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ORIGINAL RESEARCH

Geographic Patterns of Ocular Oncologist Supply and Patient Demand for Uveal Melanoma Treatment in the United States: A Supply and Demand Analysis

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Purpose: To study geographic patterns of supply and demand for uveal melanoma and other ocular oncology healthcare by ocular oncology physicians in the United States.

Methods: Google search interest data was obtained through trends.google.com. The combined-state density of ocular oncology physicians was calculated by dividing the number of practicing ocular oncologists in each state and its surrounding states by the state population. Relative search volume (RSV) values were divided by ocular oncology physician density to calculate the Google relative demand index (gRDI) for each state. Medicare (mRDI) and IRIS® Registry (iRDI) relative demand indices were calculated using prevalence data obtained through the Vision and Eye Health Surveillance System (VEHSS). Data from the US Census Bureau and Centers for Disease Control (CDC) databases were also utilized to analyze associations with poverty rates, percent living in urban or rural areas, vision screening rates, and ocular neoplasm rates.

Results: Alabama showed the highest RSV (100), while the lowest was reported in New Mexico (20). Vermont had the highest density of combined-state ocular oncology ophthalmologists (1.85 per 100,000 residents). New Mexico had the lowest RDI (0.013 gRDI, 0.015 mRDI, 0.018 iRDI) with 32 combined-state ocular oncologists and a population of 2,114,371. Ocular neoplasm prevalence rates ranged between 1.32% and 5.40% and significantly correlated with RSV. Single-state gRDI correlated with rural status and negatively correlated with urban areas (≥50,000 individuals). Single-state ophthalmologist density correlated positively with percent living in urban areas and vision screening rates, and negatively with rural status.

Conclusion: This study uncovered significant heterogeneity in the geographical distribution of ocular oncology physicians and RDI throughout the United States, highlighting potential undersupply scenarios. This may guide efforts to increase ocular oncology physician and surgeon availability in areas of need.

Keywords: ocular oncology, google trends, medicare, IRIS® Registry, uveal melanoma

Introduction

The uveal tract consists of the iris, ciliary body, and choroid. It is the site of the most common primary intraocular malignancy, uveal melanoma (UM).[1] The mean age-adjusted incidence of uveal melanoma in the United States was 5.1 per million, approximately 1500 new cases are diagnosed each year, and the majority of cases were diagnosed in patients of Caucasian descent (97.8%).[2] Another study found the annual age-adjusted incidence of UM differed by racial/ethnic groups, with 0.31, 0.38, 1.67, and 6.02 per million for patients identifying as black, Asian, Hispanic, and non-Hispanic white.[3] A recent study found 5, 10, 15, 20, 25, and 30-year relative survival rates to be 79, 66, 60, 60, 62, and 67% respectively.[4] Although uveal melanoma classically presents in older individuals, a study of 8033 eyes by Shields et al has shown that over half of cases are in adults 20 to 60 years old.[5,6]

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Treatment of primary UM includes transpupillary thermotherapy, radiation therapy, endoresection, and enucleation.[1] Treatment typically results in local control in over 90% of patients.[7] However, at least 40% of patients eventually develop distant metastases, most commonly in the liver.[7] In 2022, the United States Food and Drug Administration approved tebentafusp (Kimmtrak, Immunocore Limited) for systemic treatment of HLA-A*02:01-positive adult patients with unresectable or metastatic uveal melanoma.[7,8] Additionally, the use of systemic chemotherapy, such as dacarbazine, paclitaxel and liposomal vincristine, and gemcitabine/treosulfan, has been reviewed.[9,10] Early detection of UM and its metastasis is thought to improve prognosis and preserve visual function.[11–13]

Despite the relatively poor prognosis of the disease, diagnosis of UM may be delayed. One study done in the United Kingdom found that 10.9% of UM patients experienced over a 6-month delay in the referral process.[11] These delays occurred as a result of an improper referral from an optometrist to a primary care physician rather than an ophthalmologist and an improper referral from primary care physicians to optometrists rather than an ophthalmologist.[11] To our knowledge, no studies regarding delays in referrals of potential UM cases in the United States have been published. These issues occur in a broader landscape of expected increasing provider scarcity: a decrease of 2650 full-time equivalent ophthalmologists is projected from 2020 to 2035, hence a 30% shortage of ophthalmologist full-time equivalents relative to demand.[14] This may be due to rising demand owing to an aging population without expansion of undergraduate and graduate medical education, loan repayment assistance programs, and specialty training. To elaborate, high costs of medical education and scarcity of loan repayment assistance programs may dissuade ophthalmology residents from pursuing fellowship training in ocular oncology. Therefore, it is of growing importance to investigate the unmet needs for patients to inform initiatives aimed to remedy the discrepancy in supply and demand by bolstering ocular oncology ophthalmologists in areas of greater need. The Center of Disease Control (CDC) Vision and Eye Health Surveillance System (VEHSS) are a database for epidemiologic vision research, which contains prevalence data obtained from Medicare claims and the Intelligent Research in Sight® (IRIS) Registry. Google Trends has also been commonly used, including within the field of ophthalmology, to shed light on patient demand for physician and surgeon services.[15–17] This type of analysis had not been done for ocular tumors or the field of ocular oncology, especially using three sources of data to extrapolate physician demand. This study aims to analyze the demand for UM treatment, along with potential unmet demands for ocular oncology ophthalmologists in the United States, using Google search data, Medicare ocular cancer prevalence data, and IRIS Registry ocular cancer prevalence data.

Materials and Methods

Data Collection

Google Trends search interest data was obtained through trends.google.com, using the Search Topic "Uveal Melanoma" under the "health" category from January 1st, 2014, to January 31st, 2023. It should be noted that Google Trends differentiates "Search Topics" from "Search Terms". Queries of a single "Search Term" will only gather search interest data for that particular term, such as "London", while queries of a single "Search Topic" will encompass search interest data for terms that share the same concept, such as "London", "Capital of the United Kingdom", and the term in different languages. Google Trends calculates the Relative Search Volume (RSV) index during this period by dividing the total monthly searches for the term "uveal melanoma" by the total number of monthly searches for each of the 50 states, averaging the values across the study period, and normalized the values proportionally to search interest on a scale from 0 to 100.

Medicare eye cancer and neoplasm prevalence data were obtained through the CDC VEHSS data explorer tool by selecting "other eye disorder", "cancer and neoplasms of the eye", "diagnosed, any type", and "cancer and neoplasms of the eye" while specifying the data source to be "Medicare Claims". IRIS Registry eye cancer and neoplasm prevalence data were obtained through a similar method but instead specifying "IRIS® Registry" as the data source.

The number of ocular oncology physicians in each state was obtained from the American Academy of Ophthalmology website using the "Find an Ophthalmologist" web directory. The single-state ocular oncology ophthalmologist density (or surgeon density) per 100,000 was calculated by taking the sum of the number of ocular oncology ophthalmologists of each state, multiplying by 100,000, and dividing by the 2021 State Census Bureau population estimates. The combined-state ocular oncology ophthalmologist density (or combined surgeon density) per 100,000 was calculated using the same method but using the sum of surgeons in-state and in immediately adjacent states. The normalized Google relative demand index (gRDI) is then a result of dividing the RSV values by the combined-state density of ocular oncology physicians and then normalized between 0 and 1.00 (Formula 1). This is similar to the method utilized by Akosman et al.[15] The normalized Medicare (mRDI) and IRIS® Registry (iRDI) RDI values were calculated by taking the prevalence percentage of each state and dividing by the combined-state ocular oncology ophthalmologist density per 100,000 and then normalized between 0 and 1.00 (Formula 2). A single-state RDI value may be calculated using RSV or percentage prevalence divided by the single-state surgeon density. A normalized RDI of 1.00 was assigned to states without an ocular oncology physician in the respective state or any surrounding states.

Formula 1

$$Google\,Search\,Relative\,Demand\,Index = normalized\left[\frac{RelativeSearchVolume}{\frac{(Number\ of\ surgeons\ in\ state + number\ of\ surgeons\ in\ adjacent\ states)*100{,}000}{State\ Population}}\right]$$

Formula 2

$$Medicare\ or\ IRIS\ Relative\ Demand\ Index = normalized\left[\frac{Eye\ Cancer\ Percent\ Prevalence}{\frac{(Number\ of\ surgeons\ in\ state + number\ of\ surgeons\ in\ adjacent\ states)*100{,}000}{State\ Population}}\right]$$

The AAO "Find an Ophthalmologist" directory was validated by comparing the number of oculofacial/reconstructive surgeons listed on the tool and the American Society of Ophthalmic Plastic and Reconstructive Surgery (ASOPRS) directory across 10 states (5 most populous and 5 least populous states). Given that the ocular oncology subspecialty does not have a similar directory to the ASOPRS directory, the AAO "Find an Ophthalmologist" directory was used.

Data for this study were also sourced from US Census Bureau and CDC VEHSS databases to analyze poverty rates, urbanization status, vision screening frequencies, and ocular neoplasm rates across states.[18–20] Poverty rates per state were determined based on the proportion of the state population living below 50% of the national poverty level. The urbanization or rural status of each state was also cataloged. Urban areas are defined as areas with a population of 50,000 individuals or greater, while urban clusters, as defined by the US Census Bureau, are areas with greater than 2000 but less than 50,000 individuals. The United States Census Bureau does not define "rural" but instead state that rural areas include all geographic areas that are not classified as urban. The total urban population percentage of each state is the sum of percent in urban areas and percent in urban clusters. These data were retrieved from the United States Census Bureau's website, accessible through their data portal.[18,19] For health-related metrics, the VEHSS tool also compiled state-level information on vision screening frequencies based on Medicare claims in 2019 of any age, which included Curricular Practical Training codes 92,227, 92,228, 99,174, and 99,177, and Healthcare Common Procedure Coding System codes G0117, G0118 (Available from: https://www.cdc.gov/vision-health-data/case-definitions/screening-services.html).[20,21] The combined use of search data, government census data, Medicare claims data, IRIS Registry data (accessed through VEHSS), and health surveillance tools enabled a robust comprehensive analysis of the relationships between socioeconomic factors, healthcare access, and eye health outcomes at the state level.

This study relies on publicly accessible data and does not directly involve any individual human subjects or animals. Ethical approval was not sought in this study, given that all analyzed data are freely available to the public and do not directly involve human participants. This research complies with the principles outlined in the Declaration of Helsinki.

Statistical Analysis

To assess the relationships between healthcare provision metrics and various demographic and geographic variables, a comprehensive correlation analysis was conducted. The analysis focused on exploring how these healthcare metrics correlate with the distribution and prevalence of eye health concerns across different regions.

The initial phase of the analysis examined the correlation between the relative search volume for eye health information and the number of available ocular oncologists. This step aimed to understand the public's interest or concern regarding eye health issues in relation to the accessibility of specialized ophthalmologists. Pearson's correlation coefficients (r and r^2) were calculated to quantify the strength and direction of the linear relationships. Additionally, the statistical significance of these correlations was determined by calculating the associated p-values. Pearson correlation coefficients were calculated using the "cor" function from the 'stats' package in R ('stats' version 3.6.2). Pearson correlation coefficients were estimated between two density parameters at a time by calculating their covariance and dividing by the product of their respective standard deviations, effectively measuring the strength and direction of their linear relationship.

Subsequently, the analysis was extended to investigate the correlations and p-values between ocular oncologist density (number of ocular oncology physicians adjusted for state population size) per state and several socioeconomic and geographic variables. These variables included the Poverty Estimate, reflecting the percentage of the population living at 50% below the poverty level; Urban and Rural residency statuses, differentiated into "Inside Urbanized Areas" (≥50,000 inhabitants), "Inside Urban Clusters" (between 2001 and 49,999 inhabitants), and "Rural" areas; Eye Neoplasm Prevalence Rate; and Vision Screening Rate. This phase of the analysis provided insights into how the distribution of surgeons correlates with poverty levels, urbanization status, eye neoplasm prevalence, and the rate of vision screening across different regions.

Further expanding the investigation, correlation analyses were replicated for RSV, ocular oncology ophthalmology density per 100,000 and the three forms of normalized Relative Demand Index (Google, Medicare, and IRIS Registry). Each of these metrics was correlated with the same set of socioeconomic and geographic variables mentioned previously (Poverty Estimate, Urban/Rural distinctions, Eye Neoplasm Prevalence Rate, and Vision Screening Rate), exploring 58 total distinct associations. This framework enabled a systematic assessment of the interplay between relative demand, captured by Google Trends search terms, healthcare resources as represented by the number of state ocular oncologists, and other demographic factors in the context of eye health care and prevention.

Results

State-by-state characteristics of population, population ≥50 years old, poverty estimate, percentage living in rural and urban areas, eye neoplasm prevalence percentage from Medicare and IRIS® Registry data, vision screening rate, RSV, normalized RDIs, the number of ocular oncology ophthalmologists, and combined ocular oncology ophthalmologist density are summarized in Table 1 and Table 2. Both the RSV for uveal melanoma vary significantly across states, indicating a diverse level of public interest or concern regarding this condition. For example, Alabama and New Hampshire show the highest RSV of 100, representing a notably high level of interest, while New Mexico RSV stands at 20, suggesting a lower level of public interest or concern.

The prevalence percentages for both Medicare and IRIS® Registry source modalities vary across states (Table 1 and Figure 1). With Medicare-sourced prevalence percentages, New Mexico had the lowest at 1.32% prevalence, and Delaware (RSV 60) had the highest at 3.29%, which contrasts RSV Results indicating New Mexico having the least relative interest. For IRIS® Registry-sourced prevalence percentages, Utah (RSV 50) had the lowest prevalence at 2.03%, and Connecticut (RSV 80) had the highest at 5.4%.

The AAO "Find an Ophthalmologist" tool listed a total of 142 ocular oncology ophthalmologists in the United States. Regarding the number of ocular oncology ophthalmologists and surgeon density, the data reveals substantial variation in the availability of specialized eye care professionals across states (Table 1). California (40 RSV) had the most in-state ocular oncologists at 21, followed by Texas (50 RSV) at 15. Arizona (50 RSV) showed 7 ocular oncology ophthalmologists, resulting in the highest surgeon density of 0.094. This contrasts starkly with 17 states where no in-state ocular oncology ophthalmologists were reported. Given this limitation in data and difficulty in assigning an accurate relative demand in states without ocular oncologists, we factored the number of ocular oncology ophthalmologists in adjacent states (combined-state ophthalmologists). This results in Arizona having the most total surgeons in state and in surrounding states combined, with Alaska, Maine, and Montana 0 in-state or adjacent-state surgeons (Table 1). In terms of surgeon density, Vermont had the highest density at 1.85 surgeons per 100,000 residents, calculated from 647,464 residents, 0 in-state surgeons, and 12 adjacent-state surgeons. Omitting the three zero-surgeon states, Florida had the lowest surgeon density at 0.049 surgeons per 100,000, given its large population of over 22 million, 10 in-state surgeons, and only 1 adjacent-state surgeon. Ocular neoplasms may be more prevalent in individuals ≥50 years of age and thus combined-state surgeon densities in residents ≥50 years old were also calculated. This adjustment appears to yield changes to density; however, relative percentile rankings of state densities remain very similar (Table 1).

Table 1 State-by-State Supply and Demand Data

State	State Population	State Population (≥ 50 Years Old)	Medicare Claims Eye Cancer % Prevalence (Percentile)	IRIS® Registry Eye Cancer % Prevalence (Percentile)	Relative Search Volume (RSV)	Number of In-State Ocular Oncology Ophthal mologists	Number of Combined-State Ocular Oncology Ophthal mologists	Single-State Ocular Oncologist Density per 100,000 Residents	Combined-State Ocular Oncologist Density Per 100,000 Residents (Percentile)	Combined-State Ocular Oncologist Density Per 100,000 Residents ≥50 Years Old (Percentile)	Single-State gRDI in Total Popu lation (Per centile)	Combined-State gRDI in Total Population (Percentile)	Combined-State gRDI in Population ≥ 50 Years Old (Percentile)	Combined-State mRDI in Total Population (Percentile)	Combined-State mRDI in Population ≥ 50 Years Old (Percentile)	Combined-state iRDI in Total Population (Percentile)	Combined-State iRDI in Population ≥ 50 Years old (Percentile)
Alabama	5,108,468	1,893,459	2 (54.9)	3.52 (49)	100	0	14	0.000	0.27 (49)	0.74 (49)	1 (64.7)	0.355 (64.7)	0.323 (66.6)	0.129 (50.9)	0.117 (50.9)	0.145 (49)	0.132 (49)
Alaska	733,406	231,025	2.03 (56.8)	3.79 (64.7)	60	0	0	0.000	0 (1.9)	0 (1.9)	1 (64.7)	1 (92.1)	1 (94.1)	1 (94.1)	1 (92.1)	1 (94.1)	1 (92.1)
Arizona	7,431,344	2,690,086	1.93 (41.1)	2.77 (7.8)	50	7	36	0.094	0.48 (64.7)	1.34 (64.7)	0.096 (5.8)	0.1 (31.3)	0.089 (33.3)	0.07 (33.3)	0.063 (31.3)	0.064 (27.4)	0.057 (27.4)
Arkansas	3,067,732	1,107,420	1.98 (47)	3.1 (19.6)	50	0	25	0.000	0.81 (84.3)	2.26 (86.2)	1 (64.7)	0.06 (13.7)	0.053 (9.8)	0.043 (11.7)	0.038 (11.7)	0.043 (11.7)	0.038 (11.7)
California	38,965,193	13,325,178	1.7 (11.7)	2.9 (11.7)	40	21	30	0.054	0.08 (13.7)	0.23 (13.7)	0.135 (7.8)	0.506 (80.3)	0.424 (76.4)	0.391 (84.3)	0.328 (80.3)	0.424 (82.3)	0.356 (80.3)
Colorado	5,877,610	1,955,497	1.84 (29.4)	3.25 (25.4)	50	3	19	0.051	0.32 (50.9)	0.97 (52.9)	0.178 (17.6)	0.15 (37.2)	0.123 (37.2)	0.101 (41.1)	0.082 (39.2)	0.113 (41.1)	0.092 (41.1)
Connecticut	3,617,176	1,420,841	3.18 (96)	5.4 (98)	80	2	14	0.055	0.39 (60.7)	0.99 (56.8)	0.262 (39.2)	0.201 (47)	0.194 (47)	0.145 (54.9)	0.14 (54.9)	0.157 (50.9)	0.151 (52.9)
Delaware	1,031,890	415,792	3.29 (98)	3.72 (60.7)	60	0	11	0.000	1.07 (88.2)	2.65 (90.1)	1 (64.7)	0.055 (11.7)	0.054 (13.7)	0.055 (17.6)	0.054 (25.4)	0.039 (9.8)	0.039 (13.7)
Florida	22,610,726	9,211,387	2.75 (82.3)	4.32 (84.3)	50	10	11	0.044	0.05 (7.8)	0.12 (7.8)	0.205 (31.3)	1 (92.1)	1 (92.1)	1 (92.1)	1 (92.1)	1 (92.1)	1 (98)
Georgia	11,029,227	3,703,170	1.97 (45)	3.33 (29.4)	50	1	19	0.009	0.17 (35.2)	0.51 (35.2)	1 (64.7)	0.282 (56.8)	0.233 (54.9)	0.202 (60.7)	0.167 (60.7)	0.218 (64.7)	0.179 (58.8)
Hawaii	1,435,138	558,280	1.59 (7.8)	2.98 (15.6)	30	1	1	0.070	0.07 (11.7)	0.18 (9.8)	0.078 (3.9)	0.419 (72.5)	0.4 (72.5)	0.404 (86.2)	0.385 (86.2)	0.482 (88.2)	0.46 (90.1)
Idaho	1,964,726	664,841	2.06 (58.8)	4.59 (88.2)	40	0	12	0.000	0.61 (74.5)	1.8 (78.4)	1 (64.7)	0.064 (15.6)	0.053 (11.7)	0.06 (21.5)	0.05 (19.6)	0.085 (37.2)	0.07 (33.3)
Illinois	12,549,689	4,570,404	1.84 (29.4)	3.4 (33.3)	50	8	19	0.064	0.15 (31.3)	0.42 (33.3)	0.142 (11.7)	0.321 (60.7)	0.287 (60.7)	0.215 (64.7)	0.192 (64.7)	0.253 (66.6)	0.226 (66.6)
Indiana	6,862,199	2,436,663	1.83 (27.4)	3.67 (56.8)	50	1	18	0.015	0.26 (47)	0.74 (47)	0.622 (60.7)	0.185 (43.1)	0.162 (41.1)	0.123 (49)	0.108 (47)	0.158 (52.9)	0.137 (50.9)
Iowa	3,207,004	1,174,811	2.49 (74.5)	3.46 (41.1)	60	2	21	0.062	0.65 (78.4)	1.79 (76.4)	0.174 (15.6)	0.089 (27.4)	0.08 (29.4)	0.067 (29.4)	0.06 (29.4)	0.06 (23.5)	0.054 (23.5)
Kansas	2,940,546	1,023,958	2.34 (68.6)	2.93 (13.7)	80	1	11	0.034	0.37 (56.8)	1.07 (60.7)	0.427 (54.9)	0.208 (49)	0.178 (45)	0.111 (47)	0.095 (43.1)	0.088 (39.2)	0.075 (37.2)
Kentucky	4,526,154	1,664,798	1.8 (21.5)	4.09 (76.4)	60	2	26	0.044	0.57 (72.5)	1.56 (68.6)	0.246 (37.2)	0.102 (33.3)	0.092 (35.2)	0.055 (19.6)	0.05 (21.5)	0.08 (35.2)	0.072 (35.2)

(*Continued*)

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Table 1 (Continued).

State	State Population	State Population (≥ 50 Years Old)	Medicare Claims Eye Cancer % Prevalence (Percentile)	IRIS® Registry Eye Cancer % Prevalence (Percentile)	Relative Search Volume (RSV)	Number of In-State Ocular Oncology Ophthalmologists	Number of Combined-State Ocular Oncology Ophthalmologists	Single-State Ocular Oncologist Density per 100,000 Residents	Combined-State Ocular Oncologist Density Per 100,000 Residents (Percentile)	Combined-State Ocular Oncologist Density Per 100,000 Residents ≥50 Years Old (Percentile)	Single-State gRDI in Total Population (Percentile)	Combined-State gRDI in Total Population (Percentile)	Combined-State gRDI in Population ≥ 50 Years Old (Percentile)	Combined-State mRDI in Total Population (Percentile)	Combined-State mRDI in Population ≥ 50 Years Old (Percentile)	Combined-state iRDI in Total Population (Percentile)	Combined-State iRDI in Population ≥ 50 Years old (Percentile)
Louisiana	4,573,749	1,637,565	1.8 (21.5)	4.3 (82.3)	80	1	16	0.022	0.35 (54.9)	0.98 (54.9)	0.664 (62.7)	0.223 (50.9)	0.196 (49)	0.091 (37.2)	0.08 (37.2)	0.138 (47)	0.122 (47)
Maine	1,395,722	615,594	2.89 (88.2)	4.1 (78.4)	60	0	0	0.000	0 (1.9)	0 (1.9)	1 (64.7)	1 (92.1)	1 (94.1)	1 (94.1)	1 (92.1)	1 (94.1)	1 (92.1)
Maryland	6,180,253	2,274,378	1.98 (47)	3.76 (62.7)	70	4	13	0.065	0.21 (43.1)	0.57 (43.1)	0.196 (25.4)	0.324 (62.7)	0.292 (62.7)	0.167 (56.8)	0.15 (56.8)	0.201 (60.7)	0.182 (62.7)
Massachusetts	7,001,399	2,667,622	2.86 (86.2)	3.44 (39.2)	90	7	14	0.100	0.2 (39.2)	0.52 (37.2)	0.163 (13.7)	0.438 (74.5)	0.41 (74.5)	0.253 (70.5)	0.237 (70.5)	0.194 (56.8)	0.181 (60.7)
Michigan	10,037,261	3,881,735	1.79 (17.6)	3.83 (66.6)	60	3	14	0.030	0.14 (27.4)	0.36 (27.4)	0.364 (47)	0.419 (70.5)	0.397 (70.5)	0.227 (66.6)	0.216 (68.6)	0.309 (70.5)	0.294 (72.5)
Minnesota	5,737,915	2,078,166	1.88 (37.2)	3.68 (58.8)	70	4	11	0.070	0.19 (37.2)	0.53 (39.2)	0.182 (21.5)	0.355 (66.6)	0.316 (64.7)	0.173 (58.8)	0.154 (58.8)	0.216 (62.7)	0.192 (64.7)
Mississippi	2,939,690	1,057,568	1.57 (5.8)	3.15 (21.5)	40	0	4	0.000	0.14 (27.4)	0.38 (29.4)	1 (64.7)	0.286 (58.8)	0.253 (58.8)	0.204 (62.7)	0.18 (62.7)	0.261 (68.6)	0.23 (68.6)
Missouri	6,196,156	2,286,926	1.96 (43.1)	3.83 (66.6)	70	4	23	0.065	0.37 (56.8)	1.01 (58.8)	0.197 (27.4)	0.183 (41.1)	0.166 (43.1)	0.093 (39.2)	0.085 (41.1)	0.116 (43.1)	0.105 (43.1)
Montana	1,132,812	431,409	1.77 (13.7)	4.68 (90.1)	60	0	0	0.000	0 (1.9)	0 (1.9)	1 (64.7)	1 (92.1)	1 (94.1)	1 (94.1)	1 (92.1)	1 (94.1)	1 (92.1)
Nebraska	1,978,379	677,631	2.37 (70.5)	3.57 (52.9)	50	1	11	0.051	0.56 (70.5)	1.62 (70.5)	0.179 (19.6)	0.087 (23.5)	0.074 (23.5)	0.075 (35.2)	0.063 (33.3)	0.072 (29.4)	0.061 (31.3)
Nevada	3,194,176	1,133,579	1.59 (7.8)	2.6 (5.8)	30	0	35	0.000	1.1 (92.1)	3.09 (92.1)	1 (64.7)	0.027 (3.9)	0.023 (3.9)	0.026 (5.8)	0.022 (5.8)	0.027 (5.8)	0.023 (5.8)
New Hampshire	1,402,054	593,646	3.05 (92.1)	3.29 (27.4)	100	0	7	0.000	0.5 (66.6)	1.18 (62.7)	1 (64.7)	0.195 (45)	0.203 (50.9)	0.108 (45)	0.112 (49)	0.074 (33.3)	0.077 (39.2)
New Jersey	9,290,841	3,490,416	2.73 (78.4)	3.96 (72.5)	50	2	12	0.022	0.13 (23.5)	0.34 (25.4)	0.421 (50.9)	0.377 (68.6)	0.347 (68.6)	0.374 (80.3)	0.345 (82.3)	0.345 (76.4)	0.318 (76.4)
New Mexico	2,114,371	788,202	1.32 (1.9)	2.39 (3.9)	20	0	32	0.000	1.51 (94.1)	4.06 (94.1)	1 (64.7)	0.013 (1.9)	0.012 (1.9)	0.015 (1.9)	0.014 (1.9)	0.018 (1.9)	0.016 (1.9)
New York	19,571,216	7,448,369	2.76 (84.3)	3.84 (70.5)	60	5	21	0.026	0.11 (17.6)	0.28 (17.6)	0.426 (52.9)	0.544 (86.2)	0.508 (86.2)	0.455 (88.2)	0.425 (90.1)	0.403 (80.3)	0.376 (84.3)
North Carolina	10,835,491	3,925,804	2.26 (66.6)	3.43 (37.2)	90	4	13	0.037	0.12 (21.5)	0.33 (21.5)	0.442 (56.8)	0.73 (88.2)	0.649 (90.1)	0.333 (76.4)	0.296 (74.5)	0.322 (72.5)	0.286 (70.5)
North Dakota	783,926	258,091	1.98 (47)	2.88 (9.8)	40	0	4	0.000	0.51 (68.6)	1.55 (66.6)	1 (64.7)	0.076 (17.6)	0.062 (17.6)	0.069 (31.3)	0.055 (27.4)	0.064 (25.4)	0.051 (19.6)

Ohio	11,785,935	4,452,722	1.85 (33.3)	3.66 (54.9)	60	4	15	0.034	0.13 (23.5)	0.34 (23.5)	0.321 (45)	0.459 (76.4)	0.425 (78.4)	0.257 (72.5)	0.238 (72.5)	0.324 (74.5)	0.3 (74.5)
Oklahoma	4,053,824	1,365,907	2.18 (64.7)	4.02 (74.5)	60	2	25	0.049	0.62 (76.4)	1.83 (80.3)	0.221 (33.3)	0.095 (29.4)	0.078 (25.4)	0.063 (25.4)	0.052 (23.5)	0.073 (31.3)	0.061 (29.4)
Oregon	4,233,358	1,590,954	1.79 (17.6)	3.4 (33.3)	60	2	28	0.047	0.66 (80.3)	1.76 (74.5)	0.23 (35.2)	0.088 (25.4)	0.081 (31.3)	0.048 (13.7)	0.044 (17.6)	0.058 (21.5)	0.053 (21.5)
Pennsylvania	12,961,683	5,127,400	2.73 (78.4)	4.75 (92.1)	80	5	20	0.039	0.15 (31.3)	0.39 (31.3)	0.376 (49)	0.504 (78.4)	0.49 (84.3)	0.313 (74.5)	0.304 (76.4)	0.347 (78.4)	0.337 (78.4)
Rhode Island	1,095,962	429,052	3.07 (94.1)	3.56 (50.9)	70	0	9	0.000	0.82 (86.2)	2.1 (82.3)	1 (64.7)	0.083 (21.5)	0.08 (27.4)	0.066 (27.4)	0.064 (35.2)	0.049 (15.6)	0.047 (17.6)
South Carolina	5,373,555	2,033,112	2.39 (72.5)	4.24 (80.3)	60	1	6	0.019	0.11 (17.6)	0.3 (19.6)	0.585 (58.8)	0.523 (82.3)	0.486 (82.3)	0.379 (82.3)	0.352 (84.3)	0.428 (84.3)	0.397 (86.2)
South Dakota	919,318	328,562	2.16 (62.7)	3.15 (21.5)	60	0	7	0.000	0.76 (82.3)	2.13 (84.3)	1 (64.7)	0.077 (19.6)	0.067 (19.6)	0.05 (15.6)	0.044 (15.6)	0.047 (13.7)	0.041 (15.6)
Tennessee	7,126,489	2,577,407	1.99 (52.9)	4.34 (86.2)	70	3	18	0.042	0.25 (45)	0.7 (45)	0.302 (43.1)	0.27 (54.9)	0.239 (56.8)	0.139 (52.9)	0.124 (52.9)	0.194 (54.9)	0.172 (54.9)
Texas	30,503,301	9,168,465	1.82 (25.4)	3.02 (17.6)	50	15	18	0.049	0.06 (9.8)	0.2 (11.7)	0.184 (23.5)	0.824 (90.1)	0.608 (88.2)	0.546 (90.1)	0.403 (88.2)	0.576 (90.1)	0.425 (88.2)
Utah	3,417,734	886,880	1.55 (3.9)	2.03 (1.9)	50	5	15	0.146	0.44 (62.7)	1.69 (72.5)	0.062 (1.9)	0.111 (35.2)	0.071 (21.5)	0.062 (23.5)	0.04 (13.7)	0.052 (17.6)	0.033 (7.8)
Vermont	647,464	274,813	2.89 (88.2)	5.36 (96)	80	0	12	0.000	1.85 (98)	4.37 (98)	1 (64.7)	0.042 (7.8)	0.044 (7.8)	0.028 (7.8)	0.029 (7.8)	0.033 (7.8)	0.034 (9.8)
Virginia	8,715,698	3,122,696	2.56 (76.4)	3.46 (41.1)	50	4	17	0.046	0.2 (39.2)	0.54 (41.1)	0.198 (29.4)	0.249 (52.9)	0.219 (52.9)	0.232 (68.6)	0.204 (66.6)	0.2 (58.8)	0.176 (56.8)
Washington	7,812,880	2,714,526	1.85 (33.3)	3.5 (45)	50	5	7	0.064	0.09 (15.6)	0.26 (15.6)	0.142 (9.8)	0.543 (84.3)	0.463 (80.3)	0.365 (78.4)	0.312 (78.4)	0.44 (86.2)	0.375 (82.3)
West Virginia	1,770,071	733,290	1.78 (15.6)	5.3 (94.1)	60	0	19	0.000	1.07 (88.2)	2.59 (88.2)	1 (64.7)	0.054 (9.8)	0.055 (15.6)	0.029 (9.8)	0.03 (9.8)	0.056 (19.6)	0.057 (25.4)
Wisconsin	5,910,955	2,283,651	1.92 (39.2)	3.36 (31.3)	50	2	19	0.034	0.32 (50.9)	0.83 (50.9)	0.268 (41.1)	0.151 (39.2)	0.144 (39.2)	0.106 (43.1)	0.1 (45)	0.118 (45)	0.112 (45)
Wyoming	584,057	215,226	2.08 (60.7)	3.5 (45)	50	0	9	0.000	1.54 (96)	4.18 (96)	1 (64.7)	0.032 (5.8)	0.029 (5.8)	0.024 (3.9)	0.022 (3.9)	0.026 (3.9)	0.023 (3.9)

Abbreviations: IRIS, Intelligent Research in Sight; gRDI, Relative demand index calculated from Google relative search volumes; mRDI, Relative demand index calculated from Medicare claims eye cancer prevalence; iRDI, Relative demand index calculated from IRIS® Registry eye cancer prevalence.

Table 2 State-by-State Characteristics on Populations, Poverty Estimate, Urbanization, Rural Population Percentage, and Vision Screening Percentage

State	State Population	State Population (≥ 50 Years Old)	% of Population Below 50% National Poverty Level	Urban Population %	% Population Inside Urbanized Areas	% Population Inside Urban Clusters	Rural Population %	Vision Screening Rate %
Alabama	5,108,468	1,893,459	7.35	24.81	20.37	4.44	17.71	0.05
Alaska	733,406	231,025	5.29	24.95	16.81	8.14	16.9	0.07
Arizona	7,431,344	2,690,086	6.29	33.85	30.18	3.67	4.43	0.46
Arkansas	3,067,732	1,107,420	7.97	23.49	16.51	6.98	19.42	0.02
California	38,965,193	13,325,178	5.87	32.89	30.93	1.96	2.22	0.31
Colorado	5,877,610	1,955,497	4.73	31.29	27.52	3.77	6.36	0.18
Connecticut	3,617,176	1,420,841	4.85	36.18	34.82	1.36	4.96	0.33
Delaware	1,031,890	415,792	4.58	32.86	24.34	8.52	6.47	0.27
Florida	22,610,726	9,211,387	5.89	36.22	34.8	1.42	3.54	0.1
Georgia	11,029,227	3,703,170	6.14	27.39	23.82	3.57	9.68	0.13
Hawaii	1,435,138	558,280	5.29	32.4	23.92	8.49	3.8	0.14
Idaho	1,964,726	664,841	4.49	22.77	16.32	6.46	11.21	0.04
Illinois	12,549,689	4,570,404	6.08	37.08	33.27	3.81	5.13	0.05
Indiana	6,862,199	2,436,663	6.08	29.81	24.22	5.6	10.92	0.12
Iowa	3,207,004	1,174,811	5.25	26.45	16.91	9.54	15.22	0.03
Kansas	2,940,546	1,023,958	5.47	30.64	20.74	9.9	11.3	0.19
Kentucky	4,526,154	1,664,798	7.26	24.69	17.23	7.46	17.89	0.1
Louisiana	4,573,749	1,637,565	8.27	31.38	26.49	4.89	11.58	0.06
Maine	1,395,722	615,594	4.76	18	11.96	6.04	33.72	0.01
Maryland	6,180,253	2,274,378	4.82	33.54	31.61	1.93	4.95	0.41
Massachusetts	7,001,399	2,667,622	5.11	36.65	35.77	0.89	3.46	0.27
Michigan	10,037,261	3,881,735	6.39	32.45	28.77	3.68	12.71	0.14
Minnesota	5,737,915	2,078,166	4.38	28.55	22.47	6.07	12.36	0.16
Mississippi	2,939,690	1,057,568	8.54	21.3	11.99	9.31	22.06	0.04
Missouri	6,196,156	2,286,926	6.14	30.37	24.53	5.84	13.41	0.09
Montana	1,132,812	431,409	5.63	22.24	10.33	11.92	20.38	0.12
Nebraska	1,978,379	677,631	4.99	28.52	20.71	7.81	11.76	0.09
Nevada	3,194,176	1,133,579	6.44	34.36	31.3	3.06	2.39	0.11
New Hampshire	1,402,054	593,646	3.43	24.53	18.96	5.57	19.32	0.11
New Jersey	9,290,841	3,490,416	4.35	36.31	35.38	0.93	1.94	0.35
New Mexico	2,114,371	788,202	7.72	32.02	22.13	9.89	10.61	0.07

(*Continued*)

Table 2 (Continued).

State	State Population	State Population (≥ 50 Years Old)	% of Population Below 50% National Poverty Level	Urban Population %	% Population Inside Urbanized Areas	% Population Inside Urban Clusters	Rural Population %	Vision Screening Rate %
New York	19,571,216	7,448,369	7.3	35.44	33.17	2.27	5.99	0.34
North Carolina	10,835,491	3,925,804	5.72	25.73	21.04	4.68	14.21	0.35
North Dakota	783,926	258,091	5.39	23.22	15.62	7.6	17.28	0.04
Ohio	11,785,935	4,452,722	6.28	34.57	29.06	5.51	8.94	0.06
Oklahoma	4,053,824	1,365,907	7.1	26.92	18.5	8.41	14.14	0.02
Oregon	4,233,358	1,590,954	5.82	31.38	24.07	7.31	8.2	0.26
Pennsylvania	12,961,683	5,127,400	5.49	33.31	29.84	3.46	9.65	0.22
Rhode Island	1,095,962	429,052	5	38.25	38.01	0.24	4.03	0.17
South Carolina	5,373,555	2,033,112	6.38	26.49	22.41	4.08	13.29	0.06
South Dakota	919,318	328,562	5.46	21.86	11.43	10.43	17.67	0.07
Tennessee	7,126,489	2,577,407	6.02	25.9	21.14	4.76	13.57	0.24
Texas	30,503,301	9,168,465	6.35	27.15	24.03	3.12	5.56	0.52
Utah	3,417,734	886,880	3.77	24.84	22.05	2.78	3.83	0.15
Vermont	647,464	274,813	4.16	16.46	7.07	9.39	33.36	0.12
Virginia	8,715,698	3,122,696	5.16	28.2	25.89	2.32	10.4	0.13
Washington	7,812,880	2,714,526	5.28	30.46	27.18	3.28	6.47	0.09
West Virginia	1,770,071	733,290	7.98	23.98	16.35	7.63	25.84	0.07
Wisconsin	5,910,955	2,283,651	4.86	29.5	23.32	6.18	14.9	0.06
Wyoming	584,057	215,226	4.83	27.89	10.56	17.32	16.95	0.02

Alaska, Maine, and Montana had the highest normalized RDI value, 1, given no available surgeon. Considering states with at least 1 in-state or adjacent-state surgeon, Florida had a gRDI, mRDI, and iRDI value of 1 across all states with, indicating the highest demand, followed by Texas (0.82 gRDI, 0.55 mRDI, 0.57 iRDI) (Table 1). The state with the lowest normalized RDI values was New Mexico (0.013 gRDI, 0.015 mRDI, 0.018 iRDI), with Nevada having a slightly greater gRDI at 0.0266 and Wyoming having the next greater mRDI (0.024) and iRDI (0.026). RDI values calculated using surgeon densities accounting only for residents ≥50 years old appeared to have minimal effect on RDI values.

Vision screening rates varied across states, with Texas and Arizona showcasing the highest rates of 0.52% and 0.46%, respectively, contrasting the lower rates found in Maine (0.01%) and Arkansas (0.02%) (Table 2).

Results of Pearson correlation tests comparing population variables, prevalence, and screening rates with ocular oncology ophthalmologist densities, RSV, and various normalized RDI values are shown in Table 3. No significant associations were found between RSV and in-state or combined-state ocular oncology ophthalmologist density per 100,000 people. There was a significant negative correlation between combined-state ocular oncology ophthalmologist density per 100,000 and percentage of a state's population living inside urbanized areas ($r = -0.352$, p-value = 0.012). However, positive correlations were found between combined-state ocular oncology ophthalmologist density per 100,000 and both the percentage of a state's population living inside urban clusters ($r = 0.492$, p-value = <0.001) and the

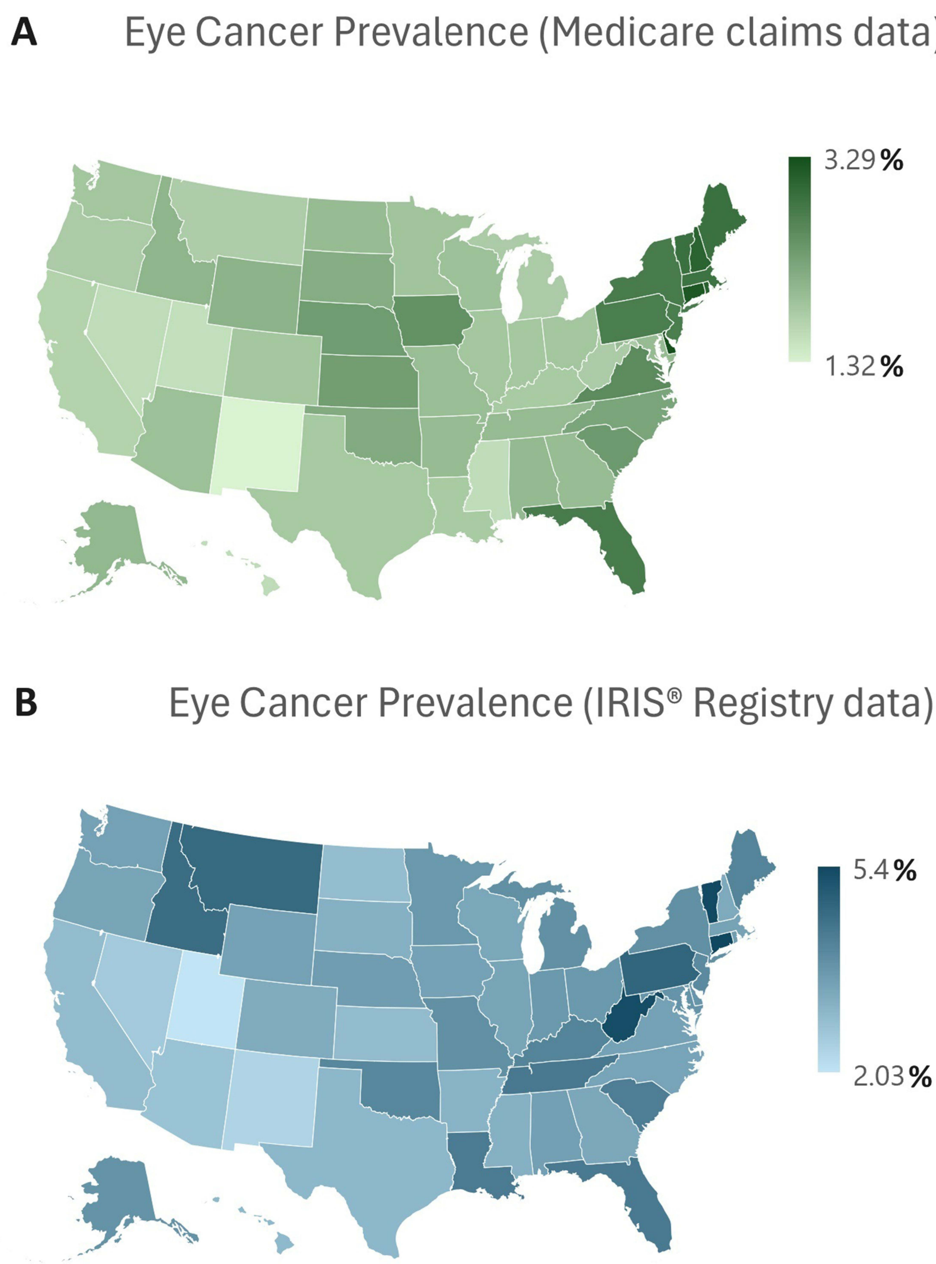

Figure 1 (**a**) Annual prevalence of diagnosed cancer and neoplasms of the eye in each state based on 2019 Medicare (Fee for Service) claims data.; (**b**) Annual prevalence of diagnosed cancer and neoplasms of the eye in each state based on 2019 IRIS® Registry data.

percentage of a state's population living in rural areas ($r = 0.285$, p-value = 0.04). No statistically significant correlations were found between combined-state surgeon density and either Medicare-sourced eye cancer percent prevalence, IRIS® Registry-sourced eye cancer percent prevalence, or vision screening rate.

RSV values were significantly correlated with eye cancer percent prevalence sourced from Medicare ($r = 0.512$, p-value < 0.001) and IRIS® Registry ($r = 0.402$, p-value = 0.004) data. No significant correlations were found between combined-state normalized gRDI values and eye cancer percent prevalence (Table 3). However, significant negative correlations were found between single-state normalized gRDI and state urban population percentage ($r = -0.478$, p-value < 0.001), percent living in urbanized areas ($r = -0.513$, p-value < 0.001), and vision screening rate ($r = -0.416$, p-value = 0.003). Significant positive correlations were also found between single-state normalized gRDI and both the percent population in urban clusters ($r = 0.415$, p-value = 0.003) and the rural population percentage ($r = 0.553$,

Table 3 Compiled Correlations

Variable 1	Variable 2	R	R^2	p-value
Relative Search Volume	Single-State Ocular Oncology Ophthalmologist Density Per 100,000 Residents	0.029	0.001	0.840
Relative Search Volume	Combined-State Ocular Oncologist Density Per 100,000 Residents	−0.113	0.013	0.435
Relative Search Volume	% of Population Below 50% Of National Poverty Level	−0.165	0.027	0.253
	Urban Population %	−0.065	0.004	0.656
	% of Population Living Inside Urbanized Areas	0.021	< 0.001	0.882
	% of Population Living Inside Urban Clusters	−0.149	0.022	0.302
	Rural Population %	0.231	0.053	0.107
	Eye Cancer Prevalence Percent (Medicare)	0.512	0.262	< 0.001*
	Eye Cancer Prevalence Percent (IRIS® Registry)	0.402	0.161	0.004*
	Vision Screening Rate	0.162	0.026	0.262
Single-state Ocular Oncology Ophthalmologist Density per 100,000	% of Population Below 50% Of National Poverty Level	−0.235	0.055	0.101
	Urban Population %	0.363	0.132	0.01*
	% of Population Living Inside Urbanized Areas	0.422	0.178	0.002*
	% of Population Living Inside Urban Clusters	−0.388	0.151	0.005*
	Rural Population %	−0.388	0.277	< 0.001*
	Eye Cancer Prevalence Percent (Medicare)	−0.135	0.018	0.348
	Eye Cancer Prevalence Percent (IRIS® Registry)	−0.259	0.067	0.069
	Vision Screening Rate	0.383	0.147	0.006*
Combined-State Ocular Oncologist Density Per 100,000 Residents	% of Population Below 50% Of National Poverty Level	−0.002	0.000	0.991
	Urban Population %	−0.193	0.037	0.179
	% of Population Living Inside Urbanized Areas	−0.352	0.124	0.01*
	% of Population Living Inside Urban Clusters	0.492	0.242	<0.001*
	Rural Population %	0.285	0.081	0.04*
	Eye Cancer Prevalence Percent (Medicare)	0.058	0.003	0.690
	Eye Cancer Prevalence Percent (IRIS® Registry)	0.026	0.001	0.859
	Vision Screening Rate	−0.231	0.053	0.107
Single-State gRDI	% of Population Below 50% Of National Poverty Level	0.145	0.021	0.314
	Urban Population %	−0.478	0.228	< 0.001*
	% of Population Living Inside Urbanized Areas	−0.513	0.264	< 0.001*
	% of Population Living Inside Urban Clusters	0.415	0.172	0.003*
	Rural Population %	0.553	0.306	< 0.001*
	Eye Cancer Prevalence Percent (Medicare)	0.101	0.010	0.487
	Eye Cancer Prevalence Percent (IRIS® Registry)	0.120	0.014	0.407
	Vision Screening Rate	−0.416	0.173	0.003*

(*Continued*)

Table 3 (Continued).

Variable 1	Variable 2	R	R^2	p-value
Combined-State gRDI	% of Population Below 50% Of National Poverty Level	−0.027	0.001	0.855
	Urban Population %	−0.011	< 0.001	0.940
	% of Population Living Inside Urbanized Areas	0.091	0.008	0.529
	% of Population Living Inside Urban Clusters	−0.222	0.049	0.121
	Rural Population %	0.017	< 0.001	0.908
	Eye Cancer Prevalence Percent (Medicare)	0.094	0.009	0.517
	Eye Cancer Prevalence Percent (IRIS® Registry)	0.180	0.032	0.211
	Vision Screening Rate	0.178	0.032	0.215
mRDI	% of Population Below 50% Of National Poverty Level	−0.072	0.005	0.619
	Urban Population %	−0.051	0.003	0.728
	% of Population Living Inside Urbanized Areas	0.020	< 0.001	0.888
	% of Population Living Inside Urban Clusters	−0.124	0.015	0.391
	Rural Population %	0.066	0.004	0.650
	Eye Cancer Prevalence Percent (Medicare)	0.131	0.017	0.363
	Eye Cancer Prevalence Percent (IRIS® Registry)	0.200	0.040	0.164
	Vision Screening Rate	0.067	0.005	0.643
iRDI	% of Population Below 50% Of National Poverty Level	−0.037	0.001	0.797
	Urban Population %	−0.053	0.003	0.712
	% of Population Living Inside Urbanized Areas	0.016	< 0.001	0.912
	% of Population Living Inside Urban Clusters	−0.119	0.014	0.411
	Rural Population %	0.067	0.005	0.642
	Eye Cancer Prevalence Percent (Medicare)	0.066	0.004	0.651
	Eye Cancer Prevalence Percent (IRIS® Registry)	0.216	0.047	0.132
	Vision Screening Rate	0.045	0.002	0.755

Notes: *p-value ≤ 0.05.
Abbreviations: IRIS, Intelligent Research in Sight; gRDI, Relative demand index calculated from Google relative search volumes; mRDI, Relative demand index calculated from Medicare claims eye cancer prevalence; iRDI, Relative demand index calculated from IRIS® Registry eye cancer prevalence.

p-value < 0.001). In contrast, no significant correlations were found between combined-state normalized gRDI, mRDI and iRDI values and any of the variables analyzed.

Discussion

Ocular cancers often require specialized care from licensed ophthalmologists, trained through highly selective and rigorous graduate schooling, residency, and fellowship programs. For patients afflicted with ocular neoplasms, it is imperative these physicians are available in a reasonably prompt timeline. This is the first study evaluating search volumes of each state for ocular oncology in the United States to explore connections between a supply-and-demand metric and various demographic and health factors, stratified by state. Further adding to the robustness of our study, we also conducted many of the same analyses using demand metrics generated from eye cancer percent prevalence data available from the VEHSS, sourced with data from Medicare claims and the IRIS® Registry. The data aggregated in this paper demonstrates wide heterogeneity in various factors related to eye care access across the US. The discrepancy in ocular oncology ophthalmologist density in various states highlights significant differences in access to specialized ocular oncology ophthalmologist services, which could impact the detection and treatment of eye cancers such as uveal melanoma.

Our investigation yielded RDI values, which were then normalized to obtain our quantitative measurement for each state's gap between demand and supply relative to that of other states. As an example, Iowa is at the 74.5th percentile for eye cancer prevalence according to Medicare data. However, the combined-state surgeon density for Iowa is at the 78.4th percentile, which yields a normalized mRDI of 0.067 (29.4th percentile). In contrast, New York has a Medicare percent prevalence at the 84.3rd percentile and a combined-state surgeon density only at the 17.6th percentile. The resulting normalized mRDI value of 0.455 (88.2nd percentile) shows the disparity in demand and supply in New York and in states with similar values. This outcome shows that RDI values of each state consider both supply and demand, while the process of normalizing RDI values allows us to generate a quantification of a state's demand and supply gap relative to the other 46 states. Alaska, Maine, and Montana were automatically assigned RDI values of 1 and were not included in the normalization process.

The normalized RDI elaborates on the disparity in healthcare resources and the corresponding need for trained ocular oncology ophthalmologists across the states. Demand metrics for New Mexico (0.013 gRDI, 0.015 mRDI, 0.178 iRDI, all in the 1.9th percentile) indicate a relative balance between the demand for ocular oncology ophthalmologists and the availability of such specialists. In contrast, an RDI value of 1 for Alaska, Florida, Maine, and Montana suggests a higher demand relative to the availability of ocular oncology ophthalmologists. These results add further support and provide quantifiable evidence to ongoing Discussions regarding the need for increased availability of ocular ophthalmologists in areas of low supply.

We also calculated the surgeon density per 100,000 persons ≥50 years of age and RDI with that density. As expected, this increased the surgeon densities in each state. However, the corresponding percentiles remain very similar. This suggests low variability between states in the proportion of individuals at least 50 years of age. Notably, Utah had the largest percentile difference between surgeon density in the overall population (0.44, 62.7th percentile) and in the population ≥50 years old (1.69, 72.5th percentile), representing a 3.85-fold increase in density. This also resulted in changes in RDI values of similar magnitude when comparing the demand-supply gap between the general versus ≥50 years old populations. No other state had greater than a 5 percentile point change in surgeon density when comparing the density in the total population and density of inhabitants ≥50 years of age. There was a 2.75-fold average increase in density when considering only the population ≥50 years of age.

The difference in RSV between states may possibly be multifactorial and future studies may shed light on factors that modulate public interest and RSV. Interestingly, Alabama (100 RSV, ranked tie-1st) and North Carolina (90 RSV, ranked tie-3rd) had notable reports of ocular melanoma clusters, with 36 and 18 patient cases reported by local media, respectively. This indicates a potential influence of current events, social media, and community awareness on the relative search volumes of a particular affected region and may potentially influence regional public interest in trending topics in health and disease.

Surgeon density may vary widely between states. For instance, despite high eye cancer prevalence above the 80th percentile, Florida has a surgeon density in the 8th percentile. This may highlight a gap between cancer prevalence neoplasm and the availability of specialized care. Meanwhile, Vermont has an upper-range prevalence, an upper-range RSV, with a matching upper-range surgeon density, which may suggest that the state's ocular oncology service needs are more likely to be met when considering surgeons in adjacent states. These dynamics between ocular neoplasm prevalence, search trends, and healthcare resource distribution underscore the complex interplay between public health awareness, disease prevalence, and healthcare accessibility.

Analyses also investigated vision screening rates, ocular neoplasm rates per state, and their link with Google search trends and ocular oncology ophthalmologist density. The variation in vision screening rate may suggest differing levels of public health initiatives or access to preventive eye care services across states. Although ocular neoplasm prevalence rates are relatively uniform across states, it appears that the relative percentage of eye cancer prevalence may vary between data sourced from Medicare claims and the IRIS® Registry. For example, the prevalence percentage of eye cancer in New Hampshire is in the upper range according to Medicare claims data but in the lower range according to the IRIS® Registry data.

The correlation analysis also yielded several notable findings that underscore the intricate relationship between healthcare resources and disease prevalence within the context of eye health. First, a significant correlation was observed between the RSV and the ocular neoplasm prevalence rate for both data sources, which suggests a strong link between public interest or concern in UM and its actual prevalence, highlighting the potential of search trend data as a proxy for disease prevalence in epidemiological studies. However, when we factor in the relative surgeon availability by examining the correlation between the normalized gRDI values and eye cancer prevalence, no significant correlations were found. This indicates that, although search interest is correlated to prevalence, no claims can be made regarding whether areas with higher RSV also have increased surgeon density. Along similar lines, correlation analyses between either surgeon densities and RSV or prevalence did not find strong evidence to conclude significant relationships. This suggests a possibility that surgeon density might not be directly influenced by patient search interest or prevalence of diseases in each state.

Significant correlations were found between single-state ocular oncology ophthalmologist density and percent living in urbanized areas of at least 50,000 inhabitants. Negative correlations were found between single-state surgeon density and both the percent living in smaller urban clusters and the percent living in rural communities. These initial findings reveal a disparity in the geographical distribution of ocular oncology ophthalmologists, with a scarcity of these specialists in states with a higher proportion of rural population. This indicates potential access issues to specialized eye care in rural areas when considering only surgeons within each respective state. This result also suggests that there may be less surgeon availability for urban clusters than urban areas, despite both being classified under "under populations". However, correlations between surgeon density and urban or rural populations are reversed when surgeons in adjacent states are accounted for. A significant negative correlation was identified between combined-state ocular oncology ophthalmologist density and the percentage of a state's population living in urbanized areas. Combined-state surgeon density was found to be positively correlated with the percent living in urban clusters and the percent living in rural areas. These correlation trends, when accounting for adjacent-state surgeons, suggest that surgeons from adjacent states may bolster the availability of ocular oncology ophthalmologist services for urban clusters and rural populations. Further studies would benefit from a deep dive into barriers to population living in rural areas or urban clusters in seeking care in adjacent states.

Correlation analyses with gRDI values calculated with single-state surgeon densities tell a similar story in terms of greater demand in rural states. Significant negative correlations were found between gRDI calculated with single-state surgeon densities and percent living in urban areas, while positive correlations were found between this gRDI and percent rural population. Again, this highlights a potential greater gap in demand and supply in rural areas.

This study has several limitations. Firstly, the Search Term selection focused solely on "uveal melanoma", potentially overlooking several alternative terms and phrases alternative terms that may be used by patients seeking providers via Google searches. Search algorithms are proprietary to Google, and thus we are unable to determine the exact search terms our query encompassed. Second, the search strategy does not encompass offline demand for ophthalmologists, such as referrals from optometrists or primary care physicians. The methodology by which RSV values are calculated may introduce variation, given that RSV values are calculated as a fraction of total searches within each state and compared among 49 other states and Washington DC. Additionally, a portion of the search volumes screening may originate from non-patient populations, including students, healthcare providers, researchers, or individuals interested in ophthalmology. However, many of the drawbacks of analyses utilizing RSV do not apply to analyses utilizing eye cancer prevalence data. Regarding VEHSS data, we chose to utilize Medicare claims and IRIS® Registry data as the data sources for eye neoplasm prevalence and screening rates, therefore this does not encompass every case of eye neoplasms and vision screening utilization in the United States. VEHSS prevalence data for ocular oncology included all eye neoplasms, including neoplasms other than uveal melanoma. However, this is still of great value in assessing the demand for ocular oncology ophthalmologists. It is also possible that Google Trends, the AAO 'Find an Ophthalmologist' tool, and government-sponsored databases may update past data or introduce minor variations to their methodologies as time progresses. It should also be noted that there is no Accreditation Council for Graduate Medical Education board for ocular oncology and not all ocular oncologists treat uveal melanoma. Finally, calculating RDI values using both in-state and adjacent-state surgeon counts might not capture barriers to accessing adjacent-state surgeons or competing with individuals from other states to secure clinic or surgery appointments.

Conclusion

In Conclusion, this study explored variations in the availability of ocular oncology ophthalmologists and predicted service demand utilizing eye neoplasm prevalence data and Google Trends data as a surrogate for demand. We observed considerable diversity in normalized RDI values and ocular oncology ophthalmologist density across states, highlighting potential under-supply scenarios. Further investigation should explore these findings with more detailed data to effectively meet the need for ocular oncology ophthalmologists in undersupplied areas throughout the United States.

Data Sharing Statement

All analyzed data are publicly available without charge through trends.google.com, American Academy of Ophthalmology, Center for Disease Control Vision and Eye Health Surveillance System (Medicare and IRIS® Registry data sources), and the United States Census Bureau.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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