Published in final edited form as:
J Am Board Fam Med. 2010 ; 23(1): 9–12. doi:10.3122/jabfm.2010.01.090119.

Geographic Information Systems (GIS): Recognizing the Importance of Place in Primary Care Research and Practice

Ethan M. Berke, MD, MPH
Department of Community and Family Medicine, Dartmouth Medical School, and The Dartmouth Institute for Health Policy and Clinical Practice, Lebanon, NH

In the mid-1800s, London was undergoing rapid urbanization and sanitation was poor. An outbreak of cholera in the Soho district of London in 1854 killed 127 residents over 3 days and caused the exodus of nearly three quarters of the population. Eight days after the initial case, the death rate in Soho had risen to twice that of the rest of London. Anesthesiologist John Snow created maps of these cholera deaths—now well known to students and practitioners of public health—and stopped the epidemic by removing the handle on the Broad Street pump.[1] What was once thought to be an airborne disease was now confirmed to be one transmitted through consumption of contaminated water. Snow's discovery prompted a renewed effort to improve sanitation and the sewage infrastructure of the rapidly expanding city and cemented the role that healthy habitats play in the wellness of a population.

Mapping of disease mortality on a map of Soho, Snow applied the basics of geographic information science. Geographic information systems (GIS), be they computer programs or on paper, have the power to relate a disease or process to a particular location. Importantly, they can also link significant nonspatial data (eg, medical record information, claims data, neighborhood measures of poverty, or environmental pollutant measurements) to that same point in space, creating a rich picture between the relationship of exposure and outcome and its variation across space. The ability to add “layers” of spatially referenced data to a research study, health promotion project, or health access intervention moves beyond a traditional relational database and frames a health issue for a user within the context of geography.

GIS in the Research Setting

Studying Populations

The concept of place in health and wellness has often been considered at the population level. Public health and health services research account for distance or travel time to health facilities, and more advanced spatial analytic techniques allow for explorations of “hot spots” or clusters of infectious diseases and malignancies. The rapid advancements in geographic information science and GIS allow more researchers and health care organizations to better understand the spatial associations between a population and an exposure or risk.

Practice-based research networks are growing as a means to translate research into everyday practice and to better understand the role of primary care in the health system.[2] Practice-

Corresponding author: Ethan M. Berke, MD, MPH, The Dartmouth Institute for Health Policy and Clinical Practice, 35 Centerra Parkway, Room 206, Lebanon, NH 03766 (ethan.berke@tdi.dartmouth.edu)..

Conflict of interest: none declared.

based research networks perform a range of research, including interventional studies, health services research, prevention research, and work pertaining to disparities. They often leverage electronic health records across an array of practice settings to better understand the spatial distribution of a population of patients, identify gaps in access to care, and allocate resources. GIS can play a significant role in these analyses through the use of individual- and area-level mapping, as well as more advanced spatial analysis.

Projects such as the Dartmouth Atlas of Health Care use large, claims-based data sets and GIS to describe variations in health care delivery and cost.[3] This and other applications of small-area analysis[4] to areal units such as primary care service areas have let us understand patterns of care and how patients access our health system.[5] The Robert Graham Center of the American Academy of Family Physicians' HealthLandscape is a powerful, easily accessible GIS web site that allows even more primary care physicians and researchers access to understanding spatial patterns of health and access.[6] These and other applications of GIS have brought the where back to the “5 Ws” of gathering and understanding health information.

GIS has the capability to integrate contextual factors of a person's environment with health characteristics. Research programs such as the Public Health Disparities Geocoding Project measure and describe socioeconomic inequalities in health and access to care by creating US Census-derived area-based measures of socioeconomic status.[7] Continued use of GIS to characterize the social determinants of health at multiple levels is vital to ensure equal access to quality care and to better understand the interplay between individual and neighborhood factors.[8–10]

Advancing the Science to Individuals

Although population-based and health services applications of GIS are clearly important and should continue, we can go further. Every individual lives somewhere and interacts with their built and natural environment. These responses to habitat, be they physical or emotional, define who we are and, importantly, impact our physical and mental health. Work in Seattle demonstrated the protective association between walkable neighborhoods and depression in older adults.[11] Others have shown associations between the built environment and levels of obesity.[12] Because we spend 100% of our time somewhere, it is reasonable to expect that place matters when it comes to our health.

GIS: A New Tool for Primary Care Researchers

The articles in this issue of the *Journal of the American Board of Family Medicine* highlight the power of GIS in better understanding the role of place in primary care, public health, and health care service delivery. Although specific training in GIS software and spatial statistics and epidemiology is crucial, even researchers with less spatial experience can consider using GIS to perform visual exploratory analysis of their data, examine patterns of disease or utilization, and create maps for presentation in manuscripts. Like all tools, its use needs to be considered in the context of the research project: Is a map the best (or even appropriate) way to communicate findings? What are the ethical issues involved in the spatial visualization of data? Are traditional statistical methods applicable when performing spatial analysis, or might there be a spatial bias affecting my conclusions? Researchers wishing to perform spatial analysis should address these issues early on and collaborate with others with experience in spatial analysis and GIS use. Tables 1 and 2 provide information about potential uses of GIS in research, as well as useful links to web-based sources of spatial data relevant to primary care research.

Translating Spatial Research to Clinical Practice

Recommendations made in the clinical setting pertaining to healthy lifestyles—more activity, better diets, avoidance of potential toxins or pollutants—cannot occur in a vacuum. Patients will follow this advice in the context of the habitat in which they live. If our patients are in a home or work environment that does not give them the opportunity to heed our recommendations, their chance of success will be diminished. If we counsel them to increase their intake of fruits and vegetables, but their proximity a store selling fresh food is low, then how will they achieve this goal? If we tell them to walk or bike more for exercise, but their neighborhood has no sidewalks or crosswalk markings, inadequate traffic control, poor lighting, or high crime rates, how can we expect them to be more physically active? Would we respond the same way in a similar environment? Koepsell et al[13] demonstrated that, despite good intentions to improve pedestrian mobility in a car-oriented society, our efforts may be working against us in the form of greater risk around specific crosswalk styles. Consideration of information pertaining to the built environment applied to our patients' specific health promotion and disease prevention needs would improve the overall effectiveness of our counseling efforts.

As primary care physicians we are trained to consider the context of the individual and family. It is now time to start considering the context of where a person lives at it relates to their health. As healthy lifestyles and chronic disease prevention take a more pivotal role in our health care system, the opportunities for integrating our knowledge of individuals and their families' habitat into health assessments, decision making, and treatment become obvious.

GIS technology, spatial analysis, improved data about land use and location of clinical services, and information from our patients about their perceived environment can be integrated to better understand the context in which people live healthy or unhealthy lives. Place becomes a vital sign—as important as a blood pressure, pulse, or pain score in providing optimal primary and secondary care to our patients. Obtaining and using information about place can be simply a qualitative assessment of our patient's habitat. As technology continues to advance, quantitative assessments more in line with traditional vital signs will be possible. For example, there are now numeric scales of neighborhood walkability.[14,15] With the integration of health information and GIS, it is possible to envision data in an electronic health record pertaining to location, nearest places for exercise or healthy food, social services, measures of walkability, and other data important in promoting healthy lifestyles. Recommendations could be tailored to each individual patient, taking their own habitat and, importantly, their perceptions of that habitat into account. The physician could alert a patient to opportunities for healthy lifestyle habits of which they might not have been aware. Suddenly, the discussion of wellness and treatment of illness becomes personalized, with an increased chance of success.

The tools need not be advanced. Most practicing physicians have access to Internet resources, including Google Earth and Google Maps. These programs, and others, are GIS, with the capability to view multiple data sources in relation to each other across space. Physicians could easily use these online tools to start understanding the neighborhoods of their patients and available resources nearby that will help shape shared treatment and decision making.

At a service delivery level, place as a vital sign would be valuable in better understanding issues pertaining to access, group health behaviors, and resource utilization. These data could identify optimal neighborhood environments that are associated with health and aid in

the distribution of resources to communities with poor health that would benefit from interventions to improve the habitat.

By considering place as a vital sign, measuring an individual's opportunity to achieve wellness through access to health-promoting resources and environments, we increase the power of prevention in medicine and public health and better understand the lives of those we serve.

Acknowledgments

Funding: none.

References

1. Snow, J. On the mode of communication of cholera. John Churchill; London: 1855.
2. Tierney WM, Oppenheimer CC, Hudson BL, et al. A national survey of primary care practice-based research networks. Ann Fam Med. 2007; 5:242–50. [PubMed: 17548852]
3. Wennberg, JE.; Cooper, MM. The Dartmouth Atlas of Health Care in the United States. American Hospital Publishing; Chicago: 1996.
4. Wennberg J, Gittelsohn. Small area variations in health care delivery. Science. 1973; 182:1102–8. [PubMed: 4750608]
5. Goodman DC, Mick SS, Bott D, et al. Primary care service areas: a new tool for the evaluation of primary care services. Health Serv Res. 2003; 38(1 Pt 1):287–309. [PubMed: 12650392]
6. Robert Graham Center. The Health Foundation of Greater Cincinnati. American Academy of Family Physicians. [Accessed 13 March 2009] HealthLandscape. Available at https://www.healthlandscape.org/.
7. Krieger N, Chen JT, Waterman PD, Rehkopf DH, Subramanian SV. Painting a truer picture of US socioeconomic and racial/ethnic health inequalities: the Public Health Disparities Geocoding Project. Am J Public Health. 2005; 95:312–23. [PubMed: 15671470]
8. Krieger N, Williams DR, Moss NE. Measuring social class in US public health research: concepts, methodologies, and guidelines. Annu Rev Public Health. 1997; 18:341–78. [PubMed: 9143723]
9. Krieger N. Why epidemiologists cannot afford to ignore poverty. Epidemiology. 2007; 18:658–63. [PubMed: 18049180]
10. Krieger N. Ladders, pyramids and champagne: the iconography of health inequities. J Epidemiol Community Health. 2008; 62:1098–104. [PubMed: 19008371]
11. Berke EM, Gottlieb LM, Moudon AV, Larson EB. Protective association between neighborhood walk-ability and depression in older men. J Am Geriatr Soc. 2007; 55:526–33. [PubMed: 17397430]
12. Frank LD, Andresen MA, Schmid TL. Obesity relationships with community design, physical activity, and time spent in cars. Am J Prev Med. 2004; 27:87–96. [PubMed: 15261894]
13. Koepsell T, McCloskey L, Wolf M, et al. Crosswalk markings and the risk of pedestrian-motor vehicle collisions in older pedestrians. JAMA. 2002; 288:2136–43. [PubMed: 12413373]
14. Berke EM, Koepsell T, Moudon AV, Hoskins RE, Larson EB. Association of the built environment with physical activity and obesity in older persons. Am J Public Health. 2007; 97:486–92. [PubMed: 17267713]
15. Moudon AV, Lee C, Cheadle A, et al. Attributes of environments supporting walking. Am J Health Promot. 2007; 21:448–59. [PubMed: 17515010]

Table 1

Example Applications of Geographic Information Systems and Health

Measure of Habitat or Place	Research Application
Proximity to destinations	Active living and physical activity; obesity reduction; functional independence in older adults
Service areas	Access to care; resource utilization
Transportation networks	Alternate modes to reach destinations, walking school bus programs
Access to quality food sources	Lifestyle modification for weight control; cardiometabolic syndrome; prenatal care

Table 2

Web Resources for Research and Practice

Name	Examples of Uses	URL
Geospatial OneStop	Administrative boundaries, environment, transportation	http://gos2.geodata.gov/wps/portal/gos
GIS Data Depot	Commercial source of data, including satellite images and Canadian data	http://data.geocomm.com/
National Atlas	Environmental exposures, geology, boundaries, census	http://www-atlas.usgs.gov/
US Census Bureau	Best source for demographic information, socioeconomics, TIGER line road data	http://www.census.gov/
National Cancer Institute GIS	Cancer mortality data, boundary files	http://gis.cancer.gov/
Centers for Disease Control GIS Data Sources	WONDER data access, infectious disease information	http://www.cdc.gov/gis/data.htm
State resources	Useful for local data, including health and economic data; quality varies by state	Vary by state

GIS, geographic information systems; TIGER, topologically integrated geographic encoding and referencing; WONDER, Wide-ranging Online Data for Epidemiologic Research.