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The Influence of Proximity of Perinatal Services on Preterm Birth Rates in Non-Metropolitan Georgia, 1999-2009

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An Abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfillment of the requirements for the degree of
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Abstract

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Preterm birth (<37 weeks) is a leading cause of perinatal morbidity and mortality and between 2000 and 2009, the rate of infants born preterm in Georgia rose from 11.6% to 13.8%. Access to perinatal services and providers, especially to women at risk of preterm delivery, is associated with a decreased risk of preterm birth. We used Georgia's birth records linked to hospital discharge records (1999 through 2009) to model the association between women's travel time from residence in rural or micropolitan regions of Georgia to hospitals and rates of preterm birth among live, singleton births born between 24 and 37 weeks gestation. Using multivariable modeling to control for confounders, we found that proximity of residence to delivery facility is associated with preterm birth. Independent of common individual and population level risk factors, women living outside of metropolitan areas in Georgia, with more than 45 minutes road-network travel time between home and delivery hospital, are more than 1.5 times as likely to experience preterm delivery compared to women with less than 45 minutes road-network travel time to delivery hospital. Addressing the geographic disparities in preterm birth may require reduction in the spatial mismatch of perinatal services and population at risk in rural Georgia.

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Table of Contents

Introduction

In 2009, 19,407 infants were born premature. Between 2000 and 2009, the rate of infants born preterm in Georgia increased from 11.6% to 13.8%. [1] Moderately preterm birth (infants born between 34 and 37 weeks gestation) and very preterm birth (infants born less than 32 weeks gestation) together complicate 12.5% of all deliveries in the United States, and remain the leading cause of perinatal morbidity and mortality, contributing to approximately 75% of perinatal death. [2]

In 2009, Georgia residents had 19,407 preterm births, representing 13.8% of all live births. [3] Although nationally, preterm birth rates have declined, experts agree that the main driving force behind the overall rise in preterm birth rates within certain states include a myriad of factors such as socioeconomic status, history of a previous preterm delivery, increased use of elective cesarean section, and a lack of access to antenatal care.[2, 4] However, little data exists that explores the relationship between a mother's travel time to a delivery facility within Georgia and perinatal outcomes. Moreover, no recent data exists on whether mothers who are at higher risk of preterm delivery are delivering at facilities equipped to handle such deliveries.

Thus, we utilized Georgia's birth records linked to hospital discharge records (1999 through 2009) to model the association between a mother's travel time to a hospital and rates of preterm delivery among singleton, live births to women living in non-metropolitan areas of Georgia.

The purpose of this study will be to examine whether an increased distance from residence to a delivery facility is associated with a risk of preterm birth controlling for individual and population-level risk factors of preterm birth.

Literature Review

Very preterm births (<32 weeks gestation) complicate approximately 2% of all deliveries and moderately preterm birth (between 32 and 37 weeks gestation) approximately 10.5% of all deliveries within the United States and together remain the leading cause of perinatal morbidity and mortality, contributing to approximately 75% of perinatal death. [2] Among live-born infants, preterm birth collectively has resulted in nearly half of all pediatric neurodevelopmental disabilities, including cerebral palsy, and intellectual disabilities, as well as respiratory problems and other various long-term morbidities that contribute to increased healthcare costs.[5] Studies have also shown association between preterm birth and an increased risk of SIDS, type II diabetes, and cardiovascular disease.

A recent report issued by the Institute of Medicine estimates that the annual economic costs in 2005 — including medical costs as well as lost productivity — associated with overall preterm birth were approximately $26.2 billion.[6] Although recent healthcare improvements in the U.S. have caused moderately preterm birth rates to decrease from 8.7% in 2009 to 8.3% in 2011, according to a 2012 report compiled by over 50 national and international health organizations, the United States ranks 131 out of 184 countries for preterm birth rates.[7]

Georgia, along with many states in the Southeast including Mississippi, Arkansas, and Louisiana, are partly to blame for contributing to this low ranking.[8] As Georgia is in the bottom 10% of states in the U.S. in terms of annual preterm birth rates [9], the March of Dimes assigned Georgia an overall D rating.

Racial Breakdown of Preterm Birth

Rates of infants born preterm or very preterm (VPT) differ dramatically amongst racial groups within the United States. In the U.S. in 2006, there was a 60% excess risk for moderately preterm birth in Black mothers as compared to White mothers and 2.5 times the risk of very preterm births in Black mothers as compared with White mothers. [10] A study that analyzed over 11,000 linked fetal birth and infant death certificates in Georgia specifically found that the odds of delivering a baby VPT was substantially greater among Blacks compared to Whites. [11] March of Dimes analysis suggests that rates of being born prior to 37 weeks gestation were highest for Blacks (17.6%), followed by Native Americans (13.1%), Whites (11.9%), Hispanics (11.2%) and Asians (10.7%).[8]

A large-scale analysis of all singleton births within the United States from 1975 to 1995 (15,246,620 pregnancies) also found that Black women had nearly twice the rates of preterm birth across each five-year period; however, within the 20-year study period, preterm delivery increased 22.3% among Whites (from 6.9% to 8.4%) yet only increased 3.6% among Blacks (from 15.5% in 1975 to 16.0% in 1995).[12] Among Black, primiparous women, rates of preterm delivery increased from 1975 to 1990 and subsequently declined, yet among White women, rates of preterm delivery increased between 1975 and 1995.

Risk factors associated with preterm or VPT births include insufficient prenatal care, drug and alcohol use during pregnancy, smoking, and chronic diseases such as diabetes and cardiovascular disease; however, these traditional risk factors do not fully explain the disproportionate amount of preterm or VPT infants born to Black mothers as compared to White mothers.[13] Differences in behavioral risk factors amongst Black and White women have long been provided as reasons why this Black-White gap in preterm birth risk exists. Other independent risk factors associated with the gap in preterm birth risk have also been identified, such as low socioeconomic status and low maternal education; however, controlling for one or more of these risk factors describes less than half of the Black–White gap in preterm birth risk.

Stress as a contributing factor

A risk factor that has been more recently hypothesized to be involved with associations between race and preterm birth is a mother's exposure to chronic psychosocial and environmental stressors.[14, 15] It has been posited that both acute stress during pregnancy or lifelong exposures to stressors in preconception can influence perinatal outcomes. Cohen et al. define stress as a process in which "environmental demands tax or exceed the adaptive capacity of an organism, resulting in psychological or biological changes that may place persons at risk for disease"[16] and assert that stress can be categorized along a sliding scale as well as across several dimensions including severity (minor stressors such as traffic or overdue bills vs. major stressors such as physical abuse, divorce, or death of a family member) timing (early or later in the course of life), and length of exposure (acute vs. chronic stressors).[16] These stressors are often categorized as being either psychosocial or environmental, and exposures to one or both of them jointly during preconception or gestation have been shown to increase the risk of preterm and VPT birth. [17] Although stress alone has not been confirmed as a causal agent of prematurity, studies have found that psychosocial and environmental stressors can lead to a variety of physiological mechanisms that can increase the risk of preterm birth.

Recent investigations have shown that due to the physiological mechanisms that relate stress with an increased risk of preterm delivery, chronic stressors may lead to processes that mimic chronological ageing thereby affecting a mother's risk of preterm delivery. [18] Lu et al. hypothesize that racial differences in exposure to environmental and psychosocial stressors could contribute to this premature ageing within Black mothers, thus potentially accounting for much of the Black-White disparity in preterm birth risk. [15, 19]

Proximity as a contributing factor

According to the Georgia OB/Gyn Society, rural Georgia has a dearth of perinatal services and this lack of services requires women to seek services that are located great distances from their places of residence.[20] Two recent investigations have found that proximity to hospitals with perinatal services is associated with prenatal care and pregnancy outcomes. A study performed by Pasquier et al. of the University of Sherbrooke in Quebec found that residential distance to hospitals with neonatal care affects the rate of prenatal diagnosis (the tests for diseases or genetic abnormalities performed in utero).[21] In this retrospective cohort study, researchers analyzed 770,000 infants born in the Rhone-Alpes region between January 1990 and December 2000 that required surgery for either omphalocele, gastroschisis, diaphragmatic hernia or spina bifida. The distance between maternal residence and the nearest maternity ward with a neonatal surgical center was estimated and subjects were differentiated by distance to a hospital: less than 11km, between 11km and 50km, and over 50km away from the nearest neonatal surgical centers. The prenatal diagnosis rate within the region was 67.7% in 1990–1995 and 80.2% in 1996–2001 (crude OR, 2.07 (95% CI, 1.24 – 3.45)). After multivariate analysis, the prenatal diagnosis rate was found to be significantly lower for women living 11–50km (adjusted OR, 0.49 (95% CI, 0.25– 0.94)), or > 50 km (adjusted OR, 0.39 (0.20 – 0.74)) from the nearest neonatal surgical center compared with those living < 11km from a surgical center. Distance, however, did not affect rates of neonatal mortality.

An investigation performed by Gould et al., also found that distance from neonatal intensive care units, as well as less than adequate prenatal care, to be the most significant factors associated with low birthweight infants (< 2500 grams) delivered at a Level I hospitals (hospitals that only provide basic neonatal care) throughout California.[21] Using multivariate analysis of California birth certificates between 1989 and 1993, researchers found that 24,094 live-born, low birthweight (LBW) infants were born at Level I hospitals. For women of all demographics, researchers found that less than adequate prenatal care, living in a 50% to 75% urban zip code, and living more than 25 miles from the nearest neonatal intensive care unit significantly increased the odds of very low birthweight delivery at a Level I hospital.

Spatial location as a contributing factor

Additional studies have found that prenatal care utilization and quality does vary spatially within a city or state and, along with a myriad of factors such as socioeconomic status, this spatial organization plays a role in perinatal outcomes.[22] A large-scale investigation by Larson et al. found that throughout the United States, risk increased between 1985-1987 to 1989-1991 to 1995-1997 among infants born in rural areas with respect to low birth weight, infant mortality, and inadequate care.[23] The study population, gathered from the National Linked Birth Data Set from the National Center for Health Statistics, was 11,081,840 for 1985, 12,022,656 for 1989-1991, and 11,352,574 for 1995-1997. Rural regions were classified using designations established by the U.S. Office of Management and Budget as well as Urban Influence codes developed by the U.S. Department of Agriculture. Researchers found that of the approximately 4,000,000 singleton deliveries per year within the twelve-year period, 19% to 20% were classified as rural births. Of this percentage, the proportion of births occurring among women less than 18 years of age was consistently higher in the rural versus urban populations (5.5% rural compared to 4.6% urban in 1985-1987 and 6.3% rural compared to 4.9% urban in 1995-1997). Additionally, LBW rates among rural residents increased from 5.6% in 1985-1987 to 6.1% in 1995-1997, whereas LBW rates among urban residents only increased slightly from 5.9% to 6.1% within the study period.

As for neonatal mortality, rates were initially lower in rural regions compared to urban regions in 1985-1987, but as of 1995-1997, rural mortality was higher (4.21 per thousand in rural regions versus 4.01 per thousand in urban regions). Although rural neonatal mortality and postneonatality decreased in both regions from 1985-1987 to 1995-1997, neonatal mortality was consistently higher in rural versus urban populations (3.7 per thousand in rural regions compared to 3.41 per thousand in urban regions in 1985-1987 and 2.7 per thousand rural compared to 2.31 per thousand urban in 1995-1997). Rates of inadequate care, as measured by the Kotelchuck Index, were also slightly lower in rural areas initially, however by 1995-1997, rates of inadequate prenatal care were higher in rural versus urban regions (13.3% versus 12.7% as indicated by the Kotelchuck Index). [23, 24]

Rates of LBW and postneonatal mortality were relatively comparable in counties adjacent to metro counties and non-adjacent counties throughout the study period. [23] Rural residents of counties that did not share a border, however, did undergo somewhat higher rates of postneonatal mortality across all time periods (3.83 in 1985-1987 compared with 3.63 in adjacent counties and 2.80 in 1995-1997 compared to 2.62 non-adjacent counties). The most pronounced rural-urban differences of poor birth outcome and inadequate prenatal care were those unadjusted rates found between counties with persistent poverty and those without persistent poverty. The rate of low birthweight infants, for example was: 7.1 ‘persistent poverty rural counties’ in 1985-1987 compared with 5.2 in non-impoverished counties and 7.7 in ‘persistent poverty rural counties’ in 1995-1997 compared to 5.7 in non-impoverished counties. Although rates of infant mortality and inadequate prenatal care decreased in both types of rural counties between 1985 and 1997, low birth weight rates were on average 30% higher and inadequate care at least 50% higher in counties with persistent poverty throughout the study period.

Researchers used a series of logistic regression models to examine the risk of poor birth outcomes and inadequate prenatal care among rural residents after adjustments were made for demographic and social risk factors between urban and rural populations.[23] After controlling for maternal age, race, and education as well as parity and marital status, Larson et al. found in 1985-1987 as compared to 1995-1997 there was “higher risk of poor birth outcome[s] and inadequate prenatal care for rural residents…”. For example, researchers found that the adjusted risk of low birthweight infants among rural residents in 1985-1987 was not significantly different from the risk among urban residents (OR = 1.002, CI 0.994, 1.001). By 1995-1997, however, the adjusted risk of low birthweight infants among rural residents was modestly greater and statistically significant (OR = 1.089, CI 1.082, 1.095).

Researchers argue that this trend seen in birth outcome and prenatal care could possibly be due more to the ramifications of poverty rather than just from rurality alone.[23] The Rural Health Research Center (RHRC) compared two communities of rural residents throughout the country: (1) residents of rural persistent poverty counties vs. residents of nonpersistent poverty counties and (2) residents of nonadjacent rural counties vs. adjacent rural counties. The RHRC found that residents of adjacent rural counties versus residents of non-adjacent rural counties had few observable differences in birth outcome and prenatal care trends. In comparison, residents of rural persistent poverty counties experienced substantially higher risks of poor outcome and inadequate care and the risks of poor outcome and inadequate appeared to increase over the study period.

The results of the study suggest that rural residence within the United States is an independent risk factor for population level poor perinatal outcomes, inadequate prenatal care, and postneonatal and infant mortality.[23] However, rurality when combined with poverty is an even greater determinant of neonatal and infant morbidity and mortality. The implications of this study as it pertains to proximity of prenatal services as a contributing risk factor for preterm birth is that mothers residing in impoverished, rural regions are less likely to be equipped with the same perinatal services, awareness of these services, and/or perceptions that these services are valuable as compared with mothers in urban regions. Although not discussed in the aforementioned study, it is plausible that greater access to and knowledge of prenatal and perinatal services within rural regions *could* decrease the risk of poor outcomes and inadequate care.

Perinatal Regionalization

The concept of establishing perinatal geographic regions and developing categories of perinatal services came to fruition in the late 1960s.[25] Data emerged in the late 1980s, however, that showed a substantial weakening of this newly established perinatal regionalization system. This prompted the March of Dimes in coordination with the Committee on Perinatal Health to issue the Toward Improving the Outcome of Pregnancy II (TIOP II) initiative in 1993.[26] The TOIP II served as an advisory committee that provided overarching initiatives, guidelines, and regulations aimed at improving the quality of perinatal care services throughout the U.S. The committee also established a system to facilitate the referral of women and infants to the appropriate level facility: level I hospitals provided basic neonatal care and the stabilization of ill infants that require transfer to better equipped facilities; level II hospitals cared for moderately ill infants; and level III hospitals were equipped to handle serious neonatal illnesses and abnormalities.[27] The American Academy of Pediatrics further expanded guidelines for medical facilities in 2004, emphasizing the need of level III care for very low birthweight (VLBW) infants (<1500 g).[28] Since the onset of these initiatives, however, concern has been raised about recent trends in deregionalization of perinatal services– that is the "breakdown in the cooperative relationship between less specialized and more specialized centers, which results in a failure to refer high-risk women and low birthweight infants [or preterm infants] to technologically appropriate facilities."[29]

A meta-analysis of 37 studies analyzing the trends in neonatal morbidity and mortality as it relates to the quality of maternal services suggests that the level or quality of facility does in fact influence the incidence of neonatal morbidity and mortality. [30] Amongst the 37 studies, inclusion criteria for the study population included live born VLBW or VPT as well as infants born after 1975. Results from the analyses showed that the combined estimate of effect of very low birthweight studies indicated a "62% increase in the odds of neonatal/predischarge mortality for infants born in non–level III hospitals compared with those born in level III hospitals (aOR, 1.62; 95% CI, 1.44-1.83)." Researchers also examined the potential differences of effect that hospital levels have on extremely low birthweight infants (<1000 g). The combined estimate of effect from 5 studies that stratified by extremely low birth weight (n = 13,093) indicated that extremely LBW infants born in non–level III hospitals as compared to level III hospitals had

80% increased odds of neonatal mortality (aOR 1.8, 95% CI 1.3-2.5). An additional four studies that reported infants by gestational age and met all other inclusion criteria (n=9,300) indicated that the combined estimate of effect of extremely LBW infants born in non-level III hospitals compared with those born in level III hospitals had a 55% increase in odds of neonatal/predischarge mortality.

An additional study that examined place of delivery for VLBW infants from 1994 to 1996 within Georgia specifically, also found there to be an association between high rates of infant mortality and a low level facility.[31] Of the 4,770 VLBW infants born within the three-year period, 77% were delivered at hospitals providing subspecialty perinatal care. According to researchers Samuelson et al., the neonatal mortality rate varied by level of perinatal care facility from 132.1 per 1000 to 283 per 1000 live births, with the highest death rate for infants born at hospitals with the lowest ranked subspecialty care. Supposing that the disparate mortality rates were due to hospital level alone, potentially 16–23% of neonatal deaths among VLBW infants could have been prevented if 90% of infants born outside subspecialty care were delivered at the recommended level.

A recent study performed by Goodman et al., approached perinatal deregionalization by assessing whether or not neonatal intensive care was located in accordance with need throughout the United States.[8] To do this, Goodman and colleagues determined the geographic distribution of neonatologists and neonatal mid-level providers within the market-based regions across the country. Referred to as neonatal intensive care regions (NICRs), researchers used 1995 American Hospital Association data to identify counties with at least twenty births per year and assessed their proximity to a neonatal intensive care unit (NICU). [32] To attain the entire scope of a region's neonatal intensive care capacity, Goodman and colleagues also estimated the amount of clinically active neonatologists as well as number of NICU beds within a region.[33] Neonatologist counts were derived from American Medical Association registries and the American Osteopathic Association Masterfiles. Members excluded from the count were neonatologists who worked less than twenty hours a week and those who worked a majority of their professional time in medical teaching. This left a total of 2,627 neonatologists. Residents and clinical fellows were counted but given a weight of 0.35 to account for their lower levels of clinical autonomy.[34] The NICU bed counts were derived from self-report surveys administered to NICU directors throughout the country.[33] After analyzing the regionalization of NICRs, researchers found the distribution of neonatal intensive care resources across the country. Results showed that the number of low birthweight infants per neonatologist in the highest quintile of neonatologist supply was 66 compared with 263 in the lowest quintile. Researchers utilized GINI indices in concurrence with the Lorenz curve to assess the extent of variation in neonatal intensive care capacity in relation to newborn populations. Researchers found high degrees of disparities between intensive care capacity and newborn populations.[35, 36] The findings substantiated previous claims made by Goodman and colleagues which said that regional variation in neonatal intensive care capacity is not explained by differences in patient need.[12] As indicated by the GINI Index and Lorenz curve, neither neonatologists nor NICU beds varied substantially in accordance with LBW outcomes. [33] Although the authors address the limitations of the study, among them being that regional variation in neonatal intensive care resources could have been due to measurement error and another being that there were potential biases due to the selection of birthweight as the only indicator for which to demonstrate low resource NICRs, the study does demonstrate that there is more than a fourfold variation across regions of similar need based on birthweight.

The experts from these aforementioned studies regarding regionalization agree that, within the U.S., neonatal intensive care capacity is not built in accordance with need or illness level. [12, 23, 33, 36] Although the etiologies of risk factors are important when addressing services for high-risk mothers, it is also imperative to assess the quality of resources utilized by these women and determine whether or not they are being referred to the appropriate level facility. Experts agree that strengthening perinatal regionalization systems in states with high percentages of very low birthweight and very preterm infants born outside of level III centers could potentially save thousands of infant lives every year.

<u>Literature Gap</u>:
Rate of preterm birth in relation to drive time to a delivery facility

As detailed above, recent research has identified a variety of independent risk factors associated with preterm delivery as it relates to proximity. Dozens of studies have also demonstrated how level and quality of a facility is associated with neonatal and infant morbidity and mortality.

The research to date suggests little to no association between proximity from residence to a delivery facility and poor perinatal outcomes. As shown in a study conducted amongst French women between 1999 and 2001, Charreire et al. found an uneven geographical distribution of poor prenatal care throughout France.[22] Although researchers found clusters of neighborhoods (populations ranging between 1800 and 5000 persons) with high rates of poor prenatal care, because researchers did not find statistically significant differences in outcome between regions, Charreire et al. concluded that “physical distance of access to health services is not the preponderant factor of poor prenatal care”. While researchers did find deregionalization of health services in the region, they deemed that in order to assess proximity as it relates to care, the study would have needed to assess the quantity of services offered, the spatial base, and the inequalities in health or access to care.

A study analyzing the effects of proximity to and availability of prenatal services on a mother's risk for delivering an infant small for gestational age at birth (SGA) also found no association between SGA and proximity to maternal services such as prenatal care providers and Women, Infants, and Children program (WIC) sites.[37] The study analyzed singleton, full-term infants born in California between 1997 and 1998 (n = 744,736). Researchers geocoded maternal place of residence as well as locations of WIC sites, prenatal care providers, and perinatal outreach programs in accordance with Census tract. Multilevel linear regression showed that there was no association between SGA and community services available for either high or low-risk women.

Although the previous studies did not find an association between proximity to health services and risk of poor infant and neonatal outcomes, neither of these studies linked the quantity and quality of services to the spatial location of a mother's residence. Also absent from these studies, is the examination of travel time taken by a mother to acquire services– not simply just the physical distance to such services.

While there is a substantial amount of literature regarding perinatal regionalization that suggests neonatal morbidity and mortality is associated with quality of maternal services, again, notably absent from the literature is research comparing travel time to perinatal facilities and birth outcomes. Although researchers might have attempted to analyze such relationships and results were not statistically significant and therefore did not reach publication, there is a dearth of any literature on the subject. After reviewing the literature on the subject and finding minimal results, we decided to investigate the association between the risk of preterm birth and a mother's travel time to a place of delivery. Among women living in rural or micropolitan Georgia, is travel time between home residence and delivery facility associated with risk of preterm birth? Does living in rural or micropolitan Georgia and having a long travel time to a hospital lead to this increased likelihood of having their child prior to 37 weeks gestation?

Methods

We performed a retrospective analysis of a cohort created through the linkage of hospital discharge records and Georgia birth records from 1999 through 2009 as well as a dataset using Core Based Statistical Area (CBSA) classifications from 2003. Using de-identified, unique maternal identifiers, we explored linked vital statistics (birth certificates) and hospital discharge data for each mother and infant pair. This procedure allowed us to gather a list of potential covariates for analysis, and we validated those variables that appeared in all three datasets.

Inclusion and Exclusion Criteria

We limited the population to live, singleton births born between 24 and 37 weeks gestation and weighing greater than or equal to 500 grams. To identify the population for analysis, we restricted the cohort to women living within the micropolitan and rural regions of Georgia as designated by Metropolitan Statistical Areas (MSA) and CBSA classifications. We therefore excluded women living in metropolitan area counties.

Model Strategy and Covariate Determination

The outcome of interest was preterm birth (<37 weeks gestation) and we sought to explore the relationship between our exposure of interest, street network estimated drive time, and preterm birth.

Network estimated drive time was calculated in a previous study that used Georgia hospital discharge records (1999 to 2009) to determine estimated road-network travel time (in minutes) from a delivery facility to a patient's residence.[38] Hospital discharge records of interest pertained to women who were hospitalized for a delivery using International Classification of Diseases Ninth Edition (ICD-9) codes 650-669. Spatial analysis was done in ArcGIS 10.1.

We used demographic values from birth certificate information to derive descriptive statistics. We calculated odds ratios (ORs) with 95% confidence intervals (CIs) using logistic regression analysis.[39] We used a chi-square statistic to compare proportions in two-by-two tables where the cell sizes were deemed sufficiently large. We determined the association among categorical variables by using a Wald Chi-square statistic. We used a multivariable logistic regression model to determine maternal and infant characteristics and interaction terms that were significantly associated ($p<0.05$) with preterm birth in univariate analysis and were not missing due to non-reporting. We deleted most observations with missing data during logistic regression modeling. Due to the large proportion of missing observations within particular variables, we coded a 'missing' category in select variables: prior poor infant outcome and maternal education level. We calculated the ORs and the corresponding CIs for each factor in the presence of the other factors within the final model.

Our outcome of interest was occurrence of preterm birth. Based on the literature, we determined those considered viable for analysis were those born between 24 and 37 weeks gestation. Our exposure of interest was the calculated road network drive time between the mother's residence and her delivery hospital. For modeling we categorized continuous drive time as a categorical variable (less than 15 minutes, between 16 and 30 minutes, between 31 and 45 minutes, and over 45 minutes).

Based on the literature, a myriad of covariates have been shown to be associated with preterm birth. Of these covariates, we analyzed the following maternal characteristics: race/ethnicity (non Hispanic White, non Hispanic Black, Hispanic, Other) maternal age (15-49), payor (received government assisted payment and did not receive government assisted payment), prior poor infant health outcome (had a prior preterm birth, LBW, or SGA infant), maternal residence (rural vs. micropolitan region), marital status (married vs. not married), maternal education status (did not complete high school, completed high school, and received at least some college education), transfer status (was transferred to a different hospital than originally admitted), and birth order (first, second, or third or more births). Data not reported on the birth certificate or hospital discharge record was considered unknown.

We employed a modeling strategy which involved identifying grouped subsets of variables that we hypothesized have substantive relationships with our outcome, preterm birth, and possibly with our exposure, drive time. We grouped our nine covariates into three domains that appeared plausibly linked with one another: demographic, socioeconomic, and obstetric. The demographic domain included the covariates race/ethnicity, marital status, and maternal age; the socioeconomic domain included the covariates payor, maternal education status, and maternal residence; and the obstetric domain included the covariates prior poor infant outcome, birth order, and transfer status. We then determined how mean drive time changed in models specified with one or all of the domains adjusted. We then analyzed whether or not drive time values from within the models that included covariate domains changed by fewer than or greater than 10% from the crude model (the model without any covariate domains).

Results

Description of sample

Of the 174,925 births within the cohort, 35% were born to non Hispanic White women, 29.5% were born to non Hispanic Black women, 9.7% were born to Hispanic women, and 9.8% to women racially classified as “Other” (Table 1a). The mean travel time between home and hospital for women aged 15 to 49 was 35.14 minutes, with women aged 45 to 49 traveling approximately 12 minutes longer than women aged 15 to 19 years. When this cohort is stratified by rural versus micropolitan region, women from rural residences had on average a 19 minute (p=0.0001) longer drive time to hospitals than did women from micropolitan regions. When stratifying the cohort by a mother’s form of payment for delivery services, there was a considerable difference in mean travel time it took women who received government funded obstetric care versus women who used other forms of payment (means of 43.65 and 23.85 minutes, respectively). Additionally, women delivering preterm lived on average 40 minutes from a delivery facility as compared to women with term deliveries who lived on average 32 minutes from delivery facility (p=0.0001).

Preterm birth in relation to drive time

The variables race/ethnicity, marital status, maternal age, payor, maternal education status, rurality, prior poor infant health outcome, birth order, and transfer status were included in multivariable logistic regression models with preterm birth as the outcome in order to assess how drive time is associated with preterm birth. Table 2 reports the odds ratios for preterm birth among women as a function of drive time, individual covariates domains, region, and population size.

The unadjusted model (Model 0), indicates the unadjusted association of drive time with preterm birth. In this model, drive time of more than 45 minutes was associated with a 59% increased odds of preterm birth when compared to a drive time of less than 15 minutes. Although drive time of 16 to 30 minutes does not appear to be associated with preterm birth, drive times between 31 and 45 minutes have a modestly protective effect on rates of preterm birth (OR 0.94, 95% CI 0.90 0.99).

Models 1 through 4 consider this association after adjustment for different domains of covariates. When adjusting for demographic covariates (race, age, and marital status) within the model, Model 1 demonstrates that driving more than 45 minutes, is associated with a 61% increased odds of preterm birth when compared to a drive time of less than 15 minutes. In this model, women aged 40 to 44 have almost twice the risk of experiencing preterm birth than do women aged 20 to 24 (OR 1.84, 95% CI 1.64 2.07). However, in Model 4, which adjusts for all covariates, this 40-44 age group-preterm birth association is modestly strengthened (OR 1.85, CI 1.64 2.09). Model 1 also demonstrates the well-known increased risk for preterm birth among women 45 to 49 (OR 1.76, 95% CI 1.03 3.04); however this association is attenuated to null in the fully adjusted model (Model 4) (95% CI 0.99 3.02).

Model 2 (adjusting for maternal education level, payor, maternal residence) demonstrates a modest increase in the association between a greater than 45 minute drive time and preterm birth (OR 1.73, 95% CI 1.65 1.80) when compared with Model 1 (OR 1.51, 95% CI 1.45 1.57). With the inclusion of socioeconomic covariates, drive times of 16 to 30 and 31 to 45 minutes do not suggest any association between drive time and preterm birth (OR 1.73, 95% CI 1.65 1.80; OR 1.03, 95% CI 1.65 1.80). Also within Model 2, rural residence appears to have a protective effect, as women from rural regions are 18% less likely to experience preterm birth than are women from micropolitan regions (OR 0.82, 95% CI 0.80 0.85). This association is weaker when assessing this variable in the fully adjusted model (OR 0.86, 95% CI 0.83 0.89). Another variable that appears to be modestly protective is public insurance as payor for delivery services. Amongst this cohort, women who received government funded obstetric care were modestly less likely to experience preterm birth when compared to women who used other resources as a means of payment (OR 0.97, 95% CI 0.94 1.00).

When adjusting for obstetric covariates, Model 3 suggests there is a weaker association between drive time in excess of 45 minutes and preterm birth, as this drive time is associated with a 31% increase in odds of preterm birth (95% CI 1.26 1.36). The model also suggests that driving 16 to 30 minutes and 31 to 45 minutes is modestly protective (OR 0.95, 95% CI 0.90 0.99; OR 0.94, 95% CI 0.89 0.98, respectively). As to be expected, both transfer status and prior infant complications were highly associated with an increased risk of preterm birth. Women with a previous preterm birth, LBW, or SGA infant were almost 4 times as likely to have a preterm birth as compared to women who did not (OR 3.96, 95% CI 3.35 4.68). Notably, women with 'missing' information for prior poor infant outcome had 12% higher odds of preterm birth (95% CI 1.08 1.16). Due to the small number of women with indication of inter-facility transfer (n=1,294), and because those women who transferred presumably had pregnancy complications, it is not surprising that the OR for preterm birth among women who transferred as compared to those who did not transfer was 32.3 (95% CI, 27.69 37.84).

There was statistically significant interaction between inter-facility transfer and distance between home and delivery facility and preterm birth (p=0.0001) as shown in Table 3. When comparing the ORs with and without this interaction term, the effect of preterm birth as it relates to a drive time of more than 45 minutes persists even amongst women who were not transferred

(OR 1.30, 95% CI 1.25 1.35). Additionally, when assessing preterm birth risk amongst women who did not transfer, a drive time between 16 and 45 minutes appears to be modestly protective of preterm birth. When assessing the model with the inclusion of transfer status, as to be expected, a drive time of greater than 45 minutes when compared with driving less than 15 minutes is strongly associated with preterm birth (OR 3.30, 95% CI 1.41 7.76).

Discussion

This study aimed to explore the burden of preterm birth as it relates to proximity of hospitals throughout non-metropolitan Georgia. The results of the study provide evidence to suggest that, independent of common individual and population-level risk factors, women living outside of metropolitan Georgia, who drive more than 45 minutes to a hospital, are more than 1.5 times as likely to experience preterm delivery compared to women who travel less than 15 minutes. We further demonstrated that there is a spatial mismatch between a mother's risk and her access to services, and that increasing the amount of providers and/or maternal services could mitigate this risk.

The association between a mother's drive time and her risk of preterm birth may be related to a myriad of causal and non-causal factors such as poor access to prenatal care or increased rates of smoking during pregnancy. As illustrated in previous research [23], evidence suggests that throughout the U.S., poor infant outcomes such as low birthweight and postneonatality have been consistently higher in rural as compared to urban areas. Although the aforementioned literature does not postulate associative reasons for high prevalence of preterm birth, the results of our study suggest that proximity to perinatal services may be associated with these deleterious infant outcomes. Consistent with prior findings [23, 30], our study indicates that perinatal services are not always accessed by women at increased risk for perinatal complications within Georgia, which may suggest a mismatch of services for women who are at high risk for experiencing preterm delivery.

Our analysis also reveals patterns and distributions that conflict with prior findings, the most surprising being that rural residents, when compared to micropolitan residents, appear to have lower risk of preterm birth, conditional on measured individual and area-level risk factors. Micropolitan women may have been more likely to experience preterm birth for reasons unique to Georgia, such as those presented by Samuelson et al., who found instances of higher risk subpopulations continuously delivering at hospitals without subspecialty care [23]. Also, as previously mentioned, although large scale studies have shown that women from rural areas are at greater risk of infant health complications as compared to urban areas [23], these studies did not delineate between gradations of rurality and did not show distribution of illness as it relates to rural versus micropolitan areas.

This study has several potential limitations. The first limitation— which is often seen in studies utilizing vital statistics—is that there is a portion of independent variables with missing data that did not appear to be systematically missing at random. For example, only 4% of data, about 4 observations, were missing for women aged 45 to 49, yet 13% of data, about 3,890 observations, were missing for women aged 15 to 19 (table 1b). This age group of 15 to 19, which has repeatedly been shown to be at higher risk of preterm birth as compared to women 20 to 24, did not appear to have a significantly high risk of preterm birth within our study. This could have been a result of the large amounts of missing observations within the data set. An additional variable that contains both varying degrees of missing data as well as issues with reporting error is the variable prior poor infant health outcome. Nearly 50,000 birth certificates birth certificates have missing data for prior history of poor pregnancy outcome (e.g. preterm birth, LBW, SGA). This large amount of missing observations is important because a history of previous poor infant health outcome would likely affect the choice of delivery facility in the current pregnancy. Women at high risk may be referred to regional centers which may be geographically further than a community delivery hospital. Thus, missing maternal risk factor data limits our ability to fully adjust for this source of bias. Potentially, the effect of association for preterm birth and previous poor infant health outcome could have been dramatically higher than was reported had there not been this issue.

A second limitation is that the exposure, drive time, was categorized in relatively arbitrary segments of 15 minute intervals. These intervals were selected based on the distribution of drive time. Although the implications of this are minor, the drive time of over 45 minutes, which is the travel time most significantly associated with preterm birth, is arbitrarily established.

A third limitation is that we lacked adequate information about important risk factors for preterm birth within the dataset (e.g. smoking status, alcohol use, and presence of a father's name on the birth certificate). The multivariable modeling we used did not control for any behavioral risk factors that have known associations with preterm birth such as alcohol use and smoking status. Although both variables are noted on the birth certificate, smoking status was not listed within the dataset. Had we been able to analyze these behavioral covariates, we could have more precisely controlled for a mother's risk of preterm birth. The presence of a father's name on the birth certificate would have also been an important variable for which to control. As seen in a study by Gaudino Jr. et al., within Georgia, the absence of a father's name on the birth certificate is a unique, independent risk factor for infant mortality.[40] Researchers found, that compared with the rates for married women who listed a father's name on the birth certificate, infant mortality rates were higher for married women who did not list the father's name on the birth certificate (RR=2.3, 95% CI 1.6 3.1). Because this indicator suggests a greater risk of neonatal morbidity and mortality than does marital status alone, it would have been beneficial to have had this variable within the dataset.

Implications

As shown in our study, women living over 45 minutes driving time to a place of delivery have an increased risk of preterm birth in non-Metropolitan Georgia. Further analysis is therefore needed to explore reasons why women who took more than 45 minutes to travel to facilities are subject to this undue burden. As shown in our analysis, travel time, and not simply the geographic distance from a hospital, is an independent risk factor for preterm birth. Because rural women were not at an increased risk of preterm birth as compared to micropolitan women, further research needs to be done to explore this relationship between road network travel time and an increased risk of preterm delivery.

Further research might include exploration of how the risk factors we analyzed are geographically distributed throughout Georgia. Knowing where women with particular risk factors are clustered could inform policy and program makers where to best focus efforts to mitigate this increased risk of preterm birth. It would also be beneficial for future analysis to explore how the association between a mother's drive time and her risk of preterm birth varies by year. Because the data spans a ten year period that incorporates events wherein many Georgia residents lost their residences due to economic recession, there may be profound variation in risk of preterm birth from year to year. This could be as result of increased maternal stress, smoking and alcohol use for purposes of mitigating stress, lack of access to transportation, etc. Future research could therefore investigate how risk of preterm birth varies by changing socioeconomic status.

Our study suggests that women at higher risk of preterm birth appear to have less geographic proximity to delivery facilities within Georgia. Once the association between travel time and preterm birth is further explored, it is imperative that programs and policies be developed to target this subpopulation that is experiencing an increased risk of preterm delivery.

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Table 1a. Descriptive statistics of singleton births by drive time, 1999 to 2009

Race	N Obs	%Missing	Mean	Std. Deviation	Min	Maximum	Median
Non-Hispanic white	104272	11.8	35	28.8	0	433.2	29.6
Non-Hispanic Black	52302	14.5	29.5	29.8	0.1	394.7	18.8
Hispanic	12326	9.7	25.8	23.6	0.3	323.6	19.6
Other	6025	9.8	33.7	34.8	0	419.8	24.7
Age							
15-19	29924	13.1	29	27.3	0.1	366.8	22.3
20-24	59453	12.8	31	28.4	0	394.7	24.7
25-29	45722	11.6	33.9	29.2	0	384	28.6
30-34	26462	11.1	35.7	30	0	419.8	30.1
35-39	11005	7	37.2	31.9	0.3	433.2	31.2
40-44	2261	6.1	38.8	33	0.6	320.3	32.7
45-49	98	4.1	40.5	34.3	0.7	169.2	29.9
Marital Status							
Married	95498	13.1	29.9	28.5	0	433.2	22.4
Unmarried	79427	10.3	35.9	29.5	0	419.8	30.7
Education							
Did not finish high school	48122	13.1	28.4	26.4	0	364.1	22.2
Finished high school	67691	12.1	32.5	28.5	0	419.8	26.9
At least some college	57205	10.5	36.4	31.3	0.2	433.2	30.6
Missing	1907	11.2	33.9	30.4	1	314.7	29.3
Payor							
No government assistance	96386	10.9	23.9	26.8	0	419.8	14.3
Government assistance	78539	12.6	43.7	28.2	0	433.2	40.7
Rurality							
Micropolitan	96386	11.2	23.9	26.8	0	419.8	14.3
Rural	78539	12.6	43.7	28.2	0	433.2	40.7
Obstetric							
Missing	50084	11.4	34.8	29.2	0	394.7	29.4
No prior preterm birth, LBW, or SGA	124065	12	31.8	29.1	0	433.2	25.6
Prior preterm birth, LBW, or SGA	776	14.4	28.7	28	0.5	262.6	19.9
Birth order							
1	72978	10.9	33.1	29.7	0	394.7	27.2
2	56221	11.6	32.9	28.9	0	433.2	27.2
3+	45726	13.5	31.6	28.4	0	419.8	25.5
Prior obstetric complication							
Missing	50084	11.4	34.8	29.2	0	394.7	29.4
No prior poor infant health outcome	124065	12	31.8	29.1	0	433.2	25.6
Prior poor infant health outcome	776	14.4	28.7	28	0.5	262.6	19.9
Transfer							
No	1294	14.3	106.8	51	1.2	394.3	99.4
Yes	173631	11.8	32.1	28.2	0	433.2	26.5
Preterm birth							
no	154342	11.2	31.7	27.6	0	433.2	26.3
yes	20583	16.9	40.5	38.3	0.1	394.3	31.2

Table 1b. Distribution of singleton births by drive time intervals, 1999 to 2009

Drive Time	**Total** Frequency	**0 < 15** Row%	**16-30** Row%	**31-45** Row%	**> 45** Row%	**% Missing** Row%
Race						
Non-Hispanic White	104272	25.2	19.9	18	26	10.9
Non-Hispanic Black	52302	38.7	12.4	12.2	22.2	14.5
Hispanic	12326	37.6	21.4	16	15.4	9.7
Other	6025	35.1	17.1	14.1	24	9.8
Age						
15-19	29924	34.1	18.5	15.3	19	13
20-24	59453	31.8	18	15.6	21.7	12.8
25-29	45722	29	17.1	16.3	25.9	11.6
30-34	26462	27.2	17.1	16.4	28.2	11.1
35-39	11005	27.8	17.5	17	30.8	7
40-44	2261	25.8	17.7	17.7	32.7	6.1
45-49	98	25.5	23.5	12.2	34.7	4.1
Marital Status						
Unmarried	32913	34.5	17.1	14.8	20.6	13.1
Married	32913	25.6	18.4	17.5	28.2	10.3
Education						
Did not finish high school	48122	34.3	19.2	15.5	18	13
Finished high school	67691	29.9	17.9	16.5	23.6	12.1
At least some college	57205	28	16.1	15.7	29.7	10.5
Missing	1907	26.6	20.1	20.4	21.8	11.2
Payor						
Medicaid no	79183	29.2	17.2	16.3	26.5	10.9
Medicaid yes	95742	31.5	18.1	15.8	22	12.6
Rural/urban						
Micro	96386	45.2	19.2	11	13.5	11.2
Rural	78539	12.3	15.8	22.2	37.1	12.6
Birth order						
1	72978	30.4	17.8	16.1	24.8	10.9
2	56221	30.1	17.8	16.2	24.4	11.6
3+	45726	31	17.4	15.6	22.5	13.5
Prior obstetric complication						
Missing	50084	26.4	18.8	16.6	26.8	11.4
No prior preterm birth, LBW, or SGA	124065	32.1	17.2	15.8	23	12
Prior preterm birth, LBW, or SGA	776	36.21	15.59	16.37	17.4	14.43
Transfer						
no (n=153128)	173631	30.7	17.8	16.1	23.6	11.8
yes (n=1109)	1294	1.8	1.7	1.6	80.7	14.3
Preterm birth						
no	154342	31	18.1	16.4	23.3	11.2
yes	20583	26.1	14.5	13	29.6	16.9

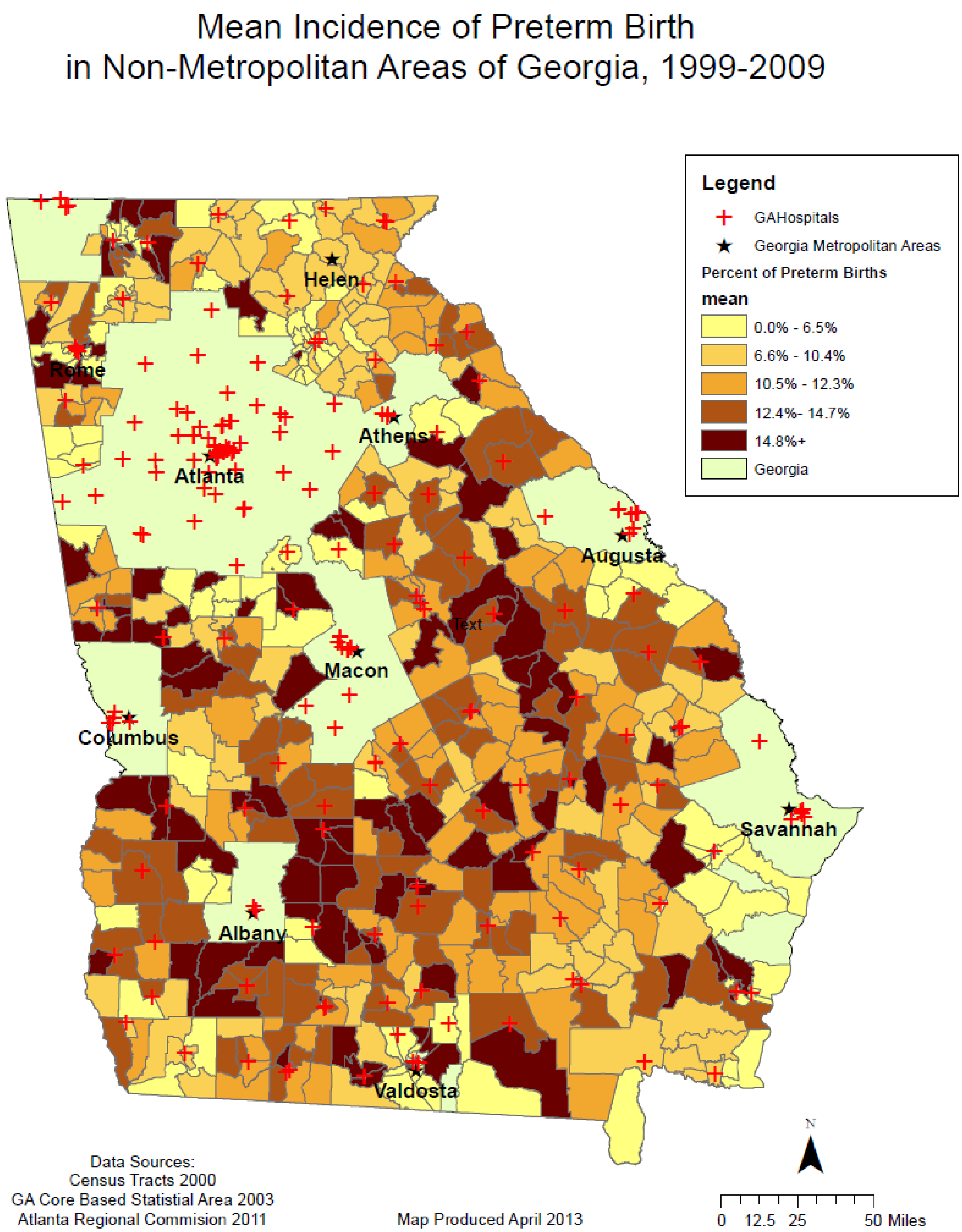
Table 2. Parameter estimates for preterm birth

	Crude			Model 1- Demographic characteristics			Model 2- Socioeconomic conditions			Model 3- Obstetric conditions			Model 4- All covariate model		
	OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI		OR	95% CI	
Drive Time															
16-30 vs. <15	0.95	0.91	1.00	1.04	0.99	1.09	0.99	0.94	1.04	0.95	0.90	0.99	1.06	1.01	1.11
31-45 vs. <15	0.94	0.90	0.99	1.02	0.98	1.08	1.03	0.98	1.09	0.94	0.89	0.98	1.09	1.03	1.14
>45 vs. <15	1.51	1.45	1.57	1.61	1.55	1.67	1.73	1.65	1.80	1.31	1.26	1.36	1.53	1.46	1.60
Race															
Black Non-Hispanic vs. White Non-Hispanic				1.53	1.47	1.59							1.49	1.43	1.55
Hispanic vs. White Non-Hispanic				0.99	0.92	1.06							0.95	0.88	1.00
Other vs. White Non-Hispanic				1.46	1.35	1.59							1.19	1.09	1 .29
Age															
15-19 vs. 20-24				1.08	1.03	1.13							1.05	0.99	1.10
25-29 vs. 20-24				0.98	0.94	1.02							1.00	0.96	1.05
30-34 vs. 20-24				1.08	1.03	1.14							1.14	1.07	1.20
35-39 vs. 20-24				1.35	1.27	1.44							1.38	1.29	1.48
40-44 vs. 20-24				1.84	1.64	2.07							1.85	1.64	2.09
45-49 vs. 20-24				1.76	1.03	3.04							1.73	0.99	3.02
Marital Status															
Not married vs. married				1.19	1.14	1.23							1.11	1.06	1.15
Education															
No high school vs. at least some college							1.26	1.21	1.32				1.23	1.17	1.30
Finished high school vs. at least some college							1.17	1.13	1.22				1.11	1.06	1.16
Missing vs. at least some college							1.20	1.03	1.40				1.15	0.98	1.34
Payor															
Government assistance vs. non Government assistance							0.97	0.94	1.00				1.14	1.10	1.18
Rurality															
Rural vs. Micropolitan							0.82	0.80	0.85				0.86	0.83	0.89
Obstetric															
Prior poor infant health outcome vs. no poor infant health outcome										3.96	3.35	4.68	3.99	3.37	4.72
Missing vs. no poor infant health outcome										1.12	1.08	1.16	1.08	1.04	1.12
Birth order															
Birth order 2 vs. 1										0.98	0.94	1.02	1.00	0.96	1.04
Birth order 3 vs. 1										1.22	1.18	1.27	1.14	1.08	1.19
Transfer															
Did transfer vs. did not transfer										32.37	27.69	37.84	28.96	24.74	33.89

Table 3. Multiplicative Interaction of Maternal Transfer and Drive Time

	OR	95% CI	
Maternal transfer			
Drive time <=15 minutes	1.00	--	
Drive time 16-30 minutes	0.45	0.14	1.47
Drive time 31-45 minutes	1.19	0.34	4.14
Drive time 45+ minutes	3.30	1.41	7.76
No maternal transfer			
Drive time <=15 minutes	1.00	--	
Drive time 16-30 minutes	0.95	0.91	1.00
Drive time 31-45 minutes	0.94	0.89	0.99
Drive time 45+ minutes	1.30	1.25	1.35

Appendix A. Map of Non-Metropolitan Areas of Georgia



Appendix B. Institutional Review Board Approval

EMORY UNIVERSITY

Institutional Review Board

December 10, 2012

RE: Determination: No IRB Review Required
eIRB#: n/a
Title: *The Influence of Proximity of Perinatal Services on Birth Outcomes on Birth Outcomes in Rural Georgia*
PI: Alexandra Anderson

Dear Ms. Anderson:

Thank you for requesting a determination from our office about the above-referenced project. Based on our review of the materials you provided, we have determined that it does not require IRB review because it does not meet the definition of "research" involving "human subjects" as set forth in Emory policies and procedures and federal rules, if applicable.

Specifically, in this project, you will analyzing de-identified data to study the relationships between the health of infants born to black mothers and the distance from a health care provider. Research using such information is not considered research involving human subjects. Please note that this determination does not mean that you cannot publish the results.

This determination could be affected by substantive changes in the study design, subject populations, or identifiability of data. If the project changes in any substantive way, please contact our office for clarification.

Thank you for consulting the IRB.

Sincerely,

Martha C. Patterson, BA
Research Protocol Analyst
This letter has been digitally signed