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The Role of Spatially-Derived Access-to-Care Characteristics in Melanoma Prevention and Control in Los Angeles County

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Abstract

Among 10,068 incident cases of invasive melanoma, we examined the effects of patient characteristics and access-to-care on the risk of advanced melanoma. Access-to-care was defined in terms of census tract-level sociodemographics, health insurance, cost of dermatological services and appointment wait-times, clinic density and travel distance. Public health insurance and education level were the strongest predictors of advanced melanomas but were modified by race/ethnicity and poverty: Hispanic whites and high-poverty neighborhoods were worse off than non-Hispanic whites and low-poverty neighborhoods. Targeting high-risk, underserved Hispanics and high-poverty neighborhoods (easily identified from existing data) for early melanoma detection may be a cost-efficient strategy to reduce melanoma mortality.

Keywords

melanoma; high-risk population; cancer surveillance data; health care accessibility; minority groups

Introduction

Incidence rates of melanoma have been increasing worldwide at a faster rate than any other cancers, excluding lung cancer in women (Ries et al., 2000). In 2012, there were 232,000 new cases of melanoma worldwide. The highest incidence occurred in Australia (40.3 per

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Conflict of Interest

The authors state no conflict of interest.

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100,000) and New Zealand (30.5 per 100,000 respectively), followed by Northern America and Northern and Western Europe (>10 per 100,000 in both sexes) (Ferlay et al., 2014). In the same year, there was an estimated 55,000 melanoma-specific deaths worldwide. In the United States, incidence rates of melanoma have been steadily increasing on average 1.4% each year since 1975 (Surveillance Epidemiology and End Results). It is currently the fifth and seventh most common cancers among males and females, respectively (Siegel et al., 2015).

Recent improvements in melanoma survival have been attributed to advancement in melanoma management, rather than to improved screening and prevention efforts (Lasithiotakis et al., 2007), despite the existence of screening modalities that are acceptable and well-suited to large scale implementation. The effectiveness of population-based skin cancer screening campaigns cannot be easily established and recommended by the U.S. Preventive Services Task Force (USPSTF), due to the lack of adequately-powered randomized clinical trials to examine the effects of population-based screening on melanoma outcomes (Wernli et al., 2016). One alternative is to focus screening efforts on high-risk subpopulations that have poor access to care and are more likely to present melanomas at later stages.

Studies evaluating the relationship between access-to-care and risk of late-stage diagnosis of screenable cancers (i.e. breast cancer, prostate cancer and cervical cancer) have defined in access in terms of contextual access (or contextual barriers to access-to-care such as area-based measures of poverty, education, race/ethnic composition, acculturation) (Barry and Breen, 2005; Greenlee and Howe, 2009; Hu et al., 2014; Pollitt et al., 2008; Pollitt et al., 2011; Reyes-Ortiz et al., 2008), potential access (i.e. health insurance coverage, wait times for appointment, affordability of services) (Fedewa et al., 2012; Plascak et al., 2015; Pollitt et al., 2008; Rouhani et al., 2010; Ward et al., 2010) and spatial access (i.e. travel distance to health care providers and neighborhood-level density of physician and screening facilities) (Amin et al., 2010; Plascak et al., 2015; Stitzenberg et al., 2007; Wan et al., 2013). We employed the same categorization of access-to-care in this study.

Access to care in the U.S. is primarily dictated by the type of health insurance one is enrolled in. The Patient Protection and Affordable Care Act (PPACA) (2010) covered more preventive services, extended funding to public health insurance programs, stopped insurers from denying coverage based on pre-existing conditions, mandated large employers to provide health insurance to their employees, and required individuals to have health coverage. Because most of the provisions of PPACA rolled out between 2013 and 2014, we are assuming that most of the study participants, diagnosed with melanoma between 2004 and 2013, have not been affected by changes brought about by PPACA. Health insurance in the U.S. is predominantly obtained through employers (i.e. employer purchases insurance from a private insurance company) using a Managed Care Organization (MCO) model (Askin and Moore, 2014). Under MCO, an individual may be enrolled in Health Maintenance Organization (HMO), Preferred Provider Organization (PPO) or Point-of Service (POS). HMO enrollees can only have their care covered if they receive them from physicians in the HMO network, and would need to get a referral from their primary care physician to see a specialist (e.g. dermatologist). PPO enrollees receive covered care from a

network of physicians who negotiated contracts with the PPO, and can also receive care from out-of-network providers but would have a higher deductible, co-insurance and co-payments. Meanwhile, POS combines features of HMO (i.e. use of primary care physician from a network and requiring an authorization to see a specialist) and PPO (i.e. use of both in- and out-of-network providers), and is now increasingly being replaced by PPO.

Approximately 30% of Americans receive health insurance from public/government programs: Medicaid, Medicare, TRICARE (active military) and Veterans Health Administration (retired military) and Indian Health Service (American Indians and Alaska Natives) (Askin and Moore, 2014). Medicaid is a federal and state-run insurance program that covers low-income families, pregnant women and children. Medicaid covers cancer-related preventative services rated “A” or “B” by the USPSTF (i.e. breast, cervical and colorectal cancers), which excludes skin cancer screening, without cost sharing in 19 states, including California (Gates et al., 2014). However, skin examinations may be covered if done as part of a routine annual exam (American Medical Association, 2013). Medicare is the public health insurance for Americans who are aged 65 and older (some younger individuals are eligible if they have disabilities or end-stage renal disease) (Centers for Medicare and Medicaid Services, 2016b; Field et al., 2000). Funded through payroll and income taxes, and premiums paid by Medicare subscribers enrolled in certain plans, Medicare is characterized by considerable cost-sharing (i.e. Medicare, employer-sponsored, private insurance companies, Medicaid and/or Medigap purchased in the individual market), that is much more considerable compared to public health insurance found in other high-income countries (National Academy of Social Insurance Study Panel on Medicare’s Larger Social Role, 1999). Only recently did Medicare start covering cancer-related preventive services (for breast, cervical, prostate, colorectal and lung cancer screenings) (National Cancer Institute Division of Cancer Control and Population Sciences) but routine examinations to screen for skin cancer are currently not covered. However, exceptions include patient-initiated visits to examine a suspicious lesion, subsequent physician visits to investigate a suspicious lesion found during a prior visit about an unrelated issue, and any skin biopsies (Field et al., 2000).

There are people for whom the private or public health insurance programs mentioned above are not suitable (unemployed, self-employed, retirees, or who work in companies that do not offer health insurance) and, therefore, have to purchase insurance through the individual market that traditionally has been expensive (Askin and Moore, 2014).

Improvements in case reporting, as well as better skin awareness and early detection, may result to increases in melanoma incidence rates, as in the case among non-Hispanic whites between 1992 and 2006 (Jemal et al., 2011). However, this increasing trend was not observed among Hispanic whites who experienced greater increases among thick than thin tumors (Cockburn et al., 2006). The low perception of melanoma risk, poor sun- protection behaviors and low rates of skin self-examination among HW (Friedman et al., 1994; Pipitone et al., 2002) do not warrant a reversal of this increasing trend anytime soon, unless we recognize and address the need in this subpopulation. This appears to be a logical step in Los Angeles County (LAC), where the study was conducted, given that it has the largest HW population of any county in the U.S. (United States Census Bureau, 2010). Most studies

examining factors associated with melanoma severity at presentation (such as age, sex, marital status) were conducted among chiefly non-Hispanic white (NHW) populations (Baumert et al., 2007; Durbec et al., 2010; Geller et al., 2009a; Grange et al., 2012; Moreau et al., 2014; Reyes-Ortiz et al., 2007; Rouhani et al., 2008; Talaganis et al., 2014). We are addressing the gap in literature by conducting race-stratified analysis of the contextual, potential and spatial aspects of access-to-care in relation to melanoma severity at diagnosis using tumor thickness, the strongest predictor of melanoma outcome (Balch, 1992; Balch et al., 1978; Balch et al., 1982; Balch et al., 1981; Breslow, 1970). We also assessed how these effects differed between high- and low-poverty neighborhoods, in order to arrive at a clearer picture of how and where to best target available screening resources.

To date, very few studies have provided truly population-based analysis of contextual, potential and spatial access-to-care, concurrently, in relation with tumor thickness. Moreover, fewer studies have examined how race/ethnicity and poverty levels modify the association which may be critical because, while we cannot modify race/ethnicity and poverty, we can certainly easily identify neighborhoods that would potentially benefit from targeted screening interventions using these variables.

Methods

Study sample

There were 10,068 primary diagnoses of invasive melanoma occurring between 2004 and 2013 in LAC identified through the Cancer Surveillance Program (CSP), the population-based cancer registry for LAC, and were included in this study. CSP also provided patients' demographic characteristics (age, sex, race/ethnicity and marital status), residential address at diagnosis and address of diagnosing facility. There were 8,653 NHW, 896 HW and 519 other race/ethnicity (includes non-Hispanic Black, Asian/ Pacific Islanders, American Indian and other/unknown). NHW and HW definitions were based on medical records or Hispanic surnames (Cockburn et al., 2006). Cases were excluded if they had missing tumor thickness, summary staging information, or residential address at the time of diagnosis. Cases who resided in the offshore islands of LAC were also excluded.

Patients' residential addresses at diagnosis were geocoded to obtain the geographic coordinates needed to generate the distance-based measures of spatial access to care described below. The geocoding process also generated the geocoding accuracy (basis of coordinates): parcel, address range interpolation or street intersect, city, zip or state centroid, listed in descending order of accuracy (Goldberg, 2008).

Breslow tumor thickness was used to identify patients who presented with thin (<1mm) or thick (>1mm) melanomas at diagnosis. The cutpoint was chosen because of the excellent prognosis for melanomas at or below 1mm (Breslow, 1970; Day et al., 1981) and its clinical significance for sentinel lymphadenectomy, a widely-accepted staging procedure for advanced melanomas (Cochran et al., 2000). When tumor thickness was not reported, we used the combined American Joint Committee on Cancer's staging guidelines (4.6%) or the summary stage at diagnosis (5.0%) to classify tumors.

Measures of access-to-care

Contextual access-to-care: census tract-level demographic and socioeconomic barriers to care

Contextual measures refer to area-level measures that provide the demographic and socioeconomic background that may hinder or facilitate the accessing of care. Census tract (CT)-level measures that were previously associated with the late diagnosis of screenable cancers were chosen from the 2008–2012 American Community Survey (Barry and Breen, 2005; Greenlee and Howe, 2009; Hu et al., 2014; Pollitt et al., 2008; Pollitt et al., 2011; Reyes-Ortiz et al., 2008; United States Census Bureau, 2012): 1) percentage of the population who are not proficient in English, 2) percentage of the population with at least a Bachelor's degree, 3) percentage of the population below poverty level, 4) median household income, 5) percentage of the population who have no health insurance, 6) percentage of the population who do not own any vehicles, 7) percentage of the population who use public transportation, 8) percentage of the population who are of Hispanic ancestry, and 9) median house value. Multicollinearity among CT-level variables was assessed using Pearson correlation coefficient (Pearson's r). Hispanic make-up (Pearson's $r=-0.83$) and median house value (Pearson's $r=0.85$) were both highly correlated to education and excluded from the analysis.

Potential access-to-care: health insurance coverage, cost of services and appointment wait-time

Potential measures refer to patient- and provider-level variables that may hinder or facilitate the accessing of care, such as health insurance coverage, cost of services and wait-time. The patients' primary source of payment at the time of diagnosis, obtained from the CSP, was used as an indicator of health insurance coverage, and was categorized into private (Managed Care Organization), public (Medicaid and Medicare), self-pay or uninsured and other (TRICARE, Veterans Health Administration, and Indian Health Service).

The cost of dermatological services (initial consultation and skin biopsy) and wait-times for appointments (i.e. the number of days between this date and the date of contact) were obtained through a phone survey administered to dermatology facilities. Between March and July 2013, trained staff made phone calls to 387 facilities in LAC identified through the online membership roster of the American Academy of Dermatology (Tsang and Resneck, 2006). 265 operating facilities were asked for the cost of dermatological services and the date of the next available appointment. There were 245 clinics included in the analysis after excluding 20 facilities that could not be contacted, were outside LAC or were exclusive pathology laboratories, HMO, Veterans Affairs, pediatric dermatology or cosmetic-only clinics. Wait-time and cost of dermatological services were averaged within 20 km of a patient's residence. There were 245 clinics included in the analysis after excluding 20 facilities that could not be contacted, were outside LAC or were exclusive pathology laboratories, HMO, Veterans Affairs, pediatric dermatology or cosmetic-only clinics.

Spatial access-to-care: travel distance and clinic density—Spatial measures of access-to-care indicate proximity to healthcare providers that may hinder or facilitate the accessing of care. Travel distance (km) was then calculated from the patient's residence to the 1) address of the facility where the melanoma diagnosis was made (diagnosing facility)

and 2) nearest dermatology clinic provided that it accepted the patient's health insurance (nearest clinic) (Esri).

Dermatology clinic density, an indicator of the availability of dermatologists in the neighborhood, was calculated by dividing the number of dermatology clinics by the total population at the CT-level. Clinic density was categorized into no clinics, 1 to 20 and >20 clinics per 100,000 population after observing a decreasing trend in risk between 1 to 20 clinics/100,000 population and an increasing trend for >20 clinics/100,000 population.

Statistical analysis

Multivariate unconditional logistic regression analysis was used to estimate the odds of presenting with a thick tumor at diagnosis. Model 1 was adjusted for potential confounders obtained from the cancer registry: general characteristics (i.e. age, sex, race/ethnicity, marital status and basis of geographic coordinates) and health insurance at the time of diagnosis. In addition to those confounders, we adjusted for CT-level confounders (i.e. all contextual access-to-care factors and clinic density) in Model 2. Since the positional accuracy of the geocoding process has been shown to affect exposure misclassification especially in spatial proximity studies, both models were adjusted for the basis of the coordinates (Oliver et al., 2005; Ward et al., 2005). Analyses were stratified by race/ethnicity (NHW vs. HW) and poverty levels (high- vs. low-poverty CTs). Due to small sample sizes, we were not able to separately analyze other race/ethnic groups. The OR and corresponding 95%CI were presented to show the magnitude and significance of the association. All tests were 2-sided with statistical significance set at $p < 0.05$.

Results

Patient characteristics by tumor thickness at diagnosis

Although majority of the study population was NHW (85.9%), a larger proportion of HW (51.7%) were diagnosed with thick melanoma compared to NHW (34.8%) (Table 1). The distribution of age, sex, race/ethnicity and marital status significantly differed by tumor thickness among NHW and HW (p from Pearson's chi-square < 0.05). The proportion of HW under 40 years old diagnosed with thick melanoma (18%) was more than double that of NHW (7%) (table not shown). In contrast to the higher proportions of males than females who were diagnosed with thick melanoma among NHW (66% males and 34% females), there was a more equal gender distribution among HW (50% males and 50% females) (data not shown).

The combined effect of patient characteristics and access-to-care on tumor thickness at diagnosis

The distribution of cases by tumor thickness varied across most of the measures of access-to care at the level of CT (p from Pearson's chi-square < 0.05). The distribution of health insurance coverage and average biopsy cost significantly differed by tumor thickness among NHW and HW ($p < 0.001$) (Table 1). Among HW diagnosed with thick melanoma, more than 60% resided in neighborhoods with lower consultation and skin biopsy costs. The majority of NHW (86%) and HW (95%) resided in CTs without any dermatology facilities.

Meanwhile, 49.0% of NHW and 75.1% of HW reside in high-poverty CTs (percentage of the population below poverty level is above the median) (data not shown). The mean travel distance to the nearest clinic was 4.0 km (range: 0.2 km–103.2 km) (data not shown).

Risk of being diagnosed with thicker tumors remained associated with being older, male, Hispanic and never married or separated/divorced/widowed, after controlling for patient characteristics, contextual access-to-care factors (or SES indicators) and clinic density (Table 2) (Model 2). Among the contextual access-to-care measures, only education remained a significant indicator of thick melanomas after controlling for patient characteristics, SES indicators and clinic density. Residents of CT with high education levels were 33% less likely to be diagnosed with thick tumors compared to residents in CT with low education levels (Model 2 OR=0.70, 95%CI=0.62–0.78) after accounting for patient characteristics, SES indicators and clinic density.

Compared to those who had private health insurance, those who were enrolled in public health insurance were 80% more likely to be diagnosed with thick melanoma (Model 2 OR=1.80, 95%CI=1.58–2.06) while self-paying patients had a 20% higher risk (Model 2 OR=1.19, 95%CI=1.04–1.36) after controlling for other factors noted above.

High clinic density was associated with a lower risk for thick tumor (Model 2 OR=0.78, 95%CI=0.65–0.94). Meanwhile, there was a 30% increase in risk for cases who lived farther from a dermatology clinic (Model 1 OR=1.26, 95%CI=1.14–1.39), but controlling for demographics, type of health insurance type, SES indicators and clinic density moved the risk estimates toward the null (Model 2 OR=1.15, 95%CI=1.03–1.27).

Variability in overall findings for HW compared to NHW

After controlling for patient characteristics, SES indicators and availability of clinics, higher education levels conferred about 50% lower risk of thick tumors among HW (Table 3) (Model 2 OR=0.52, 95%CI=0.30–0.92), but only about 30% lower risk for NHW (Model 2 OR=0.73, 95%CI=0.64–0.82).

Compared with patients enrolled in private health insurance, public health-insured patients were at significantly higher risk of thick tumors among NHW (Model 2 OR=1.65, 95%CI=1.43–1.90) and HW (Model 2 OR=2.67, 95%CI=1.78–4.01), however, the risk was higher among the latter group after adjusting for patient characteristics, sociodemographics, health insurance type and clinic density.

Variability in overall findings by poverty level

The increased risk estimates for thicker tumors associated with being older, male and Hispanic were substantially higher among patients living in high-poverty than those in low-poverty areas (Table 4). Enrollment in public health insurance was also a significant predictor but the risk was again higher among patients in high-poverty (Model 2 OR=1.97, 95%CI=1.65–2.34) than in low-poverty CTs (Model 2 OR=1.60, 95%CI=1.31–1.96).

In high-poverty CTs, the risk associated with residing in neighborhoods with a large non-English-proficient population disappeared after other SES indicators and availability of

clinics were controlled for (Model 1 OR=1.18, 95%CI=1.02–1.37) (Model 2 OR=0.98, 95%CI=0.82–1.18). This reversal of the direction of association was not observed in low-poverty areas. Meanwhile, the protective effect of education was higher in high-poverty (Model 2 OR=0.65, 95%CI=0.55–0.77) than in low-poverty areas (Model 2 OR=0.73, 95%CI=0.62–0.86).

The risk reduction associated with higher clinic density was marginally significant in low-poverty CTs (Model 2 OR=0.81, 95%CI=0.62–1.07). The higher risk associated with farther travel distance to a dermatology clinic was only significant in high-poverty (Model 2 OR=1.22, 95%CI=1.05–1.41) but not in low-poverty areas (Model 2 OR=1.08, 95%CI=0.93–1.25).

Discussion

Since current treatment advances rarely improve melanoma outcomes and long-term survival (Bhatia et al., 2009; Eggermont et al., 2014), targeted screening and preventive approaches are likely to be critical to reduce late stage presentation and melanoma mortality. We report the effects of patient characteristics and proxies for patient access-to-care on tumor thickness at diagnosis, the most important independent predictor of poor outcome for melanoma patients (Erdei and Torres, 2010).

Majority of the invasive melanoma cases included in the study were NHW but there was a much larger proportion of HW who were diagnosed with thick melanoma compared to NHW. This is consistent with trends observed globally, in the U.S. and in California where nonwhite populations are still less likely to be diagnosed with melanoma but are more likely to have thicker melanomas when diagnosed, compared with non-white populations (Cress and Holly, 1997; Curado et al., 2007; Wu et al., 2011). Although HW in this study comprised only 8.9% of the study sample, this makes up one of the largest proportion of HW within a county-specific study of this kind. In comparison, a previous statewide study in Florida, which has one of the highest concentration of HW in the US, that also selected cases within a 10-year period only had 4.0% HW (Hu et al., 2014). Nonetheless, the small HW sample size in the current study generated wide confidence intervals for some risk estimates and increased uncertainty about the magnitude of the effect.

In addition to racial/ethnic disparities, disparities by SES have been previously observed. Although melanoma is more commonly diagnosed among high SES populations, it is more often diagnosed in advanced stages among lower SES populations (Eide et al., 2009b; Hu et al., 2014; Jiang et al., 2015; Linos et al., 2009; Lyratzopoulos et al., 2013; McNally et al., 2014). To improve the tailoring and targeting of early melanoma detection for these high-risk subpopulations, we assessed individual components of SES and found that education was the most significant predictor of thick melanoma. The association between lower neighborhood levels of education and worse melanoma prognosis was consistent with previous studies (Eide et al., 2009b; Geller et al., 1996), and has been attributed to higher risk behaviors, decreased risk perception and poorer access to preventative care among individuals with lower education (Harrison et al., 1998; Lantz et al., 1998; Pollitt et al., 2012). Low-education neighborhoods may also lack health care infrastructure. In our

sample, only 5% of patients from low-education CT had at least one dermatology clinic in their CT, compared to 20% of patients from high-education CT. Among HW, only 3% of patients from low-education CT had at least one dermatology clinic in the vicinity. The shortage of dermatologists may hint at other serious forms of health care disparities in low-education neighborhoods.

Race/ethnicity and CT-level poverty level both significantly modify the protective effects of education: HW and high-poverty neighborhoods experienced bigger benefits from living in highly educated neighborhoods than NHW and low-poverty neighborhoods. Poverty and education levels were not highly correlated in our sample, which may explain why the difference in the protective effect of education by poverty level was not more striking than the difference observed by race/ethnicity. This may also echo the sentiment that education is “a great equalizer of the conditions of men” (Mann, 1957): regardless of poverty level, high-education confers “protection” against delayed diagnosis of melanoma. In this case, however, education could not eliminate the racial/ethnic differences in the late diagnosis of melanoma, and implicitly, in access to timely care that would have diagnosed the melanoma earlier. More research is needed to understand the social and environmental conditions contributing to the observed racial/ethnic disparities in access to care.

Compared to privately insured patients, patients enrolled in public health insurance programs were at increased risk of presenting with thick melanomas. The increased risk associated with Medicaid compared with fee-for-service reported in a previous study (Roetzheim et al., 1999) was observed here when private and public health insurance programs were reclassified into more detailed groups. Shortage of dermatology clinics accepting Medicaid may be affecting patients’ access to timely care and early melanoma detection; only 9% of the clinics in the study reported accepting Medicaid. This percentage may further decrease with more clinics reducing Medicaid services due to low reimbursement rates (Resneck et al., 2004). Because a greater percentage of HW (9%) than NHW (1%) used Medicaid to pay for diagnostic services, the service shortage for Medicaid enrollees may disproportionately affect HW and may result in increased rates of thick melanoma among this population, especially as people gain coverage but struggle to find providers or have difficulty accessing those designated to them.

Consistent with previous studies, our study showed that a greater supply of dermatologists decreased the risk of advanced melanoma (Aneja et al., 2012; Eide et al., 2009a; Roetzheim et al., 2000). Moreover, risk reductions were only significant, albeit marginally, among NHW and in low-poverty areas, suggesting that an increase in the number of neighborhood dermatologists may not necessarily improve access to dermatological care and may not successfully impact melanoma mortality among HW and high-poverty areas.

Higher neighborhood average costs of initial consultation and skin biopsy were not significantly associated with thicker tumors after controlling for SES factors and clinic density. Because the actual cost of services may be more relevant to patients who had to pay out-of-pocket than those who had health insurance, we restricted the analyses to uninsured or self-paying patients (n=249) and found that the costs of services were not associated with risk of thick tumors among this subgroup. As an alternative to the actual costs of services,

measures that reduce out-of-pocket costs (i.e. reducing copays, providing vouchers), shown to be associated with cancer screening uptake (Guide to Community Preventive Services), could be considered in future research.

We did not observe a significant association between tumor thickness and distance to the diagnosing facility, contrary to a previous study (Stitzenberg et al., 2007). The median travel distance to the diagnosing facility (13 km) was similar in both studies. However, Stitzenberg et al.'s study was conducted in North Carolina, which is approximately 11 times the size of LAC, and 78% of their study population resided in metropolitan areas, compared to close to 100% of the current study's sample population. In highly urbanized areas such as LAC, travel distance to the diagnosing facility may not be an important predictor of advanced stage of disease. In fact, another study conducted in LAC found that travel time, a variable highly correlated with travel distance, was not a significant predictor of breast cancer stage at diagnosis (Onega et al., 2011).

In contrast, we observed an association between travel distance to the closest dermatology clinic and tumor thickness. The risk was modified by race/ethnicity and neighborhood poverty, with HW and poorer areas experiencing greater risk associated with farther travel distance. Further research is needed to assess the spatial distribution of dermatology facilities and find optimal sites for novel platforms that will increase access to dermatological consultations (i.e. teledermatology), especially among these high-risk subpopulations. Because 25% of the participants were enrolled in HMO and our dermatology clinic sample excluded HMO providers, the results may have been underestimated due to non-differential misclassification, and this was proven when HMO enrollees were excluded from the sensitivity analyses. After exclusion of HMO enrollees, the risk of thick tumor associated with longer travel distance to the nearest clinic was underestimated but remained higher among HW than NHW (Model 2 OR=1.5, 95%CI= 0.9–2.4). The risk estimate also remained higher among patients in high-poverty areas (Model 2 OR=1.2, 95%CI=1.0–1.5). Meanwhile, the average cost of services and appointment wait-time were still not significantly associated with the risk of thick tumor.

In addition to the contextual, potential and spatial barriers to access-to-care described above, institutional barriers exist that may hinder appropriate and timely access to care. These institutional barriers may explain why the U.S., despite being one of the wealthiest nations in the world, has the lowest life expectancies and worst health outcomes among high-income countries (National Research Council and Institute of Medicine, 2013). One institutional barrier is the lack of a universal or near- universal health insurance coverage provided by other high-income countries to their citizens. Before the passage of PPACA in the U.S. (2010), approximately 16% of the population was uninsured (DeNavas-Walt et al., 2011). Under PPACA, it was estimated that about 32 million uninsured legal residents will be covered and will have regular access to preventive services (2010; Congressional Budget Office). PPACA includes provisions for health insurers to cover evidence-based preventive services and increases in Medicaid physician fees to meet Medicare rates (Doherty, 2010), in the hopes of increasing physician acceptance of Medicaid patients and provision of preventive services. However, one recent study has found that increases in Medicaid payments may not substantially increase the utilization of preventive services recommended

by the U.S. Preventive Services Task Force (i.e. screening for cervical cancer, breast cancer, colorectal cancer, blood pressure and cholesterol) (Atherly and Mortensen, 2014). The study suggests that increases in Medicaid payments may not necessarily motivate health care providers, who are already not accepting Medicaid, to change their practice. In LAC, this is especially alarming because 91% of the surveyed dermatology clinics in the current study were already not accepting Medicaid enrollees. The use of other preventive services such as melanoma screening, may not significantly improve despite the increased Medicaid payments under PPACA, especially when there are no current national recommendations for them.

Instead of having one governmental body coordinating the management and allocation of public health services as is often the case in other high-income countries, the U.S. has a fragmented public health care system that is funded by a mixture of federal, state, local and private sources (National Research Council and Institute of Medicine, 2013). Among the poorest third of the population (who are also the most likely to be eligible for public health insurance), metropolitan areas in the U.S. lag behind those from Canada (that has a single payer health care system) in terms of cancer survival rate (Gorey et al., 1997; Gorey et al., 2000). The hybrid structure of the U.S. health care system may be contributing to the poor outcomes experienced by patients enrolled in public health insurance, as seen in the current and previous similar studies.

More research is needed to elucidate the direct role of a fragmented health care system in the delayed diagnosis of melanoma and, generally, in the U.S. health disadvantage relative to other high-income countries. Inadequate and substandard care may be stemming from poor availability of resources and poor coordination of resources, if they were available, and not solely from the health care component (National Research Council and Institute of Medicine, 2013). For example, HW cancer patients were more likely to forego medical care or treatment due to institutional barriers related to accommodation (e.g. long wait-time in the office, no available appointments) in compared to NHW (King et al., 2015). Moreover, funding for public health activities do not always match the need (Congressional Budget Office). To understand the U.S. health disadvantage, the Panel on Understanding Cross-National Health Differences (created by the National Research Council's Committee on Population and the Institute of Medicine's Board on Population Health and Public Health Practice) recommended the development or strengthening of the following: 1) standardized measures of health outcomes and determinants, 2) analytical approaches that account for longitudinal data, 3) stable funding to support long-term lines of inquiry, 4) use of evidence-based strategies to achieve national health objectives, 5) public health campaigns to increase awareness of the U.S. health disadvantage, and 6) assessment of the effects of policies on the nation's health and on cross-national health differences (National Research Council and Institute of Medicine, 2013).

Strengths and limitations

One limitation is brought about by edge effects which could skew the results for features near the artificial boundaries of our chosen study region. (Bailey and Gatrell, 1995) LAC is adjacent to other major metropolitan counties, all of which include melanoma cases and

additional clinics not evaluated in our study. To examine edge effects, we performed the analyses on a subset of patients residing within 20 km of the study region boundary (n=5,369) and found the same associations observed for the entire sample.

Patterns of health care use are influenced by rules governing access to specialists, with many health insurance plans requiring a primary care referral to see a dermatologist. Thus, access to a primary care clinician might be as important, if not more than, as proximity to a dermatology clinic. With the low number of uninsured or public health insurance enrollees having access to primary care, many would not have recognized the problem on their own, or see a primary care provider who would then make the referral to a dermatologist. In addition, having a regular source of care (not necessarily from a dermatologist) may also be an important predictor of late melanoma diagnosis. This variable tends to be a strong predictor of health care use across spectrum of services independent of insurance coverage or SES (Bartman et al., 1997; Ryan et al., 2001; Ryan et al., 1996; Sox et al., 1998). However, there is a severe shortage of primary care providers in the U.S., especially in low SES neighborhoods (Council on Graduate Medical Education, 2010; Petterson et al., 2012). Unless policies are enacted to address this increasing shortage and provide a more equitable distribution of physician workforce, the proportion of the population foregoing important preventative care like skin examinations will continue to increase. Studying the effects of regular source of care and delayed presentation of melanoma has been challenging in part due to a lack of readily available, high-quality data on patient-level use of primary care. Further research is needed to address the information gap and provide evidence to support the continued expansion of health insurance coverage (in terms of population and services covered), improvements in the quality of primary care received and elimination of traditional and institutional barriers to care.

This study, by providing truly population-based concurrent analysis of contextual, potential and spatial access-to-care in relation with melanoma thickness, adds to the current literature that is disproportionately focused on only one aspect of access-to-care. The large sample size also allowed for stratification by race/ethnicity and poverty levels and identification of specific high-risk subpopulations who would most benefit from targeted interventions. Unlike hospital-based studies or studies of screened populations (Cheng et al., 2014; Geller et al., 2009b; Pollitt et al., 2012; Ward et al., 2010) that are subject to participation bias, our study included ecological measures like clinic density, appointment wait-time, and cost of services that are unaffected by these participation biases. Thus, the risk estimates provided herein could be considered more consistent with population-based estimates.

Conclusion

In the U.S., population-based (or mass) screening may be impractical because it yields only 0.1–0.4% melanoma or melanoma in situ in the screened population (United States Preventive Services Task Force, 2001). With a 15% yield of histologically confirmed melanomas, the American Academy of Dermatology's (AAD) annual national screening and educational programs is actually faring well (Geller et al., 2003). However, the overwhelming majority of individuals turning up for screening are NHW, therefore, new strategies need to be adopted to reach other high-risk subpopulations such as HW.

One strategy that may improve current early melanoma detection programs is to identify, target and screen individuals who are at increased risk of presenting melanoma at later stages (Gordon and Rowell, 2015; Losina et al., 2007). Since 98% of patients diagnosed with localized melanoma continue to survive five years after their diagnosis (American Cancer Society California Division and Public Health Institute California Cancer Registry, 2008), and 89% of the total annual cost of melanoma treatment is spent on treating late-stage disease (Guy et al., 2015; Tsao et al., 1998), this targeted approach may decrease mortality rates and provide substantial economic savings to the public.

We found that high-risk subpopulations include those who utilized public health insurance programs, or were uninsured or paid out-of-pocket. In addition, higher educational attainment was associated with lower risk of thick melanomas. The effects of these variables differed between NHW and HW, and between high-poverty and low-poverty neighborhoods, indicating easily identifiable target populations for future screening efforts.

The low yield of population-based screening in the U.S. also precludes the USPSTF from recommending for or against routine skin cancer screening through whole-body examination (Bibbins-Domingo et al., 2016; Calonge et al., 2009; Wernli et al., 2016). Considering that about 40 million Americans would have to be screened to demonstrate a significant impact on mortality, controlled trials demonstrating mortality outcomes are not considered feasible in the United States where incidence rates of melanoma are relatively low (Geller, 2009; Wolff et al., 2009). Even in a country like Australia with high rates of melanoma, a randomized trial of population-based screening confirmed only 0.20% of the screened population to be melanomas (Aitken et al., 2002; Aitken et al., 2006). In order to have sufficient statistical power, the USPSTF recommends that future research on the effectiveness of skin examination in the U.S. may consider focusing on interventions that screen among high-risk subpopulations (Wernli et al., 2016).

Meanwhile, there is strong evidence to support the effectiveness of primary prevention that focuses on minimizing ultraviolet radiation exposure (Moyer and Force, 2012) (Community Preventive Services Task Force, 2016). In 2014, the U.S. Surgeon General released a Call to Action to Prevent Skin Cancer that included the following goals: 1) increase opportunities for sun protection in outdoor settings, 2) provide individuals with the information they need to make informed, healthy choices about ultraviolet radiation exposure, 3) promote policies that advance the national goal of preventing skin cancer, 4) reduce harms from indoor tanning, and 5) strengthen research, surveillance, monitoring, and evaluation related to skin cancer prevention (U.S. Department of Health and Human Services, 2014). Current state and local policies that support skin cancer prevention efforts have the potential to make broad and lasting public health impact (e.g. school-based sun-safety programs, restrictions on the use of indoor tanning devices, recommending health insurance plans to cover behavioral counseling for younger patients, regulating all sunscreen products), but more work is needed to address barriers to successful implementation of policies, sustain funding support for programs and evaluate the effectiveness of policies to curb the increasing rates of melanoma.

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Abbreviations

BA	Bachelor's degree
CI	confidence interval
CSP	Cancer Surveillance Program
CT	census tract
HMO	Health Maintenance Organization
HW	Hispanic white
LAC	Los Angeles County
NHW	non-Hispanic white
OR	odds ratio
PPO	Preferred Provider Organization
SES	socioeconomic status
U.S	United States
USPSTF	United States Preventive Services Task Force

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Table 1

Potential and spatial access-to-care of invasive melanoma cases, Los Angeles County, 2004–2013

	Non-Hispanic white			Hispanic white		
	Thin melanoma (≤1mm) n=5,638	Thick melanoma (>1mm) n=3,015	p ^a	Thin melanoma (≤1mm) n=432	Thick melanoma (>1mm) n=464	p ^a
	n (%)	n (%)		n (%)	n (%)	
Access-to-care factors						
Potential access-to-care						
Health insurance coverage ^b			<.001			<.001
Private	2,500 (44)	1,141 (38)		187 (43)	139 (30)	
Public	1,314 (23)	1,166 (39)		76 (18)	194 (42)	
Self-pay or uninsured	879 (16)	449 (15)		86 (20)	66 (14)	
Other	105 (2)	73 (2)		9 (2)	7 (2)	
Unknown	840 (15)	186 (6)		74 (17)	58 (12)	
Average visit cost (\$) ^c			0.029			0.102
Below median	3,211 (57)	1,778 (59)		287 (66)	286 (62)	
Above median	2,391 (42)	1,219 (40)		144 (34)	177 (38)	
Missing	36 (1)	18 (1)		1 (0)	1 (0)	
Average biopsy cost (\$) ^c			0.001			0.603
Below median	2,603 (46)	1,494 (49)		277 (64)	296 (64)	
Above median	2,999 (53)	1,503 (50)		154 (36)	167 (36)	
Missing	36 (1)	18 (1)		1 (0)	1 (0)	
Average time until in-person visit (days) ^c			0.399			0.262
Below median	4,376 (78)	2,323 (77)		328 (76)	366 (79)	
Above median	1,226 (22)	674 (22)		103 (24)	97 (21)	
Missing	36 (1)	18 (1)		1 (0)	1 (0)	
Spatial access-to-care						
Clinic density (per 100,000) ^d			0.002			0.231
No clinics	4,889 (87)	2,572 (89)		407 (94)	445 (96)	
1 to 20	189 (3)	87 (3)		10 (3)	7 (1)	

Access-to-care factors	Non-Hispanic white				Hispanic white			
	Thin melanoma (≤1mm) n=5,638		Thick melanoma (>1mm) n=3,015		Thin melanoma (≤1mm) n=432		Thick melanoma (>1mm) n=464	
	n (%)	n (%)	n (%)	p ^a	n (%)	n (%)	n (%)	p ^a
>20	555 (10)	225 (8)			15 (3)	12 (3)		
Missing	5 (0)	1 (0)			0 (0)	0 (0)		
Travel distance to the diagnosing facility (km)				0.413				0.415
Below median	2,026 (36)	1,420 (47)			189 (44)	210 (45)		
Above median	2,150 (38)	1,393 (46)			174 (41)	224 (48)		
Missing	1,462 (26)	202 (7)			69 (15)	30 (7)		
Travel distance to the nearest clinic (km)				0.006				0.415
Below median	2,239 (40)	1,225 (41)			133 (31)	125 (27)		
Above median	2,533 (45)	1,587 (53)			225 (52)	297 (64)		
Missing	866 (15)	203 (7)			74 (17)	42 (9)		

Note: Boldface indicates significant difference between thin and thick tumor groups ($p<0.05$).

^aP-value from Pearson's chi-square

^bSource of payment at the time of diagnosis

^cAverage values within 20 km of patient's residence at the time of diagnosis

^dAt the census tract-level

Association of tumor thickness at diagnosis to patient's general characteristics and access-to-care, Los Angeles County, 2004–2013

Table 2

Independent variables	Model 1 ^a	95% CI		Model 2 ^b	95% CI	
		L	U		L	U
General characteristics						
Age	Reference			Reference		
3 to 39						
40 to 64	1.41	1.19	1.68	1.38	1.16	1.64
65 and over	1.52	1.25	1.84	1.48	1.22	1.80
Sex						
Male	Reference			Reference		
Female	0.69	0.63	0.77	0.70	0.63	0.77
Race						
Non-Hispanic white	Reference			Reference		
Hispanic white	2.06	1.75	2.44	1.75	1.48	2.08
Other	1.35	1.05	1.74	1.29	0.99	1.67
Marital status						
Married/in domestic partnership	Reference			Reference		
Never married	1.30	1.15	1.48	1.26	1.11	1.44
Separated/divorced/widowed	1.74	1.52	1.99	1.68	1.47	1.93
Basis of coordinates						
Parcel	Reference			Reference		
Address range/street intersect	0.96	0.86	1.06	0.97	0.88	1.08
City, zip or state centroid	1.00	0.80	1.24	1.03	0.83	1.29
Contextual access-to-care ^c						
Not English proficient (%)						
Below median	Reference			Reference		
Above median	1.23	1.12	1.36	1.08	0.96	1.22
Have at least a BA degree (%)						
Below median	Reference			Reference		
Above median	0.67	0.61	0.74	0.70	0.62	0.78

Independent variables	Model 1 ^a	95% CI		Model 2 ^b	95% CI	
		L	U		L	U
Below poverty (%)						
Below median	Reference			Reference		
Above median	1.19	1.08	1.31	1.08	0.96	1.22
Median household income (\$)						
Below median	Reference			Reference		
Above median	0.81	0.74	0.90	1.03	0.90	1.19
No health insurance (%)						
Below median	Reference			Reference		
Above median	1.19	1.08	1.31	0.92	0.81	1.06
Do not own any vehicles (%)						
Below median	Reference			Reference		
Above median	1.07	0.97	1.17	1.04	0.94	1.15
Use public transportation (%)						
Below median	Reference			Reference		
Above median	1.16	1.05	1.28	1.06	0.95	1.18
Potential access-to-care						
Health insurance coverage						
Private	Reference			Reference		
Public	1.78	1.56	2.03	1.80	1.58	2.06
Self-pay or uninsured	1.21	1.05	1.38	1.19	1.04	1.36
Other	1.02	0.75	1.39	0.94	0.69	1.28
Average visit cost (\$) ^d						

Note: BA=Bachelor's degree; CI=confidence interval; L=lower; U=upper. Boldface indicates significant difference between thin and thick tumor groups ($p<0.05$).

^a Adjusted for age, sex, race/ethnicity, marital status, basis of coordinates and health insurance coverage

^b Adjusted for age, sex, race/ethnicity, marital status, basis of coordinates, health insurance coverage, contextual access-to-care (English proficiency, education, poverty level, household income, health insurance, vehicle ownership and use of public transportation) and clinic density

^c At the census tract-level

Table 3
Association of tumor thickness at diagnosis to patient's general characteristics and access-to-care, Los Angeles County, 2004–2013

Independent variables	Non-Hispanic white				Hispanic white			
	95% CI		95% CI		95% CI		95% CI	
	Model 1 ^a	L	U	Model 2 ^b	L	U	Model 1 ^a	Model 2 ^b
General characteristics								
Age	Reference			Reference			Reference	
3 to 39								
40 to 64	1.58	1.30	1.93	1.54	1.26	1.87	0.81	0.52
65 and over	1.74	1.40	2.17	1.69	1.35	2.11	0.96	0.58
Sex								
Male	Reference			Reference			Reference	
Female	0.69	0.62	0.77	0.70	0.62	0.78	0.63	0.64
Marital status								
Married/domestic partnership	Reference			Reference			Reference	
Never married	1.30	1.14	1.49	1.27	1.10	1.46	1.24	0.82
Separated/divorced/widowed	1.72	1.50	1.99	1.68	1.45	1.94	1.74	1.06
Basis of coordinates								
Parcel	Reference			Reference			Reference	
Address range/street intersect	0.95	0.85	1.06	0.97	0.86	1.08	1.00	0.71
City, zip or state centroid	1.02	0.81	1.29	1.06	0.83	1.34	0.74	0.35
Contextual access-to-care^c								
Not English proficient (%)	Reference			Reference			Reference	
Below median								
Above median	1.19	1.08	1.32	1.08	0.96	1.22	1.34	0.87
Have at least a BA degree (%)								
Below median	Reference			Reference			Reference	
At and above median	0.70	0.63	0.78	0.73	0.64	0.82	0.52	0.33
Below poverty (%)							0.52	0.30

Independent variables	Non-Hispanic white						Hispanic white					
	95% CI			95% CI			95% CI			95% CI		
	Model 1 ^a	L	U	Model 2 ^b	L	U	Model 1 ^a	L	U	Model 2 ^b	L	U
Below median	Reference			Reference			Reference			Reference		
Above median	1.16	1.04	1.28	1.08	0.95	1.23	1.46	1.01	2.11	1.29	0.78	2.13
Median household income (\$)												
Below median	Reference			Reference			Reference			Reference		
Above median	0.83	0.75	0.92	1.00	0.86	1.15	0.79	0.53	1.18	1.87	0.98	3.56
No health insurance (%)												
Below median	Reference			Reference			Reference			Reference		
Above median	1.13	1.02	1.26	0.89	0.78	1.03	1.77	1.16	2.70	1.72	0.88	3.35
Do not own any vehicles (%)												
Below median	Reference			Reference			Reference			Reference		
Above median	1.02	0.93	1.13	1.01	0.91	1.13	1.31	0.94	1.82	1.23	0.84	1.80
Use public transportation (%)												
Below median	Reference			Reference			Reference			Reference		
Above median	1.10	1.00	1.22	1.02	0.91	1.15	1.44	1.01	2.04	1.20	0.79	1.82
Potential access-to-care												
Health insurance coverage												
Private	Reference			Reference			Reference			Reference		
Public	1.61	1.39	1.85	1.65	1.43	1.90	2.86	1.92	4.25	2.67	1.78	4.01
Self-pay or uninsured	1.17	1.01	1.36	1.16	1.00	1.34	1.17	0.76	1.80	1.18	0.76	1.84
Other	0.97	0.70	1.35	0.90	0.65	1.26	1.12	0.36	3.49	0.93	0.29	2.97
Average visit cost (\$) ^d												
Below median	Reference			Reference			Reference			Reference		
Above median	0.85	0.77	0.95	0.98	0.87	1.10	1.10	0.79	1.54	1.08	0.74	1.56
Average biopsy cost (\$) ^d												
Below median	Reference			Reference			Reference			Reference		
Above median	0.88	0.79	0.97	0.95	0.85	1.06	0.96	0.69	1.35	1.03	0.73	1.47
Average number of days before the next available appointment ^d												

Independent variables	Non-Hispanic white						Hispanic white					
	95% CI			95% CI			95% CI			95% CI		
	Model 1 ^a	L	U	Model 2 ^b	L	U	Model 1 ^a	L	U	Model 2 ^b	L	U
Below median	Reference			Reference			Reference			Reference		
Above median	1.15	1.02	1.30	0.99	0.87	1.13	0.97	0.66	1.41	0.95	0.64	1.42
Spatial access-to-care												
Clinic density(per 100,000) ^c	Reference			Reference			Reference			Reference		
No clinics												
1 to 20	0.84	0.63	1.13	0.90	0.66	1.21	0.84	0.26	2.71	1.21	0.35	4.22
>20	0.71	0.59	0.86	0.79	0.65	0.95	0.65	0.26	1.62	0.74	0.29	1.91
Travel distance to the diagnosing facility (km)	Reference			Reference			Reference			Reference		
Below median												
Above median	1.03	0.92	1.14	0.99	0.89	1.11	1.04	0.75	1.46	1.09	0.77	1.54
Travel distance to the nearest clinic (km)	Reference			Reference			Reference			Reference		
Below median												
Above median	1.24	1.12	1.37	1.13	1.01	1.26	1.44	1.02	2.03	1.32	0.91	1.91

Note: BA=Bachelor's degree; CI=confidence interval; L=lower; U=upper. Boldface indicates significant difference between thin and thick tumor groups ($p<0.05$).

^a Adjusted for age, sex, marital status, basis of coordinates and health insurance coverage

^b Adjusted for age, sex, marital status, basis of coordinates, health insurance coverage, contextual access-to-care (English proficiency, education, poverty level, household income, health insurance, vehicle ownership and use of public transportation) and clinic density

^c At the census tract-level

^d Average values within 20 km of patient's residence at the time of diagnosis

Association of tumor thickness at diagnosis to patient's general characteristics and access-to-care, Los Angeles County, 2004–2013.

High-poverty census tracts							Low-poverty census tracts						
Independent variables		95% CI			95% CI			95% CI			95% CI		
		Model 1 ^a	L	U	Model 2 ^b	L	U	Model 1 ^a	L	U	Model 2 ^b	L	U
General characteristics													
Age													
3 to 39	Reference				Reference			Reference			Reference		
40 to 64	1.53	1.22	1.92	1.48	1.18	1.85	1.25	0.96	1.63	1.23	0.94	1.61	
65 and over	1.64	1.27	2.12	1.59	1.23	2.06	1.37	1.02	1.85	1.36	1.01	1.84	
Sex													
Male	Reference				Reference			Reference			Reference		
Female	0.70	0.61	0.81	0.71	0.62	0.81	0.68	0.58	0.79	0.68	0.58	0.79	
Race													
Non-Hispanic white	Reference				Reference			Reference			Reference		
Hispanic white	2.16	1.76	2.64	1.92	1.56	2.36	1.63	1.19	2.23	1.44	1.05	1.99	
Other	1.47	1.06	2.03	1.43	1.03	2.00	1.14	0.75	1.73	1.12	0.73	1.70	
Marital status													
Married/in domestic partnership	Reference				Reference			Reference			Reference		
Never married	1.25	1.06	1.47	1.27	1.07	1.50	1.26	1.03	1.55	1.25	1.02	1.54	
Separated/divorced/widowed	1.49	1.25	1.78	1.49	1.25	1.78	2.01	1.64	2.47	1.97	1.60	2.43	
Basis of coordinates													
Purcell	Reference				Reference			Reference			Reference		
Address range/street intersect	0.88	0.77	1.01	0.92	0.80	1.06	1.01	0.87	1.18	1.04	0.89	1.21	
City, zip or state centroid	0.72	0.53	0.99	0.75	0.55	1.03	1.39	1.02	1.89	1.49	1.08	2.03	
Contextual access-to-care ^c													
Not English proficient (%)	Reference				Reference			Reference			Reference		
Below median													
Above median	1.18	1.02	1.37	0.98	0.82	1.18	1.21	1.05	1.40	1.17	0.99	1.38	
Have at least a BA degree (%)													

Independent variables	High-poverty census tracts						Low-poverty census tracts					
	95% CI			95% CI			95% CI			95% CI		
	Model 1 ^a	L	U	Model 2 ^b	L	U	Model 1 ^a	L	U	Model 2 ^b	L	U
Below median	Reference			Reference			Reference			Reference		
Above median	0.64	0.55	0.74	0.65	0.55	0.77	0.73	0.63	0.84	0.73	0.62	0.86
Median household income (\$)												
Below median	Reference			Reference			Reference			Reference		
Above median	0.82	0.69	0.96	0.94	0.77	1.15	0.90	0.76	1.06	1.15	0.94	1.40
No health insurance (%)												
Below median	Reference			Reference			Reference			Reference		
Above median	1.14	0.97	1.33	0.92	0.75	1.11	1.12	0.95	1.30	0.94	0.78	1.13
Do not own any vehicles (%)												
Below median	Reference			Reference			Reference			Reference		
Above median	0.96	0.84	1.10	0.97	0.84	1.12	1.08	0.94	1.25	1.10	0.95	1.28
Use public transportation (%)												
Below median	Reference			Reference			Reference			Reference		
Above median	1.03	0.89	1.19	1.00	0.86	1.17	1.20	1.03	1.38	1.14	0.98	1.33
Potential access-to-care												
Health insurance coverage												
Private	Reference			Reference			Reference			Reference		
Public	1.93	1.62	2.29	1.97	1.65	2.34	1.58	1.30	1.93	1.60	1.31	1.96
Self-pay or uninsured	1.24	1.03	1.50	1.22	1.01	1.47	1.17	0.97	1.43	1.17	0.96	1.43
Other	0.94	0.64	1.36	0.91	0.62	1.33	1.17	0.66	2.06	1.12	0.63	1.98
Average visit cost (\$) ^d												
Below median	Reference			Reference			Reference			Reference		
Above median	0.88	0.77	1.00	1.04	0.90	1.21	0.85	0.73	0.98	1.00	0.85	1.18
Average biopsy cost (\$) ^d												
Below median	Reference			Reference			Reference			Reference		
Above median	0.88	0.77	1.00	0.97	0.84	1.11	0.85	0.74	0.98	0.92	0.80	1.07
Average number of days before the next available appointment ^d												
Below median	Reference			Reference			Reference			Reference		

Independent variables	High-poverty census tracts						Low-poverty census tracts					
	95% CI			95% CI			95% CI			95% CI		
	Model 1 ^a	L	U	Model 2 ^b	L	U	Model 1 ^a	L	U	Model 2 ^b	L	U
Above median	1.06	0.90	1.25	0.89	0.75	1.06	1.24	1.05	1.45	1.03	0.86	1.24
Spatial access-to-care												
Clinic density (per 100,000) ^c												
No clinics	Reference			Reference			Reference			Reference		
1 to 20	0.75	0.49	1.16	0.87	0.56	1.35	1.00	0.69	1.45	1.01	0.70	1.47
> 20	0.71	0.54	0.92	0.81	0.62	1.07	0.69	0.54	0.89	0.76	0.59	0.97
Travel distance to the diagnosing facility (km)												
Below median	Reference			Reference			Reference			Reference		
Above median	1.02	0.89	1.16	0.95	0.83	1.09	1.08	0.93	1.25	1.07	0.92	1.24
Travel distance to the nearest clinic (km)												
Below median	Reference			Reference			Reference			Reference		
Above median	1.35	1.18	1.55	1.22	1.05	1.41	1.15	1.00	1.33	1.08	0.93	1.25

Note: BA=Bachelor's degree; CI=confidence interval; L=lower; U=upper. Boldface indicates significant difference between thin and thick tumor groups ($p < 0.05$).

^aAdjusted for age, sex, race/ethnicity, marital status, basis of coordinates and health insurance coverage.

^bAdjusted for age, sex, race/ethnicity, marital status, basis of coordinates, health insurance coverage, contextual access-to-care (English proficiency, education, household income, health insurance, vehicle ownership and use of public transportation) and clinic density.

^cAt the census tract-level.

^dAverage values within 20 km of patient's residence at the time of diagnosis.