The Impact of Geographic Access on Severe Health Outcomes for Pediatric Asthma

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Abstract

Background: Access to medical care and severe pediatric asthma outcomes vary with geography, but the relationship between them has not been studied.

Objective: To evaluate the relationship between geographic access and health outcomes for pediatric asthma.

Methods: The severe outcome measures include ED visits and hospitalizations for asthma-diagnosed children in GA and NC. We quantify asthma prevalence, outcome measures and factors included in the statistical model using multiple data sources. We calculate geographic access to primary and asthma specialist care using optimization models. We estimate the association between outcomes and geographic access in the presence of other factors using logistic regression. The model is used to project the reduction in severe outcomes with improvement in access.

Results: The association between access and outcomes for pediatric asthma depends on the type of outcome measure, type of care, and variations of other factors. The expression of this association is also different for the two states. Access to primary care plays a larger role than access to specialist care in explaining GA ED visits, whereas the reverse applies for hospitalizations. In NC, access to both primary and specialist care are statistically significant in explaining the variability in ED visits.

Conclusions: The variation in the association between estimated access and outcomes impacts the projected reductions of severe outcomes with access improvement. Thus applying one intervention would not have the same level of improvement across geography. To gain maximum benefit, interventions must be tailored to target regions with the potential to deliver
the highest impact.
Key Messages:

- Access to care is important for managing pediatric asthma because regular visits can improve disease control and reduce severe outcomes.

  This study estimates geographic access and finds it is statistically significant in explaining severe pediatric asthma outcomes, but the impact varies with other geographic factors.

- Improved geographic access is expected to reduce severe outcomes.

  With limited resources, interventions can be targeted to areas with the greatest potential for improvement and tailored to each community’s needs.

Capsule Summary:

Assuming universal affordability but limited Medicaid acceptability by providers, we quantify geographic access and find it is associated with severe outcomes for pediatric asthma. This association differs with the outcome measure, geography, and care type.

Key Words: geographic access; pediatric asthma; severe health outcomes
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Abbreviations:

ED – Emergency Department

DoPH – Department of Public Health

GA – Georgia

HCUP - Healthcare Cost and Utilization Project

NC – North Carolina

OASIS – Online Analytical Statistical Information System

SID – State Inpatient Database

SEDD – State Emergency Department Database
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Introduction

Asthma is a common chronic childhood condition, with over 7.1 million American children having a current asthma diagnosis (1). In addition to impairing quality of life, asthma contributes significant costs to the healthcare system, particularly for emergency department (ED) visits and hospitalizations, which in many cases could be prevented. The prevalence and cost of pediatric asthma demonstrate great disparities. In general, both minority populations and economically disadvantaged areas have lower access to asthma related healthcare (2). In 2006 the asthma hospitalization rate for children living in a zip code with a median income below $37,000 was 76% higher than for other children (3). African American and Hispanic children are more likely to have asthma and to experience a severe asthma outcome than White children (4-8).

A key contributor to health and healthcare disparities for chronic conditions, particularly pediatric asthma, is the insufficient access to healthcare services. Appropriate access is important for managing asthma because regular care visits can reduce severe outcomes, controlling asthma is at least as important as its severity, and severity and control of the disease are not always correlated (9-13). In this study, we focus specifically on geographic access. While financial access is at the forefront of the current health policy agenda, it is only salient if care is made accessible and available. Even though asthma is a common disease among children, geographic access to care for asthma is insufficient and exhibits great disparities.

Although it is well understood that geographic access can impact health care utilization and health outcomes (14-16), there is little research that addresses whether this relationship varies across states, whether it behaves uniformly across geography within a state, and how it differs across different forms of health outcomes. This is particularly important for pediatric asthma,
which is the cause of approximately 170,000 childhood hospitalizations each year (17).

Understanding the extent of this relationship will suggest interventions targeted to reduce severe outcomes.

Potential access is commonly used in place of realized access (18-29). In this paper, we study the link between potential geographic access and severe outcomes for pediatric asthma while controlling for other potentially contributing factors in Georgia (GA) and North Carolina (NC).

Improving asthma outcomes is a priority for the Georgia Department of Public Health (DoPH), which leads the Georgia Asthma Control Program. Data availability, geographic proximity to GA, and a different distribution of distance to receive asthma specialist care contributed to choosing NC as the second state for analysis. We use mathematical modeling to estimate geographic access and apply logistic regression to quantify the relationship between access and outcomes. We also investigate the potential reduction in severe outcomes with access improvement.
Methods

Study Population

The population under consideration consists of children ages 5 to 17 estimated to have a current diagnosis of asthma in GA and NC. The age group 0 to 4 is excluded because of the difficulty of diagnosing asthma for this age group. The percent of children who had a current diagnosis of asthma is reported by age group in Table C3 of the 2010 BRFSS survey for GA(30) and by the 2011 National Survey of Children’s Health (NSCH) for NC(31). The census tract population counts of children for each age group were obtained from the 2010 Census data Table B09001(32). It is assumed that prevalence for each age group is uniform across each state. The number of asthmatic children in each census tract is estimated by multiplying the population with the percent of children in each age group in each state with an asthma diagnosis. Census tract estimates are computed for use in the assignment model, and the estimates are aggregated at the county level, shown in the Online Repository (OR) Figure E1, for the regression analysis.

Overall Approach for Understanding Severe Outcomes

To predict severe outcomes, we consider covariates that fall into three categories: age indicator, health access, which is of primary interest, and socio-economics, to control for other factors over the network. For consistency, the values for all covariates are collected or aggregated at the county level. GA has 159 counties and NC has 100.

In this study, a severe outcome is defined as an ED visit or hospitalization that was caused by the child’s asthma. The response variable is the outcome rate calculated as the ratio of ED visits or hospitalizations to the estimated number of children with asthma at the county level for each age group.
For GA, ED visits and hospitalizations in 2010 were obtained from the online OASIS database(33). For NC, the ED visits and hospitalizations for 2009 were obtained from the Healthcare Cost and Utilization Project state databases which contain de-identified individual records from community hospitals(34, 35). IRB approval was obtained for this research. Severe outcomes were extracted using the ICD9 codes for asthma and the criteria that at least one of the first two diagnosis codes is for asthma.

**Covariates of Primary Interest: Travel Distances to Asthma Care Providers**

There are three variables for potential access in the model; the county-average distances to primary pediatric care (“PrimaryDistance”), the county-average distances to asthma specialist care (“SpecialistDistance”), and the intra-county variance of distance to specialist care (“VarSpecialistDistance”). We consider this third access measure because there can be a large variation across the census tract distances to specialist care. To control for mobility of the population across county lines for hospital care, the number of hospitals in each county is included as a potential predictor (“NumberHospitals”)(36).

We calculate potential geographic access to primary and asthma specialist care using recent methodology to match supply and demand(22). The approach accounts for constraints in the network (e.g., mobility) along with potential barriers to care (e.g., provider’s willingness to accept patients with Medicaid). The approach uses an optimization model that matches patients to providers, mimicking the process through which patients or their parents choose physicians. Similar to Nobles et al(22), we use distance as a primary criteria for choosing one physician over another. Using this patient-provider matching, we estimate the access measure for each census tract, which we aggregate at the county level for the regression.
For primary care, we consider physicians with an National Provider Identifier (NPI) classification of Pediatrics, Nurse Practitioner Pediatrics, Family Medicine, and Internal Medicine and obtained travel distances for GA and NC from the recent work of Gentilli et al(37).

For specialist asthma care, we extracted the locations of asthma specialists from the NPI Registry using the National Uniform Claim Committee’s taxonomy codes(38). Consistent with the identification of asthma specialists in analyses of the importance of specialist care in the literature, we considered allergists and pulmonologists as asthma specialists(39, 40). The maximum caseload of visits for pediatric asthma care was adjusted depending on the specialty and whether or not the provider has a pediatric designation, and is shown in OR Table E1. We computed the street-network distance between specialist offices and centroids of the census tracts, representing the location for the entire population of the census tract, with ArcGIS software(41).

In the optimization model for matching patients with providers, the utility function is the total statewide travel distance to access care for asthma, subject to the following constraints:

- All patient appointments are fulfilled if feasible;
- Physician capacity cannot be exceeded;
- Each specialist accepts a limited percentage of patients with Medicaid;
- No patient can be assigned to a specialist with a travel distance greater than 50 miles.

The full optimization model is in OR Figure E2, with additional details including parameter information.
We examine the distribution of distances to care for each state along with the Pearson’s correlation of the distances. Similarly to (22) we estimate the spatial correlation on distance to care using Moran’s I measure, used to evaluated systematic disparities in geographic access (42).

**Other Model Covariates**

All socioeconomic variables extracted from the 2010 Census data are restricted to data on households that have at least one child under the age of 18 (32). We include an indicator (0 or 1) variable (“AgeX-Y”) for whether the response variable is for children in each of three age ranges (X to Y) (30, 31). For income and education, we select among potential variables by investigating the strength of the association of these variables with the response variable, plotted in OR Figure E6. The variables selected are the median family income (“MedianIncome”) and the percent of the adults with less than a high school diploma (“AdultEducation”).

The final set of main effect covariates considered in the model is defined in Table I below. The model selection procedure is outlined in the Online Repository.

**Statistical Model**

We quantify the impact of geographic access on severe outcomes using logistic regression with replications (equivalent to binomial regression), and we generate separate models for hospitalizations and ED visits in each state. All of the numeric variables were scaled. To reduce the set of explanatory variables from all combinations of the variables shown in Table I, we applied stepwise model selection where the models were compared based on Akaike Information Criterion (AIC). The regression analysis was implemented using the R statistical software. For model interpretation, we point out that understanding the model coefficients is challenging mainly because of the presence of interactions between covariates. Generally, a positive sign for
an interaction term indicates that two covariates influence the odds ratio jointly, and thus, a
larger value of one covariate increases the importance of the other. The opposite is true when the
sign is negative. In the models, any variable that is used in an interaction term is also included
alone.

We also use the results of the regression model to predict the reduction of ED visits if reductions
in distance to access care are made. Specifically, we allow travel distance to decrease to 15
miles for primary care, to 5 or 15 miles for specialist care, or both. Using the regression results,
we multiply the model coefficients and the predictors (including new distances where applicable)
to obtain a predicted response. Using the predicted response, we take the inverse of the logit
function to get the percent of asthmatic children with a severe outcome and then multiply by the
number of asthmatic children to get the projected number of ED visits per county and age group.
Results

Geographic Access to Primary and Specialist Asthma Care

Figure 1 shows the number of counties with distances (primary or specialist) within specific ranges. The maps of travel distances to specialist and primary care are in Figures 2 and 3 respectively, with summary statistics in OR Table E2. Overall, in GA there are more counties with longer travel distances to asthma care than in NC. Specifically, in NC, the maximum distance to receive asthma specialist care is 30 miles, and only 5 counties have an average distance greater than 15 miles. In contrast, the specialist distances in GA are as high as 50 miles, with counties having a distance greater than 30 miles. For primary care in GA, 56 counties travel further than 15 miles, while in NC, 11 counties travel further than 15 miles. OR Figure E4 shows the difference in access to primary and specialist care in both states.

The Pearson’s correlation between the travel distances to primary and to specialist care in GA is 0.3898, while the correlation in NC is 0.0904, shown in OR Figure E5. Both GA and NC have significant spatial correlation for primary and specialist care, as indicated by significant z-values for the local Moran’s I measure, shown in OR Figure E3.

Regression Results

The detailed results of the logistic regression for ED visit and hospitalization rates are shown in Tables II (GA) and III (NC). In all models, geographic access is statistically significant, although through different access variables and in interaction with different factors. Model R-squared values are provided in OR Table E3.

ED Visit Model: General Results
For explaining ED visits in GA (Table II), access to primary care and specialist care are statistically significant in their interactions with the socioeconomic variables, and access to primary care is also significant in relation to the age of the children. The deviance residuals for this model are provided in OR Figure E7.

In NC (Table III), all three main effects for access are statistically significant by themselves. Each main effect also has significant interactions with other covariates, including median income and age group 5-8.

**Hospitalization Model: General Results**

The final selected model for hospitalizations in GA has fewer significant variables than the one for ED visits. For the GA hospitalization model, distance to primary care is the access variable with the greatest impact because it is significant by itself and in multiple interaction terms, while access to specialist care and the variance of this access are only significant in one interaction term each. The adult education is the only socioeconomic variable with a significant interaction with the access variables.

In NC, however, all three access variables are statistically significant. These access variables are also significant in more interaction terms than in the models for GA hospitalizations. Thus the NC model is more complex than the GA hospitalization model.

**Projecting Severe Outcome Reduction with Access Improvement**

We use the fitted regression model to compute the predicted number of severe outcomes when the distance is reduced at the specified levels while keeping fixed all other predictors in the model. A complete example for one county and distance improvement is in OR Table E4.
Figure 4 presents the number of county/age pairs in each state with a predicted reduction in the number of ED visits for each of the four distance interventions. For only improving specialist care to be no more than 15 miles, in NC 131 county-age pairs (out of 300) have a reduction in ED visits, and in GA 191 county-age pairs (out of 477) have a reduction in ED visits. The total reduction in ED visits is higher in NC, but both states have more than 30 county-age pairs where ED visits are reduced by more than 15.

Figure 5 shows the geographic distribution of locations with a positive improvement in outcome (full data table available in OR Tables E5 and E6). For the intervention of specialist care no more than 15 miles (figure far left), adding a reduction of primary care (third from left) only adds 1 new county in GA. In contrast, further reducing specialist care to no more than 5 miles (second from left) adds 10 additional counties although the improvement in ED visits is small for the counties that already had improvements.
Our study provides evidence for the association between severe pediatric asthma outcomes and estimated geographic access to healthcare while it underlines that this association is not uniformly impactful across geography or types of care. Existing literature has provided evidence for the association between asthma outcomes and a variety of socioeconomic and environmental variables, but not geographic access(3, 6, 15, 24, 43, 44). Additionally, there is a relationship between race, lower utilization of asthma specialists, and the rate of severe asthma outcomes(45). Mayer(46) discussed the geographic proximity of children to a variety of pediatric specialists, but without any connection to health outcomes. Other studies analyze the impact of distance on various health outcomes and resource utilization(47, 48), but the connection between geographic access to care and severe outcomes for pediatric asthma has not been investigated.

Geographic access can be quantified using methods such as distance to nearest service site(23), gravity-based model(24), or optimization-based models(22) which we use in this study. Although this approach requires more computational effort, it provides more accurate estimates than other methods, especially for dense healthcare networks(21). The results showed that access to asthma care for pediatric patients varied widely between and within states. Interestingly, the correlation in primary and specialty care distances is smaller in NC than in GA. Because asthma is a chronic condition, we expected to find the relationship between geographic access and severe outcomes to be statistically significant. However, we also find that the expression of this relationship depends on the outcome measure, ED visit versus hospitalization. For example, in GA none of the access variables are significantly associated with the occurrence of ED visits by themselves, but access to primary care is significantly associated with the
occurrence of hospitalizations. Therefore we would expect that improving access to primary care would have a greater impact on the hospitalization rate than the ED visit rate.

Moreover, a different set of access variables are associated with severe outcome rates when comparing GA to NC. For example, unlike in GA, the main effects of all three access variables are significant in the corresponding model for NC. Contrasting the models for hospitalizations, there are more significant interaction terms involving the access variables in NC than in Georgia. This is an important finding because it points to a state-by-state analysis. Different states will show significance for different forms of access measures, suggesting different interventions in improving access, and ultimately, outcomes.

There are many factors that could lead to differences in the relationship between geographic access and health outcomes for the two states, in addition to those included in our model. Generally, NC scores higher in multiple state health rankings, both in general and with respect to the state Medicaid programs(49, 50), where the analysis also covers differences related to policies. In addition, the overall population density in NC is higher than in GA, and the distribution of the population in the two states is different(51).

Importantly, we find that the impact of geographic access on severe outcomes for pediatric asthma is not uniform across geography because of the statistical significance of its interaction with the other predictors in the model. In order to get the maximum benefit from any intervention it should be tailored such that it will target regions that have the potential to show the highest impact. For instance, if the goal were to reduce the number of ED visits in GA, we would expect to see the greatest reduction by improving access to primary care in areas where
the percent of adults with less than a high school diploma is higher, and by improving access to primary or specialist care in lower income areas.

We also project the level of ED visits reduction when improving access. We compared four interventions for improving access to specialist and primary care in GA. We find that there is a significant spatial trend in the ED visits reduction with a more significant reduction in urban areas when the distance is reduced to 5 miles. This suggests that if geographic access is improved only at the level of 15 miles, primarily rural areas should be targeted for intervention. Moreover, the decrease in distance from 15 to 5 miles generally improves outcomes only marginally, while the joint improvement of access to primary and specialist care does not lead to a noticeably greater impact on the reduction of ED visits than improving specialist distances alone. This suggests that access to specialist care plays an important role in reduction of severe outcomes, while a level of access similar to the comparative state of NC will suffice.

There are several limitations of this study. The first is the unavailability of detailed data on severe outcomes and other explanatory variables, especially at levels lower than county. Each county in Georgia has between 1 and 204 census tracts, and in larger counties there is high within-county variation in all of the predictors. Thus, a county level analysis loses some of the descriptive and predictive abilities of the model. There are many potential covariates that are not included in the model because the data are not completely available across larger geographic areas. Examples of other potentially contributing factors are the percent of adults that smoke, the percent of children exposed to second hand smoke and indoor allergens(52, 53), air pollution and outdoor allergen measurements(44, 54-62), obesity(60, 62) and percent of children with insurance(63). A second limitation is the simplicity of the calculation of the number of children with asthma, as described in the Methods. The age breakdowns used for each state are slightly
different based on data availability. A third limitation is that we allow pediatric patients to be seen by adult specialists; access to specialist care would be even worse under the alternative. Standard limitations about regression apply to this study, where findings point to associations rather than to causality. Finally, we are using models to quantify potential access to care.

Taking these known limitations into consideration, the work in this article demonstrates there is a significant relationship between geographic access to both primary and asthma specialist care and severe pediatric asthma outcomes. The results clearly indicate areas that can be targeted for interventions and an approach that can be applied to other states. Finally, the framework presented can be extended to study the relationship between access and other outcomes, offering great potential for targeting interventions effectively.
References:


33. Online Analytical Statistical Information System (OASIS) [database on the Internet].


37. Gentili M, Swann, J., Serban, N.


49. Fund TC. State Health System Ranking. Center HSD, Performance ER.


Table I. The final set of main effect covariates included for consideration in the regression model. The final model also includes interaction terms between these covariates.

<table>
<thead>
<tr>
<th>Variable Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AgeX-Y</td>
<td>Number of children that are X-Y years old</td>
</tr>
<tr>
<td></td>
<td>For GA: 5-8, 9-14, 15-17</td>
</tr>
<tr>
<td></td>
<td>For NC: 5-9, 10-14, 15-17</td>
</tr>
<tr>
<td>SpecialistDistance</td>
<td>Within-county average distance to an asthma specialist</td>
</tr>
<tr>
<td>VarSpecialistDistance</td>
<td>Within-county variance of distance to an asthma specialist</td>
</tr>
<tr>
<td>PrimaryDistance</td>
<td>Within-county average distance to a primary care pediatrician</td>
</tr>
<tr>
<td>MedianIncome</td>
<td>Median family income households with children under age 18</td>
</tr>
<tr>
<td>AdultEducation</td>
<td>Percent of the adult population who have less than a high school diploma</td>
</tr>
<tr>
<td></td>
<td>and live in a household with children under age 18</td>
</tr>
<tr>
<td>NumberHospitals</td>
<td>Number of hospitals</td>
</tr>
</tbody>
</table>
Table II. GA Regression Results. For the categorical age variable, age 15 to 17 is omitted as the reference variable. The reference value for numeric variables is 0. Highlighted rows indicate access variables.

<table>
<thead>
<tr>
<th></th>
<th>ED Visits</th>
<th></th>
<th>Hospitalizations</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate (Std. Error)</td>
<td>P-Value</td>
<td>Estimate (Std. Error)</td>
<td>P-Value</td>
</tr>
<tr>
<td>(Intercept)</td>
<td>-3.068(0.033)</td>
<td>&lt; 0.001</td>
<td>-6.214(0.108)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Age 5-9</td>
<td>0.554(0.036)</td>
<td>&lt; 0.001</td>
<td>1.606(0.106)</td>
<td>&lt; 0.001</td>
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<tr>
<td>Age 10-14</td>
<td>0.974(0.039)</td>
<td>&lt; 0.001</td>
<td>1.633(0.111)</td>
<td>&lt; 0.001</td>
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<tr>
<td>MedianIncome</td>
<td>-0.375(0.023)</td>
<td>&lt; 0.001</td>
<td>-0.479(0.038)</td>
<td>&lt; 0.001</td>
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<tr>
<td>AdultEducation</td>
<td>-0.187(0.019)</td>
<td>&lt; 0.001</td>
<td>-0.120(0.051)</td>
<td>0.02</td>
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<tr>
<td>NumHospitals</td>
<td>0.127(0.005)</td>
<td>&lt; 0.001</td>
<td>0.087(0.015)</td>
<td>&lt; 0.001</td>
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<tr>
<td>SpecialistDistance</td>
<td>0.029(0.017)</td>
<td>0.102</td>
<td>-0.057(0.047)</td>
<td>0.226</td>
</tr>
<tr>
<td>PrimaryDistance</td>
<td>0.013(0.027)</td>
<td>0.648</td>
<td>-0.198(0.047)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>VarSpecialistDistance</td>
<td>-0.005(0.021)</td>
<td>0.808</td>
<td>0.050(0.052)</td>
<td>0.337</td>
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<tr>
<td>PrimaryDistance: AdultEducation</td>
<td>0.061(0.023)</td>
<td>0.009</td>
<td>0.125(0.041)</td>
<td>0.003</td>
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<tr>
<td>VarSpecialistDistance: AdultEducation</td>
<td>-0.165(0.029)</td>
<td>&lt; 0.001</td>
<td>-0.200(0.051)</td>
<td>&lt; 0.001</td>
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<tr>
<td>PrimaryDistance: Age 5-9</td>
<td>-0.157(0.027)</td>
<td>&lt; 0.001</td>
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<tr>
<td>PrimaryDistance: Age 10-14</td>
<td>-0.145(0.029)</td>
<td>&lt; 0.001</td>
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<tr>
<td>SpecialistDistance: PrimaryDistance</td>
<td>-0.070(0.017)</td>
<td>&lt; 0.001</td>
<td>-0.134(0.047)</td>
<td>0.005</td>
</tr>
<tr>
<td>VarSpecialistDistance: Age 10-14</td>
<td>0.108(0.032)</td>
<td>0.001</td>
<td></td>
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<tr>
<td>PrimaryDistance: MedianIncome</td>
<td>-0.104(0.020)</td>
<td>&lt; 0.001</td>
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<tr>
<td>SpecialistDistance: MedianIncome</td>
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<td>&lt; 0.001</td>
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<tr>
<td>SpecialistDistance: AdultEducation</td>
<td>0.083(0.017)</td>
<td>&lt; 0.001</td>
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<tr>
<td>VarSpecialistDistance: MedianIncome</td>
<td>-0.119(0.028)</td>
<td>&lt; 0.001</td>
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</tbody>
</table>
**Table III.** NC Regression Results. For the categorical age variable, age 15 to 17 is omitted as the reference variable. The reference value for numeric variables is 0. Highlighted rows indicate access variables.

<table>
<thead>
<tr>
<th></th>
<th>NC ED Visits</th>
<th>NC Hospitalizations</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Estimate (Std. Error)</td>
<td>P-Value</td>
</tr>
<tr>
<td>(Intercept)</td>
<td>-1.727(0.018)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Age 5-8</td>
<td>0.584(0.023)</td>
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</tr>
<tr>
<td>Age 9-14</td>
<td>0.165(0.021)</td>
<td>&lt; 0.001</td>
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<tr>
<td>MedianIncome</td>
<td>-0.088(0.013)</td>
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<tr>
<td>AdultEducation</td>
<td>0.071(0.012)</td>
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</tr>
<tr>
<td>NumHospitals</td>
<td>0.120(0.007)</td>
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</tr>
<tr>
<td>SpecialistDistance</td>
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<td>VarSpecialistDistance</td>
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<tr>
<td>PrimaryDistance</td>
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<td>-0.060(0.025)</td>
<td>0.017</td>
</tr>
<tr>
<td>VarSpecialistDistance:Age5-8</td>
<td>0.156(0.037)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>VarSpecialistDistance:AdultEducation</td>
<td>-0.156(0.015)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>PrimaryDist:SpecialistDist</td>
<td>0.299(0.046)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>SpecialistDistance:AdultEducation</td>
<td>-0.154(0.039)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>SpecialistDistance:VarSpecialistDistance</td>
<td>-0.095(0.031)</td>
<td>0.002</td>
</tr>
<tr>
<td>PrimaryDistance:NumHospitals</td>
<td>0.064(0.023)</td>
<td>0.0074</td>
</tr>
<tr>
<td>VarSpecialistDistance:PrimaryDistance</td>
<td>-0.318(0.056)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>MedianIncome:AdultEducation</td>
<td>-0.079(0.029)</td>
<td>0.007</td>
</tr>
<tr>
<td>MedianIncome:NumHospitals</td>
<td>0.241(0.032)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>AdultEducation:NumHospitals</td>
<td>0.302(0.048)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Age9-14:AdultEducation</td>
<td>0.075(0.035)</td>
<td>0.034</td>
</tr>
</tbody>
</table>
Figure Legends

Figure 1: Comparing the distribution of geographic access measures for GA and NC.

Figure 2: Maps of the census-tract level travel distances to specialist care for GA and NC.

Figure 3: Maps of the census tract level travel distances to primary for GA and NC.

Figure 4: The graph shows the number of county-age pairs with an expected reduction in ED visits under four types of interventions on access. The interventions include reducing distance to specialist care to be no more than 5 or 15 miles, possibly in combination with reducing the distance to primary care to no more than 15 miles.

Figure 5: Reduction in ED visits when access to primary and specialist care is improved.
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Dr. Fitzpatrick has made substantial contributions to conceptualization of variables, interpretation of data, and has been responsible for drafting the article.