfilling the promise of spatial approaches to cancer control depends on addressing a number of methodological issues related to the definition of contextual environments in which people conduct their everyday lives and seek healthcare. These issues primarily stem from lack of consideration of neighborhood context at the study design stage and convenience in leveraging existing cross-sectional geospatial or geo-referenced data without considering issues related to spatial data uncertainty (e.g., error in a street address; selection of a geographic unit of analysis). These include: 1) a focus on residence only when most people spend one third of their time elsewhere (17); 2) failure to consider cumulative exposures over time (e.g., residential history) and changes in residential neighborhood conditions over time (18); and 3) use of convenient administrative units albeit arbitrary (e.g., county, zip code, census tract) to infer neighborhood risks (19). Few studies have included both residential and nonresidential neighborhood conditions (e.g., place of work) (20–22). Neighborhoods have been defined frequently by administrative boundaries that were not created for research purposes. Although this is an efficient approach for characterizing neighborhoods in population-based secondary data analyses, residents may not perceive their neighborhood boundaries according to census designations (23). Furthermore, the resulting summary values (e.g., rates, proportions) of a unit of analysis are influenced by the scale and zonal arrangements selected (e.g. county, zip code, block group). Therefore, the same analysis using different geographic units can produce different results, also referred to as the Modifiable Areal Unit Problem (24). Most studies also have been cross-sectional, which limits the potential for detecting causal inferences regarding neighborhood factors and cancer outcomes. Moreover, potential threats in the local environment may be subject to easily missed short-term changes with the use of data about neighborhood conditions that are collected annually or even less frequently (25).

Future opportunities

To study the geographic connection with cancer disparities, studies should routinely geocode participant addresses and link these data to spatial data. An example is the availability of the census tract of the residential location of cancer patients in cancer registry data. While such geocoded data are useful in examining exposures and local availability to treatment facilities at the time of diagnosis, future research efforts should aim to include geocoded data as part of longitudinal cohort studies that include exposure locations prior to and/or after diagnosis. Studies could also include data about other contextual locations, including where individuals work and receive medical care. Multilevel research should consider the simultaneous influences of multiple levels, including clinic, hospital, physician, family, and neighborhood (26,27). Because neighborhoods also change over time, difference-in-difference models may allow for a better understanding of the impact of their dynamic nature on cancer etiology and outcomes (28). Ethical and human subjects considerations must also be taken into account when integrating spatial data into existing and future research initiatives, including development of methods for protecting inadvertent disclosure and identification of human subjects in geospatial research. Lack of standardized approaches to data sharing remains a significant barrier to fully exploring the potential of spatial data in cancer research. Human subjects approvals should be streamlined when using multiple study sites in order to reduce delays in the implementation of projects.

Future studies should incorporate attributes of both secondary data and self-reported perceptions about neighborhoods, going beyond the use of administrative boundaries as neighborhoods. Such studies could measure exposure across key time points during the life-course as part of the exposome paradigm (29–32) and integrate various types of data sources to measure environmental and community contexts at work, life, and play (33). A geographic information system (GIS) is ideally suited to integrate various types of data across multiple levels, recognizing that specific challenges need to be overcome related to ‘big data’ issues particularly when using small geographic areas and a life-course perspective, particularly when using ecological momentary assessment (34).

Future studies should integrate residential history information into cancer research. Residential histories encapsulate individuals’ multiple interactions with their social and physical environment that may have lasting health impact. Especially given the latency of cancer etiology and long course in cancer survivorship, accounting for residential history and cumulative exposures in cancer research can aid our understanding of exposure pathways as well as identify key exposure windows.

Future studies should also utilize conceptual and theoretical models that integrate various types of data to measure environmental and community contexts (such as work, residential, and activity settings) as well as biological and social factors (33,35). This calls for transdisciplinary research teams that include epidemiologists, geographers, basic scientists, and behavioral and psychosocial researchers in the development of research questions and study design phases. These models would be able to examine the molecular mechanisms (e.g., epigenetic alterations, telomere shortening) associated with adverse environmental conditions that interact to increase risk of cancer development. Little is known about what extent adverse neighborhood conditions may be associated with molecular mechanism and cancer etiology and whether such mechanisms might explain the large racial/ethnic and geographic disparities in cancer outcomes. Identifying neighborhood factors that are associated with molecular changes may help to understand the complex interplay of cellular aging and health, particularly as it relates to racial and geographic disparities in cancer outcomes. Ultimately, the pathways by which environmental factors become biologically embedded, influence cancer preventive and health seeking behaviors, and explain racial and geographic disparities in cancer etiology and outcomes should be elucidated (36). This will advance understanding of how cancer risks change in response to social environmental exposures, and how individuals adapt to their environments.

Novel statistical approaches appropriate to the geospatial and multilevel nature of the data should be developed. This may include improving traditional structural equation models by incorporating spatial aspects in the pursuit of mediators and moderators of the effect of adverse neighborhood conditions on cancer etiology and outcomes. In the examination of geographic disparities in cancer, all too often an ecologic approach is used whereby both cancers rates and potential risk factors are aggregated at the level of a particular geographic area (e.g., county) (37–39). However, the findings may be biased (40). A recently developed micro-macro statistical approach may help examine determinants of county-level cancer rates at both the individual and neighborhood level (40), but this has received only limited attention in cancer research.

The latest geospatial technologies and approaches are also increasingly playing an important role in health services research as it relates to geographic access to cancer prevention services, treatment and follow-up care (41). Researchers are increasingly using GIS and geospatial approaches to examine where people receive services. To date, the majority of studies have focused on drive times or distance from a resident’s home location based on the assumption that everyone has access to an automobile (42). Future studies should routinely consider public transportation and work location or commuting data when measuring geographic access to cancer prevention and care services. Geospatial technologies may also help identify disparities that are related to geographic barriers to such health services. While the main focus of health care reform in the US has been to improve financial accessibility to health services, these technologies will play an increasingly important role in making sure such services are conveniently located and accessible to patients.

In this issue

This issue of *Cancer Epidemiology, Biomarkers & Prevention* features two editorials and several original articles which showcase geospatial approaches to cancer control and population sciences. Together, they provide insights into cancer etiology and cancer outcomes by studying neighborhood conditions and feature methodologically novel ways of studying how neighborhood conditions affect various cancer outcomes. This Focus Issue is in part stimulated by an NCI-sponsored conference in September 2016 (43). The conference and focus issue are intended to highlight use of geospatial approaches to cancer prevention and control and stimulate new collaborative research in this promising interdisciplinary domain. Incorporating geospatial aspects into research on cancer etiology and outcomes can provide insights into disease processes, identify vulnerable populations, and provide opportunities for interventions aimed at reducing disparities.

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