A systematic review of research using geospatial analytic approaches to understand the burden of screening-detectable cancers in the United States

Sindana Ilango[1,2], Katy Torres[3], Vaishali Doshi[1], Chelsea Obrochta[1], Ming-Hsiang Tsou[3,4], Atsushi Nara[3,4], Joseph Gibbons[4,5], Su Han[3], Scarlett Gomez[6,7], Salma Shariff-Marco[6,7], Caroline A. Thompson[1,8,9]

[1]SDSU Graduate School of Public Health, [2]UCSD Department of Family Medicine and Public Health, [3]SDSU Department of Geography, [4]SDSU Center for Human Dynamics in the Digital Age, [5]SDSU Department of Sociology, [6]Cancer Prevention Institute of California, [7]Stanford Cancer Institute, [8]UCSD Clinical and Translational Research Institute, [9]Palo Alto Medical Foundation Research Institute

BACKGROUND

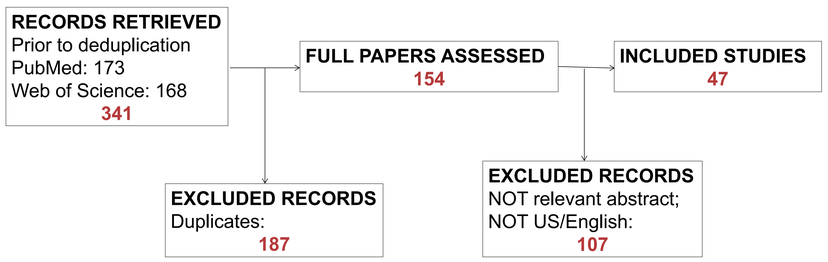
- Geospatial analysis can improve understanding of social and neighborhood contextual factors that contribute to disparities in cancer screening
- Spatial analysis techniques are not commonly used in cancer population research
- Identifying trends in the literature can help inform how and where to prioritize cancer epidemiology research using geospatial methods

We conducted a systematic review of the literature to better understand how research groups have used geospatial analytic methods to study the epidemiology of screening-detectable cancers (breast, cervical, and colorectal) in the United States (US).

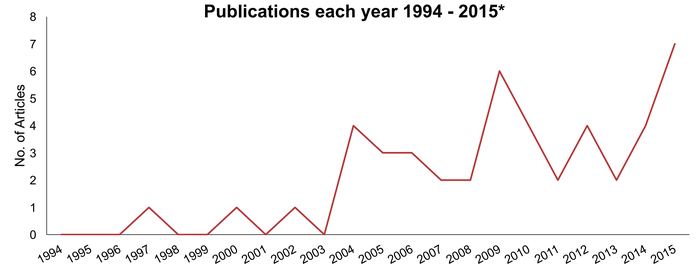
METHODS

We searched PubMed and Web of Science databases to identify US literature published from 1994 - 2016.

Cancer Type	Geographic Terms
• Breast	• Geographic information
• Cervical	• GIS
• Colorectal	• Geographic disparity
Exclude	• Geographic analysis
• Cellular, tissue, animal	• Space-time
• RCTs or clinical trials	• Spatial analysis
• Review papers	• Spatial epidemiology
• Technical/methods focus	• Spatial mismatch
• Physical environmental exposures	• Spatiotemporal analysis
Themes & Characteristics	
• Cancer type	• Geographical coverage
• Outcome	• Location
• Data source	• Spatial analytic methods
• Author group composition	



RESULTS



* Articles published in 2016 are excluded from the figure because it was not a complete year.

Theme	*n* (%)
Cancer Outcome	
Cancer site[a]	
Breast	33 (64.7)
Colorectal	15 (29.4)
Cervical	3 (5.9)
Study Focus[a]	
Early detection/screening	4 (7.8)
Diagnosis/treatment	34 (66.7)
Survival	13 (25.5)
Data Source[a]	
State cancer registry	31 (67.4)
SEER	9 (19.6)
Death data	2 (4.3)
Study	3 (6.5)
Medicare	1 (2.2)
Geography	
Study Coverage Area	
City	1 (2.1)
Sub-county	2 (4.3)
County	2 (4.3)
Multiple counties	3 (6.4)
State	28 (59.6)
Multiple states	4 (8.5)
SEER coverage area	4 (8.5)
Nationwide	3 (6.4)
Location - Top 10 Regions[b]	
Texas	8 (17.0)
SEER states	6 (12.8)
Massachusetts	4 (8.5)
United States	4 (8.5)
New Jersey	3 (6.4)
Cape Cod, MA	2 (4.3)
Eere & Niagara, NY	2 (4.3)
Illinois	2 (4.3)
Iowa	2 (4.3)
Mississippi	2 (4.3)

[b]Other studied regions: California; Chicago; Connecticut; Dane County, WI; Detroit, MI; Florida; Kentucky; Marin County, CA; Minnesota; Missouri; Pennsylvania, Ohio, and Kentucky; and Pennsylvania. One study for each region.

Characteristic	
Author Groups	***n*** **(%)**
Department Composition	
Health only	26 (55.3)
Health + geography	9 (19.1)
Geography only	6 (12.8)
Health + other	5 (10.6)
Geography + other	1 (2.1)
University Only	
Yes	29 (61.7)
No	18 (38.3)
Spatial Analytic Method[a,c]	***n***
Spatial Statistics	**28**
Exploratory Data Analysis (n=25)	
Location pattern analysis (n=1)	
Spatial Cluster Analysis (n=11)	
Spatial scan statistic (n=7)	
Elliptical spatial scan (n=1)	
Getis-Ord Gi* (n=2)	
Spatial Regression (n=3)	
GWR models (n=1)	
Spatial GLMM (n=1)	
Spatial GEE models (n=1)	
Spatial Interpolation	**5**
Kernel density (n=3)	
Two-step floating catchment area (n=2)	
Network Analysis	**3**
Spatio-Temporal Analysis	**4**
Bayesian spatiotemporal models (n=2)	
Space and time scan statistics (n=2)	
Spatial Functions	**1**
Adaptive spatial filtering (n=1)	

[a]These counts are not mutually exclusive.
[c]Spatial analytic methods were classified using techniques described in publication method sections. Specificity of methods descriptions varied across articles and journals.

Research reported in this poster was supported by the National Cancer Institute of the National Institutes of Health under award numbers: U54CA132384 & U54CA132379

CONCLUSIONS

Key Findings

- 67% of studies focused on cancer diagnosis and treatment outcomes
- Majority of research groups studied disparities across state using state registries
- Fewer than 20% of author groups had both health and geography experts

Limitations

- Grey literature database searches not included
- Article thematic groups depend on journal format
- Common geospatial keywords vary by field

Sophisticated efforts to describe contextual disparities in space and time can improve detection efforts and ultimately, reduce the burden of cancer.

LITERATURE REVIEWED

1. Anderson RT, Yang TC, Matthews SA, et al. Breast cancer screening, area deprivation, and later-stage breast cancer in appalachia: Does geography matter? *Health Serv Res.* 2014;49(2):546-567.
2. Bambhroliya AB, Burau KD, Sexton K. Spatial analysis of county-level breast cancer mortality in Texas. *J Environ Public Health.* 2012;2012:959343.
3. Beyer KMM, Rushton G. Mapping cancer for community engagement. *Prev Chronic Dis.* 2009;6(1):A03.
4. Crabbe JCF, Gregorio DI, Samociuk H, Swede H. Secular trends, race, and geographic disparity of early-stage breast cancer incidence: 25 years of surveillance in Connecticut. *Am J Public Health.* 2015;105:e64-e70.
5. Dai D. Black residential segregation, disparities in spatial access to health care facilities, and late-stage breast cancer diagnosis in metropolitan Detroit. *Heal Place.* 2010;16(5):1038-1052.
6. DeChello LM, Sheehan TJ. Spatial analysis of colorectal cancer incidence and proportion of late-stage in Massachusetts residents: 1995-1998. *Int J Health Geogr.* 2007;6:20.
7. Ed Hsu C, Jacobson H, Soto Mas F. Evaluating the disparity of female breast cancer mortality among racial groups - a spatiotemporal analysis. *Int J Health Geogr.* 2004;3(1):4.
8. Faruque FS, Zhang X, Nichols EN, et al. The impact of preventive screening resource distribution on geographic and population-based disparities in colorectal cancer in Mississippi. *BMC Res Notes.* 2015;8(1):423.
9. Han D, Rogerson PA, Bonner MR, et al. Assessing spatio-temporal variability of risk surfaces using residential history data in a case control study of breast cancer. *Int J Health Geogr.* 2005;4(1):9.
10. Han D, Rogerson PA, Nie J, et al. Geographic clustering of residence in early life and subsequent risk of breast cancer (United States). *Cancer Causes Control.* 2004;15(9):921-929.
11. Han Y-Y, Talbott E, Donovan M. Time Trends and Racial Differences in Female Breast Cancer Incidence in Pennsylvania, 1985-2004. *J Womens Health (Larchmt).* 2011;20(3).
12. Henry K a, Sherman R, Roche LM. Colorectal cancer stage at diagnosis and area socioeconomic characteristics in New Jersey. *Health Place.* 2009;15(2):505-513.
13. Hsu CE, Mas FS, Hickey JM, Miller J a, Lai D. Surveillance of the colorectal cancer disparities among demographic subgroups: a spatial analysis. *South Med J.* 2006;99(9):949-956.
14. Huang B, Dignan M, Han D, Johnson O. Does distance matter? Distance to mammography facilities and stage at diagnosis of breast cancer in kentucky. *J Rural Heal.* 2009;25(4):366-371.
15. Jacquez GM, Barlow J, Rommel R, et al. Residential mobility and breast cancer in Marin County, California, USA. *Int J Environ Res Public Health.* 2013;11(1):271-295.
16. Joseph Sheehan T, DeChello LM, Kulldorff M, Gregorio DI, Gershman S, Mroszczyk M. The geographic distribution of breast cancer incidence in Massachusetts 1988 to 1997, adjusted for covariates. *Int J Health Geogr.* 2004;3(1):17.
17. Kulldorff M, Feuer EJ, Miller B a, Freedman LS. Breast cancer clusters in the northeast United States: a geographic analysis. *Am J Epidemiol.* 1997;146(2):161-170.
18. Lin Y, Zhan FB. Geographic variations of racial/ethnic disparities in cervical cancer mortality in Texas. *South Med J.* 2014;107(5):281-288.
19. Liu Z, Zhang K, Du XL. Risks of developing breast and colorectal cancer in association with incomes and geographic locations in Texas: a retrospective cohort study. *BMC Cancer.* 2016;16(1):294.
20. MacKinnon JA, Duncan RC, Huang Y, et al. Detecting an association between socioeconomic status and late stage breast cancer using spatial analysis and area-based measures. *Cancer Epidemiol Biomarkers Prev.* 2007;16(4):756-762.
21. Mandal R, St-Hilaire S, Kie JG, Derryberry D. Spatial trends of breast and prostate cancers in the United States between 2000 and 2005. *Int J Health Geogr.* 2009;8(Figure 1):53.
22. McElroy JA, Remington PL, Gangnon RE, Hariharan L, Andersen LD. Identifying geographic disparities in the early detection of breast cancer using a geographic information system. *Prev Chronic Dis.* 2006;3(1):A10.
23. Mobley LR, Kuo TM, Watson L, Gordon Brown G. Geographic disparities in late-stage cancer diagnosis: multilevel factors and spatial interactions. *Health Place.* 2012;18(5):978-990.
24. Mobley LR, Kuo T-M, Urato M, Subramanian S, Watson L, Anselin L. Spatial Heterogeneity in Cancer Control Planning and Cancer Screening Behavior. *Ann Assoc Am Geogr.* 2012;102(5):1113-1124.
25. Nelson EJ, Hughes J, Kulasingam SL. Spatial patterns of human papillomavirus-associated cancers within the state of Minnesota, 1998-2007. *Spat Spatiotemporal Epidemiol.* 2014;9:13-21.
26. Nichols EN, Bradley DL, Zhang X, Faruque F, Duhé RJ. The geographic distribution of mammography resources in Mississippi. *Online J Public Health Inform.* 2014;5(3):226.
27. Pollack LA, Gotway CA, Bates JH, et al. Use of the spatial scan statistic to identify geographic variations in late stage colorectal cancer in California (United States). *Cancer Causes Control.* 2006;17(4):449-457.
28. Roche LM, Niu X, Henry KA. Invasive Cervical Cancer Incidence Disparities in New Jersey--a Spatial Analysis in a High Incidence State. *J Health Care Poor Underserved.* 2015;26(4):1173-1185.
29. Roche LM, Skinner R, Weinstein RB. Use of a Geographic Information System To Identify and Characterize Areas with High Proportions of Distant Stage Breast Cancer. *J Public Health Manag Pract.* 2002;8(2):26-32.
30. Rushton G, Peleg I, Banerjee A, Smith G, West M. Analyzing geographic patterns of disease incidence: rates of late-stage colorectal cancer in Iowa. *J Med Syst.* 2004;28(3):223-236.
31. Schootman M, Jeffe DB, Lian M, Gillanders WE, Aft R. The role of poverty rate and racial distribution in the geographic clustering of breast cancer survival among older women: A geographic and multilevel analysis. *Am J Epidemiol.* 2009;169(5):554-561.
32. Schootman M, Lian M, Deshpande AD, et al. Temporal trends in geographic disparities in small-area breast cancer incidence and mortality, 1988 to 2005. *Cancer Epidemiol Biomarkers Prev.* 2010;19(4):1122-1131.
33. Schootman M, Lian M, Deshpande AD, McQueen A, Pruitt SL, Jeffe DB. Temporal trends in geographic disparities in small-area-level colorectal cancer incidence and mortality in the United States. *Cancer Causes Control.* 2011;22(8):1173-1181.
34. Sheehan TJ, Gershman ST, MacDougall LA, et al. Geographic assessment of breast cancer screening by towns, zip codes, and census tracts. *J Public Health Manag Pract.* 2000;6(6):48-57.
35. Sheehan TJ, DeChello LM. A space-time analysis of the proportion of late stage breast cancer in Massachusetts, 1988 to 1997. *Int J Health Geogr.* 2005;4:15.
36. Siegel RL, Sahar L, Robbins A, Jemal A. Where can colorectal cancer screening interventions have the most impact? *Cancer Epidemiol Biomarkers Prev.* 2015;24(8):1151-1156.
37. Tarlov E, Zenk SN, Campbell RT, Warnecke RB, Block R. Characteristics of mammography facility locations and stage of breast cancer at diagnosis in Chicago. *J Urban Heal.* 2009;86(2):196-213.
38. Tatalovich Z, Zhu L, Rolin A, Lewis DR, Harlan LC, Winn DM. Geographic disparities in late stage breast cancer incidence: results from eight states in the United States. *Int J Health Geogr.* 2015;14:31.
39. Tian N, Gaines Wilson J, Benjamin Zhan F. Female breast cancer mortality clusters within racial groups in the United States. *Health Place.* 2010;16(2):209-218.
40. Tian N, Goovaerts P, Zhan FB, Chow TE, Wilson JG. Identifying risk factors for disparities in breast cancer mortality among African-American and Hispanic women. *Womens Health Issues.* 2015;22(3):e267-76.
41. Vieira VM, Webster TF, Weinberg JM, Aschengrau A. Spatial-temporal analysis of breast cancer in upper Cape Cod, Massachusetts. *Int J Health Geogr.* 2008;7:46.
42. Vieira V, Webster T, Weinberg J, Aschengrau A, Ozonoff D. Spatial analysis of lung, colorectal, and breast cancer on Cape Cod: An application of generalized additive models to case-control data. *Environ Heal A Glob Access Sci Source.* 2005;4(1):11.
43. Wan N, Zhan FB, Lu Y, Tiefenbacher JP. Access to healthcare and disparities in colorectal cancer survival in Texas. *Heal Place.* 2012;18(2):321-329.
44. Wan N, Zhan FB, Zou B, Wilson JG. Spatial Access to Health Care Services and Disparities in Colorectal Cancer Stage at Diagnosis in Texas. *Prof Geogr.* 2013;65(3):527-541.
45. Wang F, Luo L, McLafferty S. Healthcare access, socioeconomic factors and late-stage cancer diagnosis: an exploratory spatial analysis and public policy implication. *Int J Public Pol.* 2010;5(2/3):237.
46. Wang F, McLafferty S, Escamilla V, Luo L. Late-Stage Breast Cancer Diagnosis and Health Care Access in Illinois. *Prof Geogr.* 2008;60(1):54-69.
47. Williams F, Jeanetta S, O'Brien DJ, Fresen JL. Rural-urban difference in female breast cancer diagnosis in Missouri. *Rural Remote Health.* 2015;15(3):3063.