AMERICAN ACADEMY™
OF OPHTHALMOLOGY

Assessing Geographic Variation in Strabismus Diagnosis among Children Enrolled in Medicaid

Joshua R. Ehrlich, MD, MPH,[1,2] *Rebecca Anthopolos, MA,*[3] *Joshua Tootoo, MS,*[3] *Chris A. Andrews, PhD,*[1] *Marie Lynn Miranda, PhD,*[3,4,5] *Paul P. Lee, MD, JD,*[1,2] *David C. Musch, PhD, MPH,*[1,2,6] *Joshua D. Stein, MD, MS*[1,2,7]

Purpose: To determine how strabismus diagnosis varies within a given community and across communities among children with Medicaid health insurance.

Design: Retrospective cohort analysis.

Participants: Children aged ≤10 years enrolled in Medicaid in Michigan or North Carolina during 2009.

Methods: Children who met the study inclusion criteria were identified from the Medicaid Analytic Extract database, which includes claims data for all children enrolled in Medicaid throughout the United States. Residential location was determined by the last known 5-digit ZIP code for each child, which was linked to the centroid of a ZIP Code Tabulation Area (ZCTA) for geo-referencing and spatial analyses. International Classification of Diseases, 9th Revision, Clinical Modification billing codes were used to identify children diagnosed with strabismus (code 378.xx). Bayesian hierarchical intrinsic conditional autoregressive spatial probit models were used to determine the risk of a child receiving a strabismus diagnosis in communities throughout Michigan and North Carolina. Maps display communities (ZCTAs) where the 95% credible intervals for the spatial random effects estimates do not cross zero, allowing for identification of locations with increased and decreased strabismus diagnosis risk relative to other communities in the states.

Main Outcome Measures: Likelihood of receiving a diagnosis of strabismus.

Results: In 2009, among 519 212 eligible children in Michigan, 7535 (1.5%) received ≥1 strabismus diagnosis, and in North Carolina, 5827 of 523 886 eligible children (1.1%) were diagnosed with strabismus. In both states, the proportion receiving a strabismus diagnosis among black (0.9% in Michigan; 0.7% in North Carolina) and Hispanic (1.1% in Michigan; 0.8% in North Carolina) children was lower than the proportion for white children (1.8% in Michigan; 1.6% in North Carolina). Children living in poorer communities in both states were less likely to be diagnosed with strabismus independent of their race/ethnicity.

Conclusions: A child's likelihood of being diagnosed with strabismus is associated with characteristics of the residential community where he or she resides. The findings of this study highlight the importance of ensuring that children who live in less affluent communities have access to the necessary services and eye care professionals to properly diagnose and treat them for this condition. *Ophthalmology 2016;■:1–10 © 2016 by the American Academy of Ophthalmology.*

Supplemental material is available at www.aaojournal.org.

It is estimated that 1.3% to 3.5% of children between the ages of 6 months and 6 years in the United States and worldwide have strabismus.[1–4] Strabismus may lead to irreversible sight loss from amblyopia,[5] and its impact on the eyes' appearance can negatively affect a child's self-image and adversely affect social interactions.[6,7] Prompt identification and treatment of strabismus early in life often results in better visual outcomes and the need for fewer corrective ocular surgeries.[8–10] Moreover, correction of strabismus has been shown to improve health-related quality of life.[11] Treatment of strabismus is known to be among the most cost-effective interventions in ophthalmology because of the potential lifelong consequences of irreversible vision loss from this condition if left untreated.[12–15]

Several large population-based studies have identified factors that increase a child's risk of developing strabismus. Such factors include genetics; refractive error; older parental age; maternal cigarette smoking during pregnancy, neurodevelopmental impairment, prematurity, low appearance, pulse, grimace, activity, and respiration (APGAR) score, craniofacial and chromosomal abnormalities, in utero toxin exposure, retinopathy of prematurity, and cesarean delivery.[16,17] In prior analyses, these risk factors were identified after children underwent complete ocular examinations by eye care professionals with expertise in diagnosing

http://dx.doi.org/10.1016/j.ophtha.2016.05.023
ISSN 0161-6420/16

strabismus. However, in a real-world setting, not all children have the opportunity to undergo a thorough examination by a pediatric ophthalmologist or orthoptist to be evaluated for strabismus. Their risk of being diagnosed with strabismus is affected not only by the aforementioned factors but also by community-level factors, such as the availability and accessibility of vision screenings at schools and through organizations such as Lions Clubs,[18] and whether there are adequate numbers of eye care professionals in the community who are able and willing to see children who fail vision screenings to evaluate children for this condition.

This study analyzes health care claims data for a large cohort of children who are socioeconomically disadvantaged to explore the extent to which their claims record ZIP code tabulation area (ZCTA), which we use as an approximation for their community of residence, affects their chance of receiving a diagnosis of strabismus. Prior work by Kemper et al[19] established that use of eye care services among children on Medicaid varied by race, urbanicity, and supply of eye care providers in a given locale, but the extent to which this affects diagnosis of strabismus in these children is unknown. Moreover, identifying communities with relative increases or decreases in the likelihood of strabismus diagnosis can be of critical importance to health policymakers who are tasked with improving the health and well-being of children and reducing disparities in childhood ocular diseases.[20,21] This study uses spatial statistical analysis to aid researchers in appreciating the often complex relationships between residential location and likelihood of being diagnosed with specific diseases.

Methods

Data Source

The Medicaid Analytic Extract database contains de-identified health care claims data for children and adults in all 50 state-run Medicaid programs (and Washington, DC). This data source has been used in other areas of medicine by researchers to study patients with Medicaid health insurance.[22–24] For each enrollee, we had access to all medical claims for ocular and nonocular conditions, as identified on the basis of International Classification of Diseases, 9th revision, Clinical Modification billing codes,[25] and all visits, diagnostic and therapeutic procedures as identified on the basis of Current Procedural Terminology, 4th edition, and Healthcare Common Procedure Coding System billing codes.[26] In addition, the Personal Summary file contains information on date of birth, sex, race/ethnicity, number of months of Medicaid eligibility in a given year, and most recent 5-digit ZIP code of residence for each child. This study was approved by the University of Michigan Institutional Review Board.

Participants and Sample Selection

We identified all children aged ≤10 years on January 1, 2009, who had at least 9 months of enrollment in Medicaid during the 2009 calendar year. The majority of children included in the analysis (90.0%) were in the plan for 11 or 12 months during 2009. We excluded children with restricted benefits or those participating in a Children's Health Insurance Program because these children may have received a strabismus diagnosis during that year that may not have been captured by our data source. Within this cohort, we identified children who were diagnosed with strabismus during 2009. Strabismus was identified by ≥1 record of International Classification of Diseases, 9th revision, Clinical Modification billing codes 378.xx.

Geographic Areas of Interest

We chose to study eye care among children with Medicaid in the states of Michigan and North Carolina. Studying Michigan allowed us to build on the work of Kemper et al,[19] who previously assessed rates of ocular examinations among children in Medicaid in this state. We restricted all analyses for Michigan to the Lower Peninsula of the state. A separate model run on the discontiguous Upper Peninsula suffered from convergence issues, likely because few eligible children (only 2.6%) resided there. We selected North Carolina as a comparison state because it has a large number of children enrolled in Medicaid, is racially and geographically diverse, and is known to have high-quality Medicaid data.[27]

In addition to assessing statewide strabismus diagnosis patterns, we also selected 1 major combined statistical area (CSA) from each of the 2 states to explore strabismus diagnosis at a more granular level. For Michigan, we selected the Detroit-Warren-Ann Arbor CSA, and for North Carolina, we chose the Raleigh-Durham-Chapel Hill CSA.

Sociodemographic Characteristics of the Children

Race/ethnicity for each child was recorded as non-Hispanic white (henceforth "white"), non-Hispanic black (henceforth "black"), Hispanic, or other/unknown based on data from the Personal Summary file. The database does not contain direct estimates of family household income. We used the 5-digit residential ZIP code to determine the ZCTA of residence for each child. The ZCTAs are an aggregation of census tracts in each community that approximate the US Postal Service's ZIP codes.[28] By using 2012 American Community Survey data, we determined the median household income for each ZCTA and linked this to each child's record. Thus, ZCTA-level median household income served as a proxy for each child's household income.

Analyses

Data extraction was conducted using SAS software, version 9.4 (SAS Institute, Inc., Cary, NC). Statistical models were fit in the R computing environment, version 3.1.2 (R-Foundation for Statistical Computing, Vienna, Austria). Continuous variables were summarized using means and standard deviations or medians and interquartile ranges. For categorical variables, frequencies and percentages were calculated. The strabismus diagnosis proportion in a given community (ZCTA) was calculated as the number of children residing there who met the study inclusion criteria and received ≥1 diagnosis of strabismus during 2009 divided by the total number of children in the ZCTA who met the study inclusion criteria.

Bayesian hierarchical intrinsic conditional autoregressive spatial probit models[29] were used to estimate the likelihood of receiving a strabismus diagnosis for children across Michigan and North Carolina. The model for the likelihood of strabismus diagnosis included a fixed effect for race/ethnicity (white, black, and Hispanic) and a random effect for ZCTA of residence. The random effect is specified by a spatial structure that permits correlated observations among children with residence in adjacent ZCTAs. An expanded model including ZCTA-level