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Contribution of Geographic Location to Disparities in Ovarian Cancer Treatment

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1. Introduction

By the end of 2018, approximately 22, 240 women in the U.S. are estimated to receive an ovarian cancer (OC) diagnosis.[1] Considered the most fatal of the gynecological cancers,[2] this malignancy kills more than 14,000 U.S. women each year.[1] Fortunately, substantial advances in treatment in the last four decades have led to gradual but consistent improvements in survival.[3] Stage-specific guidelines have been established by the National Comprehensive Cancer Network (NCCN)[4] for best care practices in treating OC and adherence to these recommendations has been validated as a significant predictor of disease-specific survival.[5] Despite these evidence-based guidelines, inequities in access to and delivery of appropriate care still exist.

Although most efforts to understand the drivers of OC disparities have largely focused on factors such as race and socioeconomic status,[6–13] there has been growing consideration of the role that geographic location may play.[6,8,14–17] A study of national data from the National Cancer Institute's Surveillance, Epidemiology, and End Results (SEER) Program explored spatial variations in the delivery of OC treatment for Medicare recipients and found discrepancies existed by Hospital Referral Region.[14] In British Columbia, despite

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Verónica Vieira and Robert Bristow conceived the study design. Jenny Chang and Argyrios Ziogas acquired and assembled the data. Carolina Villanueva performed the analyses. Scott Bartell and Verónica Vieira provided technical support in the analysis. All authors provided input on the interpretation of results. Carolina Villanueva and Verónica Vieira drafted the initial manuscript. All authors read, reviewed, and approved the final manuscript.

theoretically having equal health care access under a single-payer system, differences were found in treatment practices by health authority region.[15] Even with rising consensus that receiving specialized care is critical for OC outcomes,[6,8,14–24] a U.S. nationwide study emphasized the disparities in access to gynecological oncologists, highlighting their concentration in metropolitan-centers.[16] The vast geographic areas without specialists represent a geographic barrier for those who must cover greater distances to reach them.

The objective of the current study is to examine how geocoded residence at diagnosis contributes to receiving care that is compliant with OC NCCN treatment guidelines in California (CA) among women of all stages, while exploring differences by race/ethnicity, SES, and insurance. CA accounts for 11% of all ovarian cancer cases diagnosed nationally and is highly relevant as a standalone study setting because of the large number of cases and its racial/ethnic diversity.

2. Methods

2.1. Study Population

We used a retrospective study design to examine the relationship between residential address at diagnosis and adherence to NCCN treatment guidelines. All cases of invasive epithelial OC diagnosed in CA between January 1, 1996 and December 31, 2014 were ascertained from the California Cancer Registry (CCR), with follow up data obtained through December 31, 2016. Reporting to the CCR within 6 months of diagnosis is close to 99%, with follow up nearly as high (95%).[25,26] CCR data was linked with California's Office of Statewide Health Planning and Development (OSHPD) patient discharge data.

Women of all OC stages (International Federation of Gynecology and Obstetrics (FIGO) - Stage I-IV) were eligible for inclusion. Cases 18 years of age or older at time of diagnosis were identified from the CCR using the International Classification of Disease Codes for Oncology (ICD-O-3 C56.9). The analysis was restricted to women with complete clinical information and no prior history of OC. After exclusions, presented in Figure 1, a total of 29,844 women diagnosed with incident invasive epithelial OC were included in the analyses. The study was approved by the Institutional Review Board of the University of California, Irvine (UCI 14–66/HS# 2014–1476).

2.2 Study Data

The primary outcome was non-adherence to stage-specific NCCN treatment guidelines, examined as a binary variable (adherent vs. non-adherent). Non-adherence required either surgical or chemotherapy treatment be non-adherent to the NCCN guidelines of women's respective diagnosis period.[19,27–32] Surgical guideline adherence for stages I-IIIB was a minimum of oophorectomy (± hysterectomy), pelvic and/or para-aortic lymph node biopsy, and omentectomy. Adherence for stages IIIC-IV was a minimum of oophorectomy (± hysterectomy) and omentectomy. For chemotherapy, receiving no adjuvant treatment was only appropriate for early stage and grade (stages IA-IB, grades 1–2). For all other stages (stage IC-IV) and grade 3 disease, multi-agent chemotherapy was guideline adherent.

Chemotherapy must have been delivered subsequent to surgery, with the exception of stages IIIC-IV, in which it could have been received before or after surgery.[19,27–32]

Several important patient characteristics were included as predictors: age at diagnosis, race/ethnicity, marital status, SES, insurance type, diagnosis year, tumor characteristics, and the Deyo-adapted Charlson Comorbidity Score.[33,34] Race/ethnicity was categorized as non-Hispanic White, non-Hispanic Black, Hispanic, Asian/Pacific Islander, and American Indian/Other. Insurance type was categorized as managed care, Medicare, Medicaid, other insurance, not insured, and unknown. SES was stratified into quintiles using the Yost score[35] for patients diagnosed prior to 2006 and the Yang index[36] for those with a diagnosis after 2006. Tumor characteristics included tumor grade, size, histology type, and stage at diagnosis. The observed-to-expected (O/E) adherence ratio of women's initial reporting hospital was included as a measure of hospital quality.[19] This metric was calculated as the number of OC cases that received NCCN adherent care divided by the amount expected to receive standard care for that hospital, distributed into quartiles, and classified by annual hospital case volume.[19] High quality hospitals were in the highest O/E quartile and had ≥5 cases/year.

To assess the role of geographic location on accessibility and potential barriers to treatment, we calculated the distance from each woman's geocoded residential address at the time of diagnosis to the geocoded location of their initial reporting hospital. We also calculated how far each woman lived from the nearest high-quality hospital. Each variable was categorized into quintiles, with distances for both measures calculated with a geographic information system (GIS) using the Streetmaps routing dataset in the network analysis extension (ArcGIS version 10.4.1, ESRI; Redlands, CA).

2.3 Statistical Analysis

The main predictor variable of interest was geographic location as a smooth function of women's geocoded residential location at diagnosis. We used generalized additive models (GAMs) to estimate the effect of a locally-weighted loess smoother of longitude and latitude on the log odds of not receiving adherent treatment while also adjusting for covariates.[37,38] Details of the methods used are described elsewhere.[38] Briefly, log odds of adherence was computed at thousands of locations points throughout California holding all other covariables constant, using the average odds for all of California as the referent group. Odds were not computed for areas with very few or no cases.[8] The amount of smoothing depends on the span size, which represents the proportion of cases used locally to calculate the log odds at each point. The span size of 0.3 was chosen because it minimized the Akaike's Information Criterion (AIC) for the majority of the models.[37,38]

Our base model examined the effect of residential location, while adjusting only for age and cancer characteristics at diagnosis. A fully-adjusted model additionally adjusted for demographic and treatment factors: SES, race/ethnicity, insurance type, marital status, quality of reporting hospital, comorbidities, and the two distance variables. Any differences in geographic areas of increased or decreased risk between the base and fully-adjusted models indicate that the additional demographic and treatment factors were affecting geographic variation in adherent care. We also conducted stage-stratified analyses.

Permutation tests were used to calculate a global p-value for the importance of location. We produced color maps for each model displaying the odds ratios for treatment non-adherence throughout California, with contour lines delineating geographic areas that excluded odds ratios of 1. We also conducted Chi Square tests for differences between racial/ethnic, SES, and insurance groups across the distribution of distance variables. Statistical modeling and mapping were done in R version 3.4.0 using the MapGAM package.

3. Results

Patient characteristics are detailed in Table 1, with the case distribution shown in Figure 2. Of the 29,844 cases included in the analysis, 9,734 (32.6%) women were diagnosed at early stages (Stage1 and Stage2). The majority of the population was non-Hispanic White (63.4%) and the median age at time of diagnosis was 60 years old. Only 11,419 (38.3%) of all patients received care adherent to the National Comprehensive Care Network (NCCN) treatment guidelines. Women with Stage 3 disease were more likely to receive adherent care as compared to those diagnosed in early stages or Stage 4 (52.8% versus 25.2% and 34.2%, respectively).

3.1 Spatial Analysis of Treatment Adherence

Residential location was significantly associated with non-adherence to NCCN treatment guidelines among California women diagnosed with OC. All analyses, including stage-stratified models, resulted in a highly significant global test for location (<0.001). Compared to base model odds ratios (ORs) adjusted for only age and cancer characteristics for all stages (OR range: 0.46–1.57), fully-adjusted ORs were attenuated in some locations, but increased in other areas (OR range: 0.70–1.89). Figure 3 shows the protective effects observed in northern California were attenuated and no longer present in the San Francisco Bay area after full adjustment. Although the reduced risk observed in the southern-most portion of California was no longer present after full adjustment, risk in northern Los Angeles County and western Kern County increased. Spatial variability in risk of non-adherent treatment with the fully-adjusted models indicates geographic disparities in adherent treatment that are not explained by distance to initial reporting hospital, distance from the nearest high-quality hospital, or the other demographic and treatment variables included in our analyses.

Patterns of geographic risk for NCCN non-adherence varied across the different stage-stratified analyses. Regions of increased and decreased risk in the early stage analyses differed greatly from the other stages (comparison of Figure 3 to Figure 4). When controlling for age and cancer characteristics alone, we identified areas of increased risk of non-adherent treatment for early stage OC in mid-Central Valley and decreased risk in Northern California (OR range: 0.49–2.90). After full adjustment of the early stage model, there is no longer an association in northern California and San Diego County; however, Ventura and Santa Barbara Counties in the Central Coast become largely protective (OR range: 0.49–2.90). Models for Stages 3 and 4 display similar patterns to those of all stages combined although areas of higher and lower risk are smaller (Figure 4) and the magnitude of ORs are attenuated (OR ranges 0.61–2.13 and 0.47–1.86 for Stages 3 and 4 respectively).

Associations between all-stage non-adherent care and additional variables included in the spatial model are presented in Table 2. Increasing distance traveled to receive care decreased non-adherence ORs. Compared to patients living <6km of their initial reporting facility, those traveling >32km had decreased odds (OR=0.76, 95%CI=0.70–0.84) of receiving care that deviated from the NCCN guidelines. Increasing distance traveled to receive care was significantly protective against receiving non-adherent care for those in early stages (Table 3). Compared to women in closest proximity to a high-quality hospital (within 9km), living >48km was a significant deterrent to receiving adherent care for women diagnosed in early stages. Patterns with distance were similar for Stages 3 and 4 but generally not significant (not shown).

3.3 Geographic Disparities

The distribution of distance traveled to the reporting hospital by patient characteristics are shown in Table 4. Greater proportions of women treated at high-quality facilities traveled further for care. Among women reported by a high-quality hospital, more than a third (38.1%) lived within 9km, whereas only 9.3% lived >48km (Table 5). In contrast, women reported by low quality hospitals tended to live further from high-quality hospitals (31.4% in furthest category vs. 11.8% in closest).

Non-Hispanic White women and American Indian/Other race made up the largest proportions of women traveling >32km for care (Table 4). Non-Hispanic Black women were the least likely to travel greater distances for care across all analyses. Overall, women diagnosed in Stage 4 were the least likely to travel far, regardless of race, SES, or insurance (data not shown). Noteworthy, Asian/Pacific Islanders (30.4%) and Non-Hispanic Blacks (21.8%) made up the largest proportion of those living <9km of the closest high-quality hospital (Table 5). While less than 10% of women of the highest SES lived >48km from a high-quality hospital, more than 25% of the lower SES quintiles lived >48km.

4. Discussion

Overall, just over one third of women received NCCN guideline-adherent care. This is possibly a result of comorbidities, disease progression, access to specialized facilities, and lower SES.[5–7,12,13,39] Studies examining other cancers have shown similar low rates (<50%) of adherence to NCCN guidelines.[40,41] The current study found residential location to be significantly associated with the likelihood of receiving NCCN adherent treatment for women diagnosed with OC. Due to a growing awareness of the impact of residential location on health and the development of more sophisticated analysis tools, the value of geospatial research in cancer is increasing.[42] With the availability of geocoded addresses and the use of GAMs, we identified disparities within the state of California where women were more or less at risk of non-adherent care, despite adjusting for numerous important factors and further showed that the impact of location depended on stage at diagnosis. This methodology was previously used to examine late-stage OC survival disparities across California census tracts.[8]

Differences in spatial patterns of care are increasingly being recognized in the OC literature. One population-based study exploring geographic patterns in treatment delivery and

epithelial OC mortality by Health Referral Regions found hospital region to be associated with regional discrepancies in cancer-specific surgery, with women in more remote areas less likely to receive it.[14] Our results also show that women living in remote areas of central California, especially those diagnosed at early stages, are more vulnerable to receiving substandard care. Although there is a low density of high-quality centers in nonmetropolitan areas, the risk of treatment non-adherence in California differed depending on residential location. While patients living in rural areas of Northern California had favorable odds, those residing in counties encompassing greater Los Angeles received nonstandard care despite the availability of high-quality centers.

It is well documented that the location of initial treatment for OC is important, in particular high-volume and high-quality centers showing superior outcomes.[19,20,22,43] A comprehensive cancer center examining its own patients' travel distance found that those residing farthest from the hospital had worse cervical cancer outcomes,[44] yet a similar analyses of gynecological malignancies treated at a National Cancer Institute-designated center found women living less than 10 miles were less likely to be treatment compliant although those making the longest journey had greater mortality before treatment completion.[45] We found women were more likely to access a high-quality hospital if they lived close to one, an association similarly observed by Tracey and colleagues.[17] They found more than half of women living within 5km of high-quality hospitals utilized these facilities compared to 16% of women in the farthest quintile.[17]

The considerable financial challenges already faced coupled with the additional burden that travel poses for women diagnosed with OC must be acknowledged.[45] Travel is a geographic barrier to treatment and may disproportionately affect those of lower SES,[46] a point illustrated by their overall remoteness from high-quality centers. The implications of geographic access and travel are worth noting, given that women of lower SES and with safety-net insurance or uninsured were less likely to travel for care, obtain care at quality centers, or receive NCCN guideline treatment. Furthermore, women may choose to stay local for care. One study found that approximately 20% of women indicated that they would not travel over 50 miles for care, despite the potential survival advantages.[47] This may be particularly true for older women, those with comorbidities, or with limited social support. Greater distances may be less viable for women who may be managing multiple conditions.[48] We found women with two or more comorbidities and over 65 years were less likely to travel farther, which is consistent with prior work that older age is associated with shorter journeys.[24,48]

The present study has several noteworthy features. Among them is the large sample size, with almost 20 years of data available from the CCR, a registry with demonstrated reliability. Additionally, the investigation of geocoded residential location and its differing effects on OC treatment adherence by stage and social demographics is novel. Unlike previous studies that used zip code and census block variables as spatial proxies, utilizing an individual-level measure of patient location allows for a more accurate assessment of the effect of geographic location. Furthermore, the network analyst tool in GIS provided a more precise calculation of travel distance. We were also able to adjust for several important covariates including comorbidity which has been shown to be a main reason for failure to

complete chemotherapy.[39] Lastly, the GAM framework is particularly useful for investigating nonlinear geographic disparities while accounting for known risk factors.

The study is limited by the potential for reporting bias and the presence of unmeasured confounders given reliance on previously collected registry data. Furthermore, the collection and interpretation of CCR data may be limited by the possibility that reporting facilities are not the main treating hospital, satellite hospitals may report under one hospital, and chemotherapy treatment may be underreported. However, these are thought to be uncommon and unlikely to influence the results in this secondary analysis of large population-based data. Also, we cannot account for several potentially important access characteristics such as travel times and utilization or availability of public transportation. We assumed patients would drive the shortest route between their residence and hospitals to compute distances. However, when reliable transportation is unavailable, difficult, or expensive, travel may pose additional burdens to patients of lower SES. Another limitation is that the CCR does not collect information on the treating physician's OC case volume or their medical specialty. These characteristics may vary geographically and have been previously found to be predictors of treatment adherence and survival.[49–51]

5. Conclusions

Quality care is vital to decreasing OC mortality, yet the majority of women do not receive it. Future research should examine how location differentially affects access to care and impacts survival. Non-Hispanic Black women, those of lower SES and non-married women were less likely to travel far for care and were more likely to receive non-adherent treatment. Spatial analyses of geographic barriers, using linear and nonlinear methods may provide an opportunity for targeted intervention to broaden access to care among vulnerable populations. Providing transportation, opening satellite clinics, employing patient navigators, and ensuring that those services are covered by all insurance carriers are potential avenues to facilitate access to high-quality care, ultimately improving OC survival overall.[16,45]

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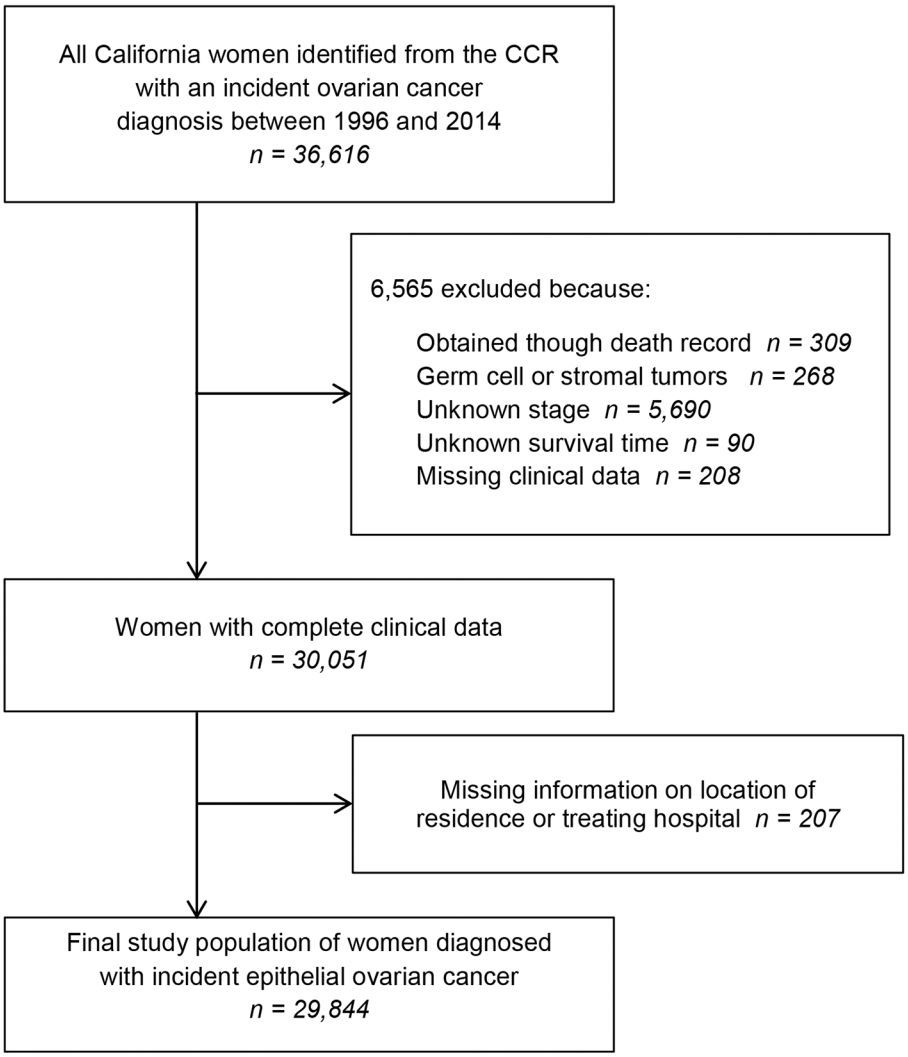

Figure 1: Study Population Exclusions

This diagram details how patients diagnosed between 1996 to 2014 were included in the study. CCR stands for the California Cancer Registry.

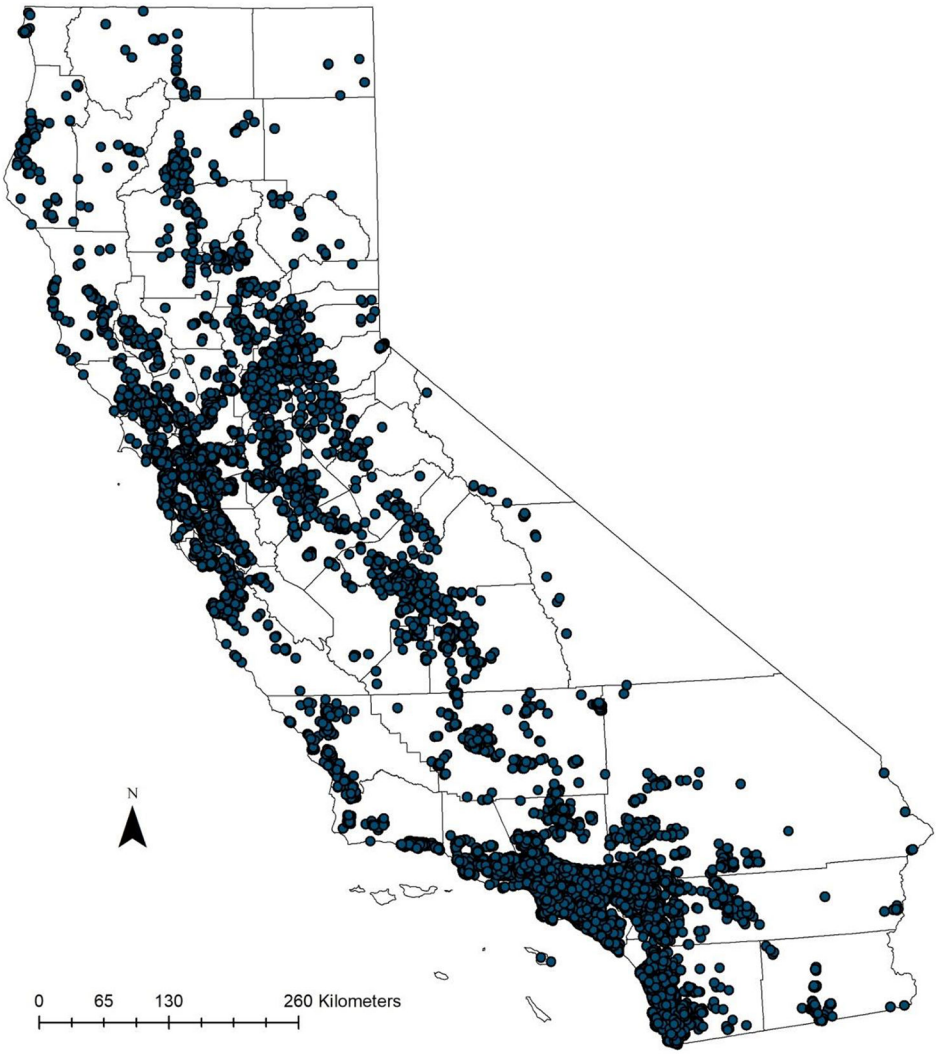

Figure 2:
Epithelial Ovarian Cancer Case Distribution in California between 1996 – 2014

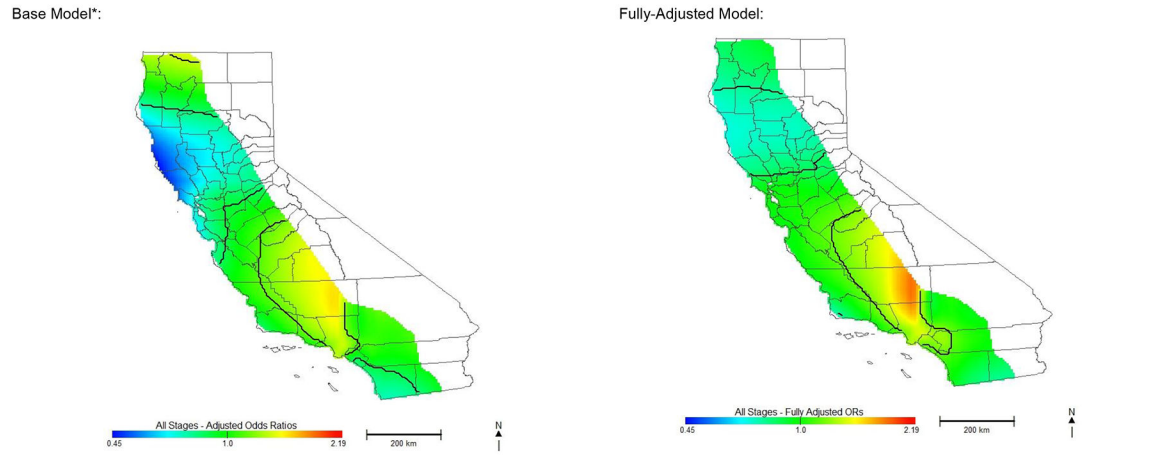

Figure 3: Odds of Receiving Non-Adherent Care for Ovarian Cancer in California

Effect of geographic location on risk of receiving non-adherent National Comprehensive Cancer Network guideline treatment for invasive epithelial ovarian cancer.

*Base model is adjusted for age and cancer characteristics only

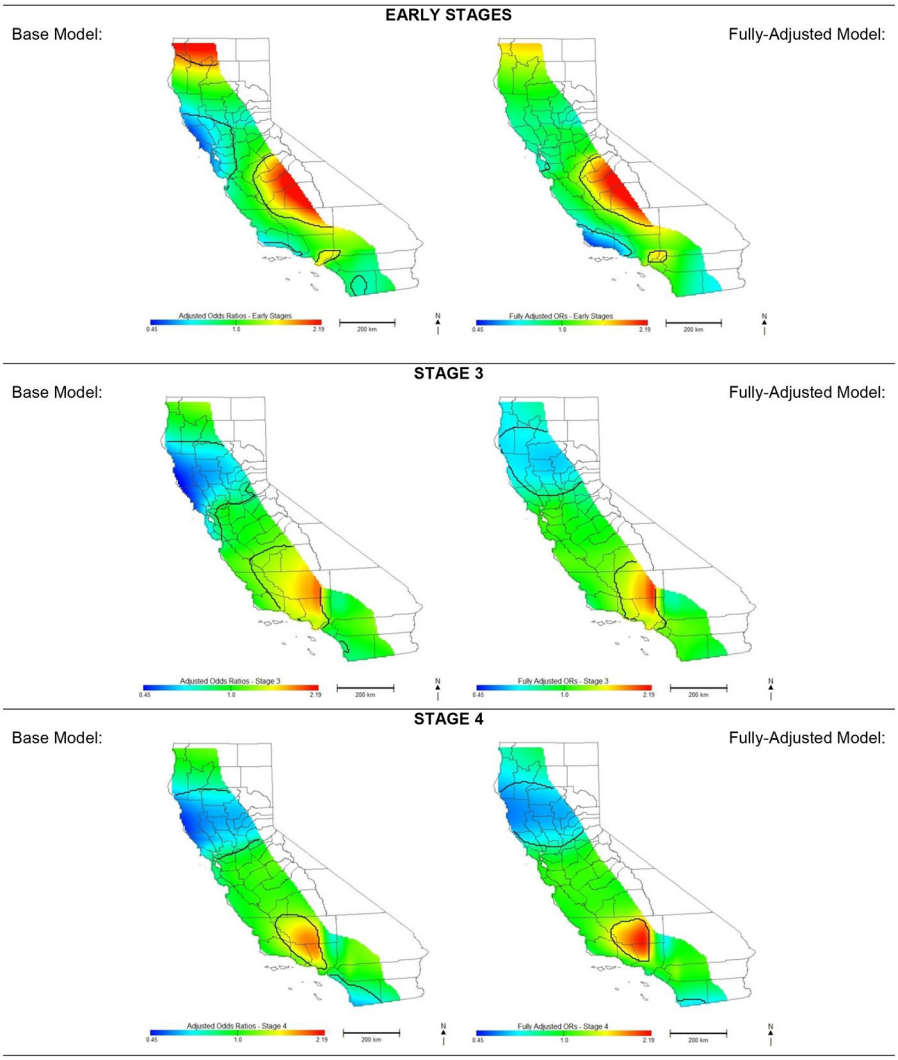

Figure 4: Odds of Receiving Non-Adherent Care for Ovarian Cancer in California

Effect of geographic location on risk of receiving non-adherent National Comprehensive Cancer Network guideline treatment for invasive epithelial ovarian cancer, stratified by stage. Early stages includes stage 1 and stage 2.

*Base model is adjusted for age and cancer characteristics only.

Table 1:

Patient Characteristics by NCCN Treatment Adherence (n=29,844)

Characteristic	Treatment Adherent		Treatment Non-Adherent	
	N	%	N	%
Total	11419	38.3	18425	61.7
Age Group				
18–44	1511	35.9	2699	64.1
45–54	2806	43.7	3617	56.3
55–64	3359	46.5	3862	53.5
65+	3743	31.2	8247	68.8
Race/Ethnicity				
Non-Hispanic White	7533	39.8	11387	60.2
Non-Hispanic Black	424	29.9	992	70.1
Hispanic	2020	35.1	3729	64.9
Asian/PI	1378	38.7	2186	61.3
American Indian/Other	64	32.8	131	67.2
Socioeconomic Status				
Lowest SES	1222	30.3	2815	69.7
Lower-Middle SES	1878	34.6	3557	65.4
Middle SES	2374	37.5	3950	62.5
Higher-Middle SES	2769	40.4	4091	59.6
Highest SES	3176	44.2	4012	55.8
Insurance Type				
Managed Care	5830	41.2	8320	58.8
Medicare	2438	31.9	5215	68.1
Medicaid	1001	36.7	1724	63.3
Other Insurance	1636	42.8	2189	57.2
Not insured	275	30.9	614	69.1
Unknown	239	39.7	363	60.3
Marital Status				
Not Married	5029	34.2	9659	65.8
Married	6390	42.2	8766	57.8
Charlson Comorbidity Score				
CCS 0	5931	41.7	8288	58.3
CCS 1	2743	40.3	4064	59.7
CCS 2+	2078	30.9	4648	69.1
CCS Unknown	667	31.9	1425	68.1
Stage				
Stage 1	1720	23.8	5518	76.2
Stage 2	731	29.3	1765	70.7
Stage 3	5943	52.8	5320	47.2
Stage 4	3025	34.2	5822	65.8

Characteristic	Treatment Adherent		Treatment Non-Adherent	
	N	%	N	%
Hospital Quality Measure				
Low	1912	27.4	5078	72.6
Intermediate	6533	37.8	10742	62.2
High	2974	53.3	2605	46.7
Distance Traveled to Care				
<6 km	1911	32.0	4058	68.0
6–9 km	2133	35.7	3836	64.3
10–16 km	2262	37.9	3706	62.1
17–32 km	2358	39.5	3611	60.5
>32 km	2755	46.2	3214	53.8
Closest High Quality Hospital				
<9 km	2501	41.9	3468	58.1
9–14 km	2247	37.6	3722	62.4
15–24 km	2228	37.3	3740	62.7
25–48 km	2289	38.3	3680	61.7
>48 km	2154	36.1	3815	63.9

CCS, Charlson Comorbidity Score; *km*, kilometers; *NCCN*, National Comprehensive Cancer Network; *PI*, Pacific Islander; *SES*, socioeconomic status

Table 2:

Multivariate Analysis of NCCN Treatment Non-adherence for All Stages

Characteristic	OR	95% Confidence Interval
Age	1.02	1.02 - 1.02
Size Category		
<50mm	1.00	Referent
50–99mm	0.93	0.85 - 1.02
100+mm	0.91	0.83 - 0.99
Size Unknown	1.12	1.03 - 1.22
Grade		
Grade I	1.00	Referent
Grade II	1.00	0.89 - 1.13
Grade III	0.85	0.76 - 0.95
Grade IV	0.73	0.65 - 0.83
Grade Unknown	2.25	2.00 - 2.54
Stage		
Stage 1	1.00	Referent
Stage 2	0.75	0.68 - 0.84
Stage 3	0.25	0.23 - 0.27
Stage 4	0.33	0.30 - 0.36
Histology		
Serous	1.00	Referent
Mucinous	1.40	1.24 - 1.58
Endometrioid	1.22	1.11 - 1.34
Clear cell	0.91	0.81 - 1.03
Adenocarcinoma, NOS	2.89	2.59 - 3.22
Others	1.78	1.66 - 1.91
Race/Ethnicity		
Non-Hispanic White	1.00	Referent
Non-Hispanic Black	1.21	1.06 - 1.39
Hispanic	1.01	0.93 - 1.09
Asian/Pacific Islander	1.02	0.93 - 1.11
American Indian/Other	1.47	1.05 - 2.05
Socioeconomic Status		
Lowest SES	1.28	1.16 - 1.42
Lower-middle SES	1.15	1.06 - 1.26
Middle SES	1.09	1.01 - 1.19
Higher-middle SES	1.06	0.98 - 1.14
Highest SES	1.00	Referent
Insurance		

Characteristic	OR	95% Confidence Interval		
Managed Care	1.00	Referent		
Medicare	1.10	1.03	-	1.19
Medicaid	1.04	0.94	-	1.15
Other Insurance	1.01	0.93	-	1.10
Not insured	1.34	1.14	-	1.58
Unknown	0.99	0.82	-	1.20
Marital Status				
Not Married	1.00	Referent		
Married	0.85	0.81	-	0.90
Charlson Comorbidity Score				
CCS 0	1.00	Referent		
CCS 1	0.99	0.92	-	1.05
CCS 2+	1.19	1.10	-	1.28
CCS Unknown	1.26	1.13	-	1.41
Year of Diagnosis	1.01	1.00	-	1.01
Hospital Quality Measure				
Low	2.57	2.35	-	2.81
Intermediate	1.76	1.64	-	1.89
High	1.00	Referent		
Distance Traveled to Care				
<6 km	1.00	Referent		
6–9 km	0.92	0.85	-	1.00
10–16 km	0.89	0.82	-	0.97
17–32 km	0.91	0.84	-	1.00
>32 km	0.76	0.70	-	0.84
Closest High Quality Hospital				
<9 km	1.00	Referent		
9–14 km	1.06	0.97	-	1.15
15–24 km	1.05	0.97	-	1.15
25–48 km	1.13	1.04	-	1.23
>48 km	1.18	1.07	-	1.29

CCS, Charlson Comorbidity Score; km, kilometers; *NCCN*, National Comprehensive Cancer Network; *NOS*, Not otherwise specified; *OR*, Odds Ratio

Table 3:

Multivariate Analysis of NCCN Treatment Non-adherence for Early Stages (Stage 1 and Stage 2)

Variable	OR*	95% Confidence Interval		
Distance Traveled to Care				
<6 km	1.00	Referent		
6–9 km	0.82	0.69	-	0.96
10–16 km	0.83	0.70	-	0.98
17–32 km	0.77	0.66	-	0.91
>32 km	0.57	0.49	-	0.68
Closest High Quality Hospital				
<9 km	1.00	Referent		
9–14 km	0.96	0.82	-	1.12
15–24 km	1.02	0.87	-	1.20
25–48 km	1.14	0.97	-	1.34
>48 km	1.25	1.05	-	1.49

km, kilometers; *NCCN*, National Comprehensive Cancer Network; *OR*, Odds Ratio

*OR adjusted for geographic location, age, race/ethnicity, socioeconomic status, insurance, marital status, Charlson comorbidity score, stage, hospital quality

Table 4:

Comparison of Patient Characteristics by Distance Traveled to Receive Care (n=29,844)*

	<6 km		6 – 9 km		10 – 16 km		17 – 32 km		> 32 km		Total
Age Group	N	%	N	%	N	%	N	%	N	%	N
18–44	737	17.5	815	19.4	887	21.1	930	22.1	841	20.0	4210
45–54	1148	17.9	1130	17.6	1303	20.3	1421	22.1	1421	22.1	6423
55–64	1252	17.3	1320	18.3	1432	19.8	1535	21.3	1682	23.3	7221
65+	2832	23.6	2704	22.6	2346	19.6	2083	17.4	2025	16.9	11990
Race/Ethnicity											
Non-Hispanic White	3831	20.2	3716	19.6	3545	18.7	3657	19.3	4171	22.0	18920
Non-Hispanic Black	291	20.6	293	20.7	345	24.4	300	21.2	187	13.2	1416
Hispanic	1099	19.1	1205	21.0	1241	21.6	1226	21.3	978	17.0	5749
Asian/PI	715	20.1	718	20.1	804	22.6	750	21.0	577	16.2	3564
American Indian/Other	33	16.9	37	19.0	33	16.9	36	18.5	56	28.7	195
Socioeconomic Status											
Lowest SES	924	22.9	828	20.5	858	21.3	672	16.6	755	18.7	4037
Lower-Middle SES	1127	20.7	1027	18.9	1070	19.7	1039	19.1	1172	21.6	5435
Middle SES	1239	19.6	1212	19.2	1178	18.6	1257	19.9	1438	22.7	6324
Higher-Middle SES	1357	19.8	1303	19.0	1382	20.1	1420	20.7	1398	20.4	6860
Highest SES	1322	18.4	1599	22.2	1480	20.6	1581	22.0	1206	16.8	7188
Insurance Type											
Managed Care	2528	17.9	2763	19.5	2926	20.7	3111	22.0	2822	19.9	14150
Medicare	1913	25.0	1687	22.0	1423	18.6	1194	15.6	1436	18.8	7653
Medicaid	604	22.2	532	19.5	534	19.6	563	20.7	492	18.1	2725
Other Insurance	675	17.6	717	18.7	730	19.1	764	20.0	939	24.5	3825
Not insured	145	16.3	155	17.4	202	22.7	223	25.1	164	18.4	889
Unknown	104	17.3	115	19.1	153	25.4	114	18.9	116	19.3	602
Marital Status											
Not Married	3300	22.5	3051	20.8	2905	19.8	2821	19.2	2611	17.8	14688
Married	2669	17.6	2918	19.3	3063	20.2	3148	20.8	3358	22.2	15156
Charlson Comorbidity Score											
CCS 0	2664	18.7	2699	19.0	2844	20.0	2967	20.9	3045	21.4	14219
CCS 1	1360	20.0	1394	20.5	1328	19.5	1321	19.4	1404	20.6	6807
CCS 2+	1597	23.7	1468	21.8	1338	19.9	1204	17.9	1119	16.6	6726
CCS Unknown	348	16.6	408	19.5	458	21.9	477	22.8	401	19.2	2092
Stage											
Stage 1	1345	18.6	1391	19.2	1485	20.5	1542	21.3	1475	20.4	7238
Stage 2	473	19.0	480	19.2	461	18.5	548	22.0	534	21.4	2496
Stage 3	2148	19.1	2161	19.2	2203	19.6	2238	19.9	2513	22.3	11263
Stage 4	2003	22.6	1937	21.9	1819	20.6	1641	18.5	1447	16.4	8847
NCCN Treatment Adherence											
Adherent	1911	16.7	2133	18.7	2262	19.8	2358	20.6	2755	24.1	11419

	<6 km		6 – 9 km		10 – 16 km		17 – 32 km		> 32 km		Total
Non-Adherent	4058	22.0	3836	20.8	3706	20.1	3611	19.6	3214	17.4	18425
Hospital Quality Measure											
Low	2157	30.9	1594	22.8	1315	18.8	1121	16.0	803	11.5	6990
Intermediate	3036	17.6	3488	20.2	3590	20.8	3597	20.8	3564	20.6	17275
High	776	13.9	887	15.9	1063	19.1	1251	22.4	1602	28.7	5579
Closest High Quality Hospital											
<9 km	1843	30.9	1850	31.0	975	16.3	809	13.6	492	8.2	5969
9–14 km	1100	18.4	1240	20.8	2003	33.6	1109	18.6	517	8.7	5969
15–24 km	860	14.4	1082	18.1	1404	23.5	1879	31.5	743	12.4	5968
25–48 km	1023	17.1	1052	17.6	862	14.4	1375	23.0	1657	27.8	5969
>48 km	1143	19.1	745	12.5	724	12.1	797	13.4	2560	42.9	5969

*Statistical significance of differences between groups were calculated using chi-square tests. *P*-values were <0.001 for all categories

CCS, Charlson Comorbidity Score*; km*, kilometers; *NCCN*, National Comprehensive Cancer Network; *PI*, Pacific Islander; *SES*, socioeconomic status

Table 5:

Patient Characteristics by Distance to Closest High Quality Hospital (n=29,844)*

	< 9 km		9 – 14 km		15 – 24 km		25 – 48 km		> 48 km		Total
Age Group	N	%	N	%	N	%	N	%	N	%	N
18–44	877	20.8	893	21.2	895	21.3	817	19.4	728	17.3	4210
45–54	1328	20.7	1309	20.4	1273	19.8	1353	21.1	1160	18.1	6423
55–64	1444	20.0	1452	20.1	1455	20.1	1401	19.4	1469	20.3	7221
65+	2320	19.3	2315	19.3	2345	19.6	2398	20.0	2612	21.8	11990
Race/Ethnicity											
Non-Hispanic White	3418	18.1	3399	18.0	3547	18.7	4034	21.3	4522	23.9	18920
Non-Hispanic Black	308	21.8	319	22.5	436	30.8	234	16.5	119	8.4	1416
Hispanic	1121	19.5	1275	22.2	1267	22.0	1050	18.3	1036	18.0	5749
Asian/PI	1083	30.4	939	26.3	692	19.4	619	17.4	231	6.5	3564
American Indian/Other	39	20.0	37	19.0	26	13.3	32	16.4	61	31.3	195
Socioeconomic Status											
Lowest SES	814	20.2	902	22.3	691	17.1	553	13.7	1077	26.7	4037
Lower-Middle SES	851	15.7	1094	20.1	1006	18.5	955	17.6	1529	28.1	5435
Middle SES	1165	18.4	1163	18.4	1196	18.9	1185	18.7	1615	25.5	6324
Higher-Middle SES	1433	20.9	1264	18.4	1480	21.6	1529	22.3	1154	16.8	6860
Highest SES	1706	23.7	1546	21.5	1595	22.2	1747	24.3	594	8.3	7188
Insurance Type											
Managed Care	3034	21.4	2867	20.3	3055	21.6	3166	22.4	2028	14.3	14150
Medicare	1412	18.5	1421	18.6	1385	18.1	1393	18.2	2042	26.7	7653
Medicaid	595	21.8	662	24.3	496	18.2	399	14.6	573	21.0	2725
Other Insurance	647	16.9	684	17.9	702	18.4	749	19.6	1043	27.3	3825
Not insured	166	18.7	187	21.0	203	22.8	167	18.8	166	18.7	889
Unknown	115	19.1	148	24.6	127	21.1	95	15.8	117	19.4	602
Marital Status											
Not Married	3205	21.8	3049	20.8	2926	19.9	2815	19.2	2693	18.3	14688
Married	2764	18.2	2920	19.3	3042	20.1	3154	20.8	3276	21.6	15156
Charlson Comorbidity Score											
CCS 0	2844	20.0	2800	19.7	2789	19.6	2925	20.6	2861	20.1	14219
CCS 1	1324	19.5	1319	19.4	1380	20.3	1360	20.0	1424	20.9	6807
CCS 2+	1296	19.3	1363	20.3	1407	20.9	1250	18.6	1410	21.0	6726
CCS Unknown	505	24.1	487	23.3	392	18.7	434	20.7	274	13.1	2092
Stage											
Stage 1	1476	20.4	1548	21.4	1500	20.7	1396	19.3	1318	18.2	7238
Stage 2	536	21.5	502	20.1	475	19.0	477	19.1	506	20.3	2496
Stage 3	2246	19.9	2177	19.3	2261	20.1	2312	20.5	2267	20.1	11263
Stage 4	1711	19.3	1742	19.7	1732	19.6	1784	20.2	1878	21.2	8847
NCCN Treatment Adherence											
Adherent	2501	21.9	2247	19.7	2228	19.5	2289	20.0	2154	18.9	11419

	< 9 km		9 – 14 km		15 – 24 km		25 – 48 km		> 48 km		Total
Non-Adherent	3468	18.8	3722	20.2	3740	20.3	3680	20.0	3815	20.7	18425
Hospital Quality Measure											
Low	827	11.8	1042	14.9	1448	20.7	1477	21.1	2196	31.4	6990
Intermediate	3017	17.5	3712	21.5	3604	20.9	3687	21.3	3255	18.8	17275
High	2125	38.1	1215	21.8	916	16.4	805	14.4	518	9.3	5579
Distance to Receive Care											
<6 km	1843	31.5	1100	18.8	860	14.7	1023	17.5	1023	17.5	5849
6–9 km	1850	29.5	1240	19.8	1082	17.2	1052	16.8	1052	16.8	6276
10–16 km	975	16.0	2003	32.8	1404	23.0	862	14.1	862	14.1	6106
17–32 km	809	12.4	1109	16.9	1879	28.7	1375	21.0	1375	21.0	6547
>32 km	492	9.7	517	10.2	743	14.7	1657	32.7	1657	32.7	5066

*Statistical significance of differences between groups were calculated using chi-square tests. P-values were <0.001 for all categories

CCS, Charlson Comorbidity Score*; km*, kilometers; *NCCN*, National Comprehensive Cancer Network; *PI*, Pacific Islander; *SES*, socioeconomic status