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Evaluating Access to Eye Care in the Contiguous United States by Calculated Driving Time in the United States Medicare Population

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Abstract

Purpose—To quantify the proximity to eye care in the contiguous United States by calculating driving routes and driving time using a census-based approach.

Design—Cross-sectional study based on United States (US) census data, Medicare payment data, and OpenStreetMap.

Participants—2010 US census survey respondents older than 65 years.

Methods—For each state in the United States, the addresses of all practicing ophthalmologists and optometrists were obtained from the 2012 Medicare Provider Utilization and Payment Data from the Centers for Medicare and Medicaid Services (CMS). The US census data from 2010 then were used to calculate the geo-location of the US population at the block group level and the number of people older than 65 years in each location. Geometries and driving speed limits of every road, street, and highway in the United States from the OpenStreetMap project were used to calculate the exact driving distance and driving time to the nearest eye care provider.

Main Outcome Measures—Driving time and driving distance to the nearest optometrist and ophthalmologist per state.

Results—Driving times for 3.79×10^7 persons were calculated using a total of 3.88×10^7 available roads for the 25 508 optometrists and 17 071 ophthalmologists registered with the CMS.

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Nationally, the median driving times to the nearest optometrist and ophthalmologist were 2.91 and 4.52 minutes, respectively. Ninety percent of the population lives within a 13.66- and 25.21-minute drive, respectively, to the nearest optometrist and ophthalmologist.

Conclusions—While there are regional variations, overall more than 90% of the US Medicare beneficiary population lives within a 30-minute drive of an ophthalmologist and within 15 minutes of an optometrist.

The identification of medically underserved geographic areas is critical to health care policy and delivery models.^{1,2} The issue of rural access to care has been cited as a reason to increase eye care providers, as has providers' arguments for expansion, including increased responsibilities and scope of practice for optometrists.^{3–5}

Geographic information systems often have been used to aid in geospatial analysis. Driving time in particular is used to estimate access to medical care in other fields of medicine such as cardiology, obstetrics, and emergency medicine.⁶ Many of these studies have estimated driving distance at the zip code level and have used a direct spherical distance (time of flight) and have converted the distance to time using validated heuristics.⁷ OpenStreetMap (available at: <https://www.openstreetmap.org/>) is a collaborative open-source mapping project in which the geographic data for every drivable surface and the speed limit for each segment of road are captured. OpenStreetMap can be used to estimate the shortest driving distance and time between 2 addresses, thus measuring the burden of travel and location of patients relative to a clinic.

Access to ophthalmic care has been evaluated by visit rates to an eye care provider^{8,9} and by the number of providers per 100 000 persons at the United States (US) county level to approximate overuse or underuse.¹⁰ However, the analysis of driving distance or time to health care providers can provide useful information regarding key barriers to access to adequate health care providers in a particular region. In this study, we sought to leverage the geographic data from the OpenStreetMaps project and combine it with the US census data from 2010 to calculate driving routes and driving times directly for every census block group, a much smaller geographic unit of analysis than in prior studies. By using this strategy, we attempted to measure the driving time to the nearest optometrist and ophthalmologist, one of the key components of access to care. To our knowledge, this is the first study in medicine to evaluate the accessibility of care by directly calculating driving routes and time.

Methods

Public data from the 2010 US census were obtained from the US Census Bureau. Census data were analyzed at the block group level, and the geolocation for all participants older than 65 years who responded to the US census was analyzed. The data were loaded into a PostGIS database (available at: <http://postgis.net/>). Geometries for all block group polygons were calculated, and the number of people living inside each block group also was extracted from the census data.

All optometrists and ophthalmologists who billed Medicare in 2012 were extracted from the 2012 Medicare Provider Utilization and Payment Data from the Centers for Medicare and Medicaid Services. When this research was initiated, this data set was the most recently available from the Centers for Medicare and Medicaid Services. All provider addresses were converted to global positioning satellite coordinates by geocoding the addresses after natural language processing. This data set contains only 1 office location per provider, and no data from additional satellite offices or the percentage of coverage of these offices were available to be included in the analysis.

Data for each state were downloaded from the OpenStreetMap servers and the geometries for every drivable surface (road, streets, and highways) were extracted, along with the speed limit for each segment of the road. The line geometries of each drivable segment then were used to create a collection of nodes and edges. Dijkstra's algorithm was used to calculate the shortest route, defined as the path of shortest driving time from one location to another.¹¹

For each state, a list of optometrists and ophthalmologists was created, and the shortest driving distance and time for all locations of every census participant were calculated. In addition, the distance for each optometrist to the nearest ophthalmologist was calculated for the US Medicare population.

Data analysis was performed by custom code written in Ruby (available at: <http://www.ruby-lang.org>). All statistics were calculated using R (available at: <http://r-project.org>). Database technologies included PostgreSQL (available at: <http://www.postgresql.org/>), PostGIS, and pgRouting (available at: <http://pgrou-ting.org/>). Maps were rendered using Mapnik (available at: <http://mapnik.org/>).

Results

Driving routes and times to the nearest optometrist and ophthalmologist were mapped for 3.79×10^7 people older than 65 years in each state in the contiguous United States. Nationally, addresses for 17 071 ophthalmologists and 25 508 optometrists were geo-coded from the 2012 Medicare Provider Utilization and Payment Data. A total of 3.88×10^7 available roads from OpenStreetMap were used to compute the shortest driving time to the nearest eye care provider. Nearly half a million driving route geometries and driving times were calculated (Fig 1).

Nationwide, median driving times to the nearest optometrist and ophthalmologist in the Medicare population were 2.91 and 4.52 minutes, respectively, without considering traffic patterns and stopping at intersections. Ninety percent of the Medicare population lived within 13.66 minutes of an optometrist and 25.21 minutes of an ophthalmologist. Each region of the United States was subanalyzed by US economic regions (Fig 2). The time to the nearest optometrist and ophthalmologist for 75% of the national population was 6.23 and 11.34 minutes, respectively. The region with the least difference between optometrists and ophthalmologist was the Mideast, with only 2.10 minutes' difference for 75% of the population. The 2 regions with the highest differences were the Plains and the Rocky Mountains, with a difference of 16.84 and 10.23 minutes, respectively.

At a state level, the average state median driving times to the nearest optometrist and ophthalmologist were 3.309 minutes (interquartile range [IQR], 1.90 minutes) and 6.20 minutes (IQR, 4.93 minutes), respectively. The average state driving time for 90% of the population was 16.17 minutes (IQR, 9.30 minutes) to an optometrist and 29.65 minutes (IQR, 17.47 minutes) to an ophthalmologist. Figure 3 shows a state-level Circos plot encapsulating these data, with the arc length of each state scaled by the number of people older than 65 years living in each state, the outermost track shaded by the difference between driving time to an ophthalmologist versus to an optometrist, the middle track shaded by the absolute driving time to an ophthalmologist, and the inner track shaded by the absolute driving time to an optometrist.

To evaluate how much farther a patient would have to drive to see an ophthalmologist after seeing an optometrist, the driving routes and times from every optometrist to the nearest ophthalmologist were calculated. Nationally, the median additional driving time was 1.96 minutes, and 90% of optometrists practiced within 19.62 minutes of an ophthalmologist. The average median state driving time between optometrist and nearest ophthalmologist was 2.27 minutes (IQR, 0.85 minutes), and the average median state driving time for 90% of optometrists was 27.80 minutes from the nearest ophthalmologists (IQR, 20.79 minutes).

Discussion

Access to eye care often is cited as a medical burden.¹² In this study we sought to measure the access to optometric and ophthalmic eye care directly and to compare the burden on the US Medicare population by driving time. By combining the data from the US census and the OpenStreetMaps project, we were able to create driving routes from each census block group to the nearest eye care provider. In addition, by using the speed limit data, we were able to measure the driving time directly in minutes in every state in the contiguous United States.

Prior studies addressing accessibility to medical care used direct time of flight or distance to major highways.⁶ These previous methodologies likely underestimated the access in remote regions, where circuitous driving routes may further hinder patients' ability to seek medical care, specifically eye care. The latter method, using distance to major highways, is more realistic but has several drawbacks. First, it does not take into consideration the difficulty of reaching a major highway. Second, it makes the assumption that as soon as a major highway is reached, access is universally available. In this study, we sought to overcome these limitations by definitively calculating the driving route using a public mapping project. To our knowledge, this is the first study in medicine to measure access to care through direct driving routes and driving time. In addition, we used the smallest feasible geographic unit of analysis by using census block groups in contrast to larger regions distinguished by zip codes. We found that the overwhelming majority of the US Medicare population lives within less than half an hour of an ophthalmologist.

Our findings contrast with the results of Gibson,¹⁰ who analyzed 3143 counties in the United States and found that 24.1% of the counties were in the lower 2 quartiles of ophthalmologist availability but in the upper 2 quartiles of optometrist availability. For each US county,

Gibson analyzed the number of optometrists or ophthalmologists and the population of the respective county. However, this method of analysis grossly underestimates availability, because neighboring counties within a reasonable driving distance may have vastly different numbers of practicing eye care providers. In contrast, this study analyzed 2.1×10^5 geographic units and used a much more sensitive method for assessing access to care.

Access to care is associated not only with delivery of care, but also with clinical outcomes.¹³ In children, the inadequate supply of primary care physicians has been shown to be associated with higher rates of missed preventative care, primary care, or newborn visits, resulting in higher incidence of asthma- and diabetes-related admissions.¹⁴ Similarly, in eye care, access to care may lead to earlier detection and better clinical outcomes of potentially blinding diseases.¹⁵ Nevertheless, insurance coverage and social and cultural factors play an important role in shaping access to care. Both optometrists and ophthalmologists are essential in eye care delivery in the United States. Thus, determining the availability of both providers is critical to assess our ability to deliver a comprehensive range of routine eye care to complex surgeries.

Our study has several limitations. First, our driving time analysis does not take into account any traffic or stop signs, which likely would add to the overall driving time. However, our driving time calculation included only routes within each state, likely overestimating driving time for patients who live closer to an eye provider in a neighboring state. Second, the list of actively practicing ophthalmologists and optometrists were obtained from the Medicare payments data from 2012; thus, our study does not include providers who see only pediatric and young adult patients. Third, only 1 office location is recorded in the data set, and no data are present on additional branches or secondary offices; proximity to the nearest provider thus may be less than we have calculated. Fourth, the census and Medicare data are from different years but represent the latest available data from each data source. Fifth, our study does not differentiate subspecialists; access for patients with conditions requiring particular subspecialty expertise likely will be less than our estimates. Additionally, this study focuses on driving time and distance in a particular region and does not account for patients who may not have access to transportation via cars (either because of visual disability or socioeconomic factors) and may rely on public transportation as their primary method to arrive at eye care. This will increase the average time to receive eye care from both optometrists and ophthalmologists. Nevertheless, most of our limitations likely would cause a systematic bias, underestimating the driving time to the nearest provider, and the true driving time to the nearest provider may be even lower than estimated in our work. An even higher proportion of optometrists may be missing from this study because approximately 40% of optometrists do not bill Medicare^{16,17}; however, this would reduce the driving time to the nearest optometrist and would not dilute the finding that 90% of the US Medicare population lives within half an hour of an ophthalmologist. Indeed, 95% of the US Medicare population lives within 36.18 driving minutes of an ophthalmologist. Finally, we estimated the burden of the number of Medicare participants in each geolocation by assuming that everyone older than 65 years is eligible for Medicare, which may overestimate the size of this population.

In conclusion, we estimate that 90% of the US Medicare population live within 15 minutes' driving time of an optometrist and half an hour of an ophthalmologist. In the case that a patient is seen by an optometrist and needs an elevated level of care, 90% of optometrists practice within 20 minutes of an ophthalmologist. Our findings have implications in the future planning of adequate eye care delivery in the United States.

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Abbreviations and Acronyms

IQR interquartile range

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Figure 1.

Map of the continental United States with calculated driving routes for every United States census block group. Blue lines represent routes to the nearest ophthalmologist and red lines represent routes to the nearest optometrist. The width of the line is determined by the number of people who would use that road segment.

Figure 2.

Graphs showing the cumulative distributions of driving time to the nearest ophthalmologist and optometrist for national and United States economic regions. The black area represents the percentage of people under a given driving time to an ophthalmologist. The grey area represents the incremental percentage of people under a given driving time to an optometrist.

Figure 3.

Circos plot of state statistics on distribution of driving time. The outermost track designates the states as well as the number of people living in the state (in millions of people). Track 1 shows the difference in driving time in minutes (M) to the nearest optometrist versus ophthalmologist. Tracks 2 and 3 show the driving time in minutes to the nearest ophthalmologist and optometrist, respectively.