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ORIGINAL RESEARCH

Geographic Distribution of Melanoma Cases in Maine: Identifying Vulnerable Counties for Targeted Intervention

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ABSTRACT

Introduction: Maine has the twelfth highest incidence of melanoma in the United States. The purpose of this study was to identify which Maine counties were the most impacted by melanoma through the use of geographic methods. Identification of counties with the highest prevalence of melanoma will help with targeting future training and public health interventions.

Methods: All melanoma cases (n = 5340) reported to the Maine Cancer Registry from 2013 to 2018 were sorted by pathologic T stage. Data were sorted by county and population-adjusted. Population and provider data came from Area Health Resource Files. County and zip-code maps were constructed to highlight which counties have the greatest burden of melanoma in the state.

Results: Hancock County, Knox County, Sagadahoc County, and Washington County had the highest rates of late-stage melanoma cases when adjusting for age and population.

Conclusions: With geospatial methods, counties with the highest rates of late-stage melanoma could be identified. Particular counties of note include Hancock County, Knox County, Sagadahoc County, and Washington County. These counties had the greatest need and can be launch points for targeted public health interventions.

Keywords: Melanoma, Maine, Dermoscopy, Rural health

1. Introduction

The incidence of melanoma is on the rise in the United States. Although melanoma is a national problem, Maine consistently has incidence rates above the national average. Data from recent years show that Maine has the twelfth highest age-adjusted rate of melanoma at 27.0 cases per 100 000 people, which is substantially higher than the national rate of 22.9 cases per 100 000 people.[1] Early-stage melanoma has a 5-year survival rate of 99%, which decreases to 70.6% after regional spread, and even further to 33.4% with distant metastasis.[1] Thus, detecting and treating melanoma early is crucial for minimizing the morbidity and mortality associated with the disease.

Maine is a very rural state, which further exacerbates difficulties in accessing the care needed to diagnose melanoma early. A study analyzing the North American Association of Central Cancer Registries data from 2009 to 2013 found the incidence

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of early-stage melanoma diagnosis was lower in rural areas, but the incidence of later-stage melanoma was significantly higher in rural vs urban areas.[2] Beyond the timing of diagnosis, it is becoming increasingly difficult for people living in rural areas to access the specialty care needed for completely treating melanoma. This lack of access increases the case-fatality rate of melanoma by approximately 20% in rural vs urban areas.[3] These barriers to care are further worsened by escalating health care costs, which often prevent people from accessing the diagnosis and treatment they need.[4]

Although high rates of melanoma exist across the entire state, certain counties disproportionately bear the burden of melanoma. In determining which regions should be considered 'high-need,' we examined the following county data: melanoma counts and rates, late-stage melanoma counts and rates, the number of dermatologists in each county, the ratio of primary care providers (PCPs) to residents in each county, and the distance traveled to primary care visits.

Geospatial methods have been used widely to identify how a multitude of health outcomes vary across space and time. For example, the Maine Center for Disease Control and Prevention routinely reports the geographic distribution of a large variety of infectious diseases, such as hepatitis, dengue fever, and anaplasmosis.[5] By differentiating these outcomes based on geography, understanding these distributions can lead to targeted public health interventions. Beyond infectious disease, further work based in Maine has used a similar approach to understand trends in substance misuse among people receiving buprenorphine treatment during the COVID-19 pandemic.[6] Both methods illustrate the importance of geospatial methods in determining the specific need an area may have, and how this need can be used to develop intentional public health interventions.

Based on advancing the findings of prior work, the primary objective of this study was to use geospatial methods to identify the Maine counties with the greatest need for interventions and potential for improving early melanoma detection and diagnosis. These data can then be used to drive targeted public health interventions at local levels and help to reduce the morbidity and mortality associated with late-stage melanoma. Similar studies have yet to be conducted in Maine to determine the current spatiotemporal distribution of melanoma across the state. Determining this distribution would, ultimately, lead to better understanding the disease burden of melanoma in Maine, which could guide future public health interventions. Specifically, interventions that focus on expanding access to dermoscopy training for PCPs would substantially impact the rate of melanoma detection and treatment in Maine.

2. Methods

2.1. Data source

This project was deemed exempt research by the Maine Medical Center Institutional Review Board (#1445217-1 GIS). We obtained melanoma data from the Maine Cancer Registry of the Maine Center for Disease Control and Prevention. These data were reported by hospitals and physicians between 2013 and 2018. Population data for each Maine county were obtained from the 2018 American Community Survey conducted by the US Census Bureau. Data for each county were used to provide information that would be tangible for interventional purposes. PCP and dermatologist rates in Maine were obtained from Area Health Resource Files of the Health Resources and Services Administration. These data were collected from 2018 and 2019 because they represented the melanoma incidence and Maine provider rates available at the time of analysis and publication.

2.2. Study population

The study population included all melanoma cases reported to the Maine Cancer Registry from 2013 to 2018 (n = 5841). Before analysis, 358 non-melanoma cases were removed according to the histologic type of the tumor code. Non-Maine residents (n = 143) not initially filtered out of the dataset were also removed. This filter resulted in a total of 5340 melanoma cases used for analysis.

2.3. Melanoma staging

We analyzed pathologic tumor stage because this variable was the most complete variable reported by the Maine Cancer Registry. This variable is also valuable in assessing disease prognosis. The pathologic tumor stage classifies melanoma cases primarily by measuring cell mass thickness from the superficial portion of the granular layer of the epidermis to the deepest invasive cell across the broad base of the tumor.[7] Thicker tumors are associated with a greater tumor stage as follows: Tis (in situ) is 0 mm, T1 is less than or equal to 1.0 mm, T2 is 1.0 to 2.0 mm, T3 is 2.0 to 4.0 mm, and T4 is greater than 4.0 mm.

Tumor stage was reported for 4577 melanoma cases in our dataset. The other 763 melanoma cases had a pathologic tumor stage that was left blank (n = 584) or marked unknown (n = 179). Cases without a noted pathologic tumor stage were filled in using other clinically relevant variables, such as clinical-stage group, pathologic-stage group, and clinical-tumor stage. Of the 763 melanoma cases without a stated pathologic tumor stage, 444 were identified as melanoma in situ. The final 319 pathologic tumor stages were grouped into 6 categories (Tis, T1, T2, T3, T4, and unknown) based on an algorithmic approach using the aforementioned variables. These categories were then further subcategorized into low risk (Tis and T1a), intermediate risk (T1b and T2), and high risk (T3 and T4).

Thicker melanomas are associated with worse clinical outcomes. We used data from the American Joint Committee on Cancer to assign 5-year survival rates to the assigned stages. The 2018 report found that when isolating tumor stage as the only predicting factor for tumors without metastasis, the prognoses are as follows: Tis, T1a, and T1b are 99%; T2a is 97%; T2b and T3a are 94%; T3b and T4a are 87%; and T4b is 82%.[8] However, if there is evidence of metastasis, the 5-year survival rates decline to 70.6% for regional metastasis and 31.9% for distant metastasis. To calculate the average 5-year survival rates, each melanoma was designated as local, regional, or distant using information about positive sentinel lymph nodes or distant metastasis. If the value was left blank, we assumed the melanoma was localized for the assigned stage and prognosis.

2.4. Statistical analysis and mapping

Maps were created in R (version 4.2.1) using simple features, tidycensus, and cartography packages.[9–11] County shapes were downloaded from the US Census Bureau.[12] Melanoma data were uploaded as described above. All covariates were adjusted to a per 10 000 population rate to control for population differences across the state. PCPs were included for the following specialties: family medicine, internal medicine, and general practice. Prevalence rates were calculated by summing the total number of cases by county divided by that county's population and then standardized to a per 10 000 population rate. Rates were grouped into categories by quantile.

3. Results

The number of melanoma cases reported per year in the state of Maine increased from 2013 to 2018 (Fig. 1). The statewide melanoma count peaked in 2016 with 972 melanoma cases. The population-adjusted rate of melanoma cases also increased during this time. The rate of melanoma cases within Maine in 2013 was 5.62 cases per 10 000 people. This rate peaked at 7.30 per 10 000 people in 2016 and was 7.21 per 10 000 people in 2018.

In addition to statewide data, melanoma incidence and rates were disproportionately distributed

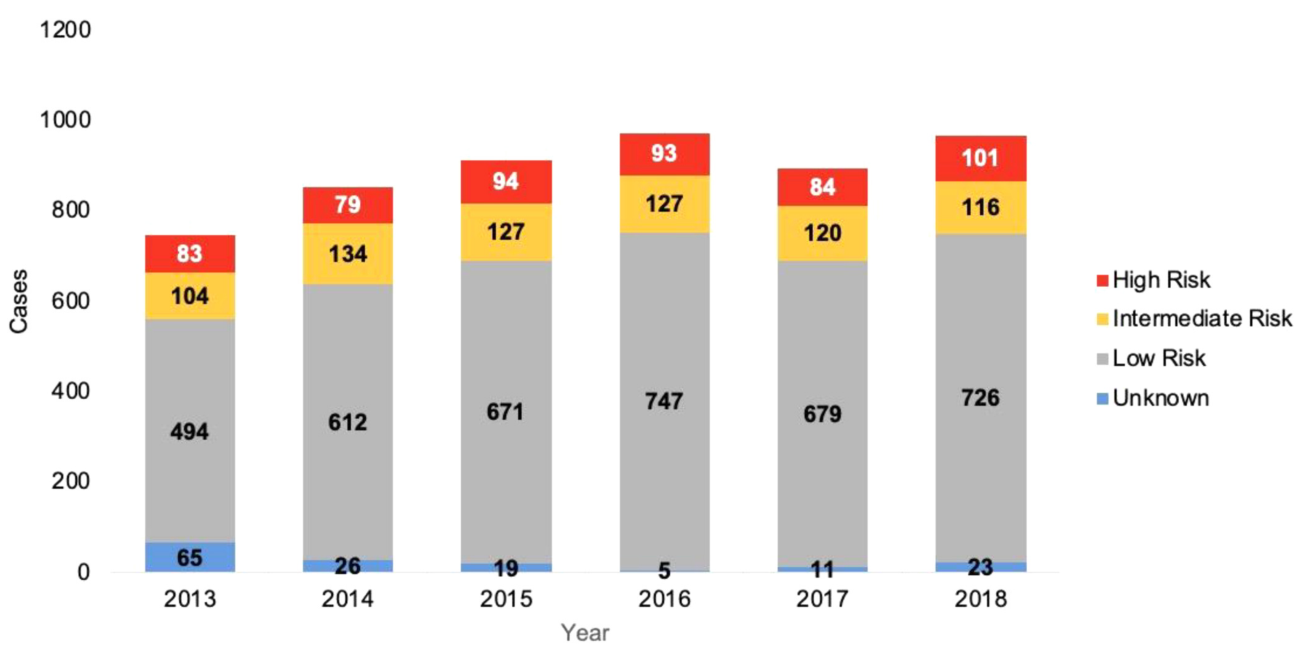

Fig. 1. Number of melanoma cases in Maine from 2013 to 2018. Grouping melanoma cases into low-risk, intermediate-risk, and high-risk categories illuminates statewide trends from 2013 to 2018. Overall, during this 6-year period, the proportion of high-risk and intermediate-risk melanoma cases decreased, whereas the proportion of low-risk melanoma cases increased.

Table 1. Number of melanoma cases and providers in Maine counties.*

Country	Melanoma country	Population	Melanoma cases per 10 000 people	PCPs	PCPs per 10 000 people	Dermatologists	Dermatologists per 10 000 people
Androscoggin	194	537 220	3.61	88	1.64	2	0.04
Aroostook	156	341 345	4.57	66	1.93	0	0.00
Cumberland	1466	1 454 720	10.08	478	3.29	17	0.12
Franklin	112	150 095	7.46	25	1.67	0	0.00
Hancock	316	272 705	11.59	62	2.27	1	0.04
Kennebec	404	607 725	6.65	160	2.63	7	0.12
Knox	199	199 115	9.99	40	2.01	1	0.05
Lincoln	167	170 335	9.80	34	2.00	0	0.00
Oxford	119	286625	4.15	35	1.22	1	0.03
Penobscot	690	758 740	9.09	188	2.48	5	0.07
Piscataquis	72	84 435	8.53	13	1.54	0	0.00
Sagadahoc	168	176 385	9.52	24	1.35	0	0.00
Somerset	144	253 550	5.68	30	1.18	0	0.00
Waldo	150	197 090	7.61	28	1.42	1	0.05
Washington	135	158 470	8.52	14	0.88	0	0.00
York	838	1 015 510	8.25	140	1.38	0	0.00

Abbreviations: PCP, primary care provider.

*Melanoma cases are aggregated from 2013 to 2018, and the number of providers is from 2018 to 2019.

in certain counties. As detailed in Table 1, Cumberland County had the highest total number of melanoma cases, with 10.08 cases per 10 000 people reported between 2013 and 2018. Following Cumberland County, the counties with the highest melanoma counts were York County, Penobscot County, Kennebec County, and Hancock County. Hancock County had the highest population-adjusted incidence rate of melanoma at 11.59 cases per 10 000 people between 2013 and 2018. Cumberland County, Knox County, Lincoln County, and Sagadahoc County also had some of the highest population-adjusted melanoma rates in the state.

Cumberland County had the greatest number of PCPs (n = 478), as well as the lowest ratio of people to PCP at 1 PCP for every 624 people. Other counties had a greater number of people per PCP. For instance, Washington County has the highest population-to-PCP ratio at 1 PCP for every 2248 people. Other counties with high ratios of people to PCPs included Somerset County, Oxford County, Sagadahoc County, and York County. Cumberland County also had the greatest number of dermatologists (n = 17). The second highest dermatologist count across the state was in Kennebec County (n = 7). No dermatologists were found in 9 counties: Sagadahoc County, Washington County, Lincoln County, Franklin County, Piscataquis County, Waldo County, York County, Oxford County, and Somerset County.

Grouping melanoma cases into risk categories (high, intermediate, or low) by T stage showed the differential distribution of high-risk melanoma across the state. Washington County, Knox County, Sagadahoc County, and Lincoln County had the highest rates of high-risk melanoma cases. All these counties had average incidence rates of high-risk melanoma that were greater than 1 per 10 000 people. Knox County, Piscataquis County, Sagadahoc County, and Hancock County had the highest rates of intermediate-risk melanoma cases. Low-risk melanoma cases were most prevalent in Hancock County, Cumberland County, Penobscot County, and Lincoln County.

As illustrated in Fig. 2, Oxford County had the greatest proportion of high-risk melanoma cases (19.9%). Other counties with high proportions of high-risk melanoma cases included Androscoggin County, Washington County, Sagadahoc County, and Knox County. Androscoggin County had the greatest proportion of intermediate-risk melanoma cases (23.7%). Oxford County, Piscataquis County, Sagadahoc County, and Knox County also had high proportions of intermediate-risk melanoma cases. Penobscot County was the county with the greatest proportion of low-risk melanoma cases (82.4%). York County, Franklin County, Waldo County, and Hancock County also had high proportions of low-risk melanoma cases. Oxford County had the lowest proportion of low-risk melanoma cases (55.1%). Androscoggin County, Sagadahoc County, Knox County, and Somerset County also had low proportions of low-risk melanoma cases.

4. Discussion

This review of melanoma data in Maine from 2013 to 2018 revealed geographic trends in the distribution of the disease. The data show an overall increase in the number of melanoma cases in the state of Maine from 2013 to 2018, specifically in rural areas

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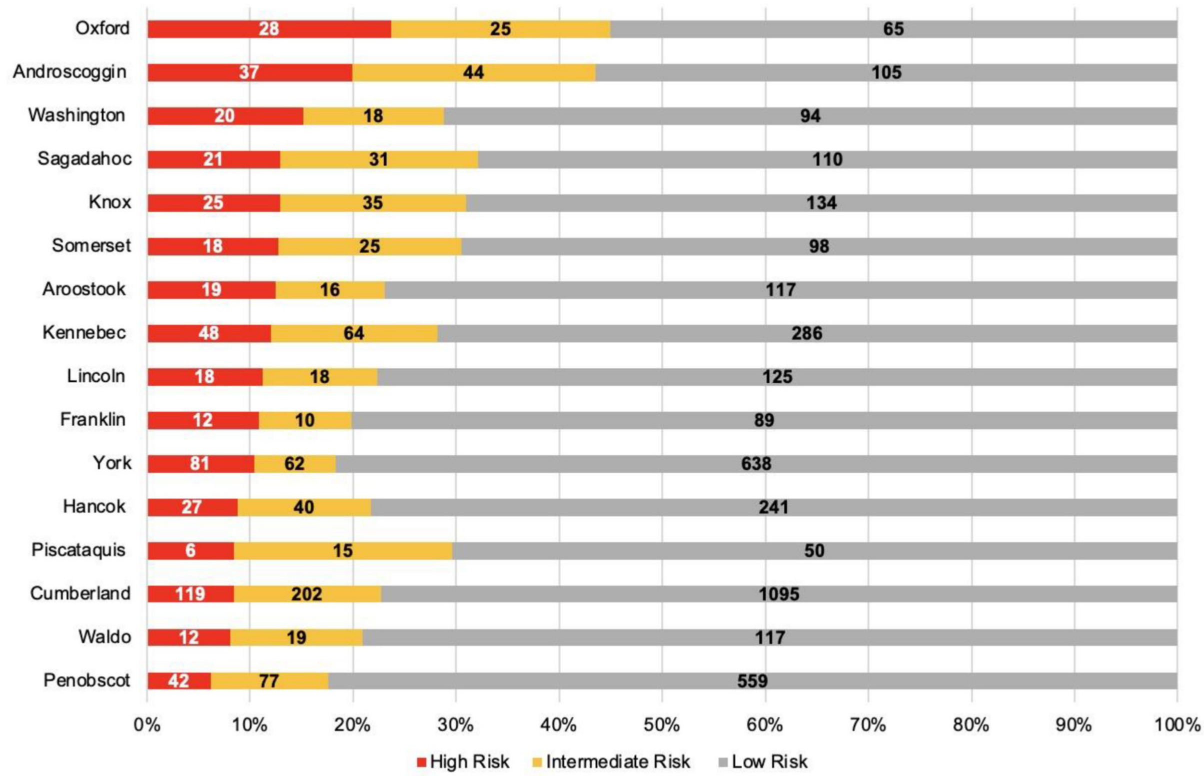

Fig. 2. Proportion of low-risk, intermediate-risk, and high-risk melanoma in Each Maine County From 2013 to 2018.

of the state. Although this phenomenon is seen across the United States, given the changes in thresholds needed to biopsy a suspicious skin lesion, the dramatic increase in cases in Maine is cause for concern.[14]

In particular, rural areas are disproportionately impacted by later-stage melanomas for a variety of reasons. As previously discussed, people living in remote areas may have difficulty accessing the specialty care they need for early diagnosis and treatment of melanoma. Numerous studies identified rural areas as having higher rates of late-stage melanoma than urban areas. For example, a similar study found a significant increase in the incidence and mortality rates of melanoma among its rural counties in Michigan.[15] Further research in Iowa found that people living in rural areas had a 26% higher mortality rate than people living in urban environments.[16] Given these disparities, many rural areas have turned toward PCPs to help bridge the gap between remote regions and high-quality dermatology care. Although connecting these people with a specialist is of utmost importance, people living in areas with access to PCPs may have earlier detection and lower mortality rates associated with melanoma.[17] As such, it is equally important to assess the distribution of care related the detecting and treating melanoma.

In conjunction with the dataset from the Maine Cancer Registry, data on access to primary and dermatologic care in Maine were also evaluated. These data included the number of PCPs and dermatologists in each county, average distances traveled to primary care visits, and locations of e-consult sites. Based on these data, 4 counties had the highest need for training in skin cancer detection: Hancock County, Knox County, Sagadahoc County, and Washington County. All 4 counties had some of the highest rates of melanoma incidence in the state of Maine, with Hancock County having the highest average rate. These 4 counties also had the highest rates of late-stage melanoma cases.

These 4 counties also face some of the greatest barriers to health care access within the state. Neither Washington County nor Sagadahoc County have a single dermatologist, Hancock County has only 1 dermatologist, and Knox County has 2 dermatologists.[13] Given the shortage of dermatologists in these rural regions of Maine, PCPs play a critical role in detecting and diagnosing skin cancer. Unfortunately, some of these counties also have limited access to primary care. Washington County has the highest ratio of people to PCPs, with 1 PCP for every 2248 people. Sagadahoc County also has a high ratio of people to PCPs, with 1 PCP for every 1163 people.[13]

In comparison, Cumberland County has a ratio of 1 PCP for every 488 people.[13] Also, patients in Hancock County, Washington County, and Sagadahoc County must travel further for primary care visits. In Hancock County, 37.6% of patients had to travel more than 30 miles for their primary care visit—the second highest percentage in the state.[14]

Limited access to dermatologic care might account for the high rates of late-stage melanoma cases in certain counties. Many of the counties with higher rates of late-stage melanoma cases have few or no dermatologists. In addition, there are differences in the types of melanoma cases seen by each county. As shown in Fig. 2, the distribution of high-risk melanoma cases varies widely across the state. For example, Cumberland County has a very high incidence of melanoma, but most of these cases are low risk for metastasis and generally found at an early stage.

Counties with fewer dermatologists and PCPs may also be underdiagnosing melanoma. One possible reason for this underdiagnosis is that patients have less access to care and, therefore, are not receiving needed skin checks or annual primary care visits. Based on previous data, higher numbers of PCPs in a region corresponds with higher rates of early-stage melanoma cases reported in that region. This finding indicates that areas with more PCPs are more likely to detect and diagnose melanoma cases early on. As such, ensuring that PCPs are adequately trained in the early detection of melanoma could substantially impact the morbidity and mortality associated with the disease in rural areas.

Furthermore, geographic, environmental, and occupational factors could help explain regional trends in melanoma rates. One potential reason for these regional trends could be varying levels of UV radiation or exposure to UV radiation between different counties. Many of the counties with high rates of melanoma are coastal. Proximity to the ocean corresponds to greater UV exposure due to occupation, such as work in the lobster, fishing, and boating industries. Population age is another important characteristic that may be related to the differential distribution of melanoma across the state. This factor is increasingly important given the aging population in Maine and the greater risk of developing melanoma associated with older age. Overall, more research is needed to determine the underlying cause or reasons for geographic differences in melanoma and late-stage melanoma rates.

4.1. Limitations and future directions

We assumed that any melanoma without a reported sentinel lymph node status or MET was localized. Thus, the average 5-year survival rate was likely underestimated. We also did not adjust for potential confounders other than population in our analysis, which may bias the results. Furthermore, the Maine Cancer Registry only includes the area in which people were diagnosed, but not where they previously lived, which may skew the results.

Future directions include the implementation of training modules in counties identified as having the greatest need. If successful, these targeted interventions could help elucidate the reasons behind the geographic distribution of melanoma cases in Maine. Further research into geographic, meteorologic, behavioral, and occupational differences between regions or counties should also be done to fully understand how these variables can best be addressed to lower the morbidity and mortality associated with melanoma in Maine.

5. Conclusions

This research shows the differential distribution of melanoma across the state of Maine. It also shows how the incidence related to the number of providers varies in each county, which can be used to develop targeted public health interventions. Although the exact mechanism underlying the geographic distribution of melanoma in Maine is unknown, understanding which counties are disproportionately burdened by the disease supports strategic location of future interventions. With this notion in mind, the provided recommendations focus on detecting the most high-risk melanoma cases in the most high-risk counties. By implementing these interventions in the counties with the greatest need, the impact of these trainings can be maximized. Based on the presented findings, targeted interventions should first focus on Hancock County, Knox County, Sagadahoc County, and Washington County.

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