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Geographic Accessibility to Health Services and Neonatal Mortality Among Very Low Birthweight Infants in South Carolina

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DEDICATION

I would like to thank God, family, and friends for their support and encouragement.

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ABSTRACT

Introduction: Infant mortality is commonly denoted as a marker of population health with more than half of all infant deaths occurring during the neonatal period (0-27 days) of infancy. Mortality for infants born very low birthweight (<1500 grams) is markedly higher than the babies born with normal birthweight (2500-4000 grams). The purpose of this research project was to assess geographic access to perinatal health services and the risk of neonatal death among infants born with very low birth weight.

Data and methods: The linked birth and death records of a retrospective cohort of very low birthweight (<1500 grams) infants born in South Carolina between the years 2010 and 2012 were used (n=3191). We assessed the impact of travel time from maternal residence to delivery hospital and travel time from maternal residence to the nearest prenatal care provider (obstetricians/gynecologists, community health center, or rural health clinic). Logistic regression modeling was performed with adjustments for maternal characteristics (race, age, chronic/gestational hypertension, chronic/gestational diabetes mellitus, smoking, prenatal care), newborn characteristics (gestational age, birthweight, gender, NICU admission at birth), and the birth in a level III hospital.

Results: There were a total of 563 neonatal deaths in this population and the neonatal mortality rate was 17.64 neonatal deaths per 100 live births. We did not find significant

associations of travel time from maternal residence to delivery hospital and to a closest prenatal care provider with neonatal death after adjusting for confounders. However, we found that a one-week increase in gestational age (OR: 0.61 [95% CI: 0.57-0.65]) and non-Hispanic Black mothers (versus non-Hispanic White mothers) (OR: 0.65 [95% CI: 0.45-0.94]), were associated with the lower odds of neonatal death, while non-NICU admission at birth (OR: 5.99 [95% CI: 4.05-8.84]) was associated with an increased odds of neonatal death.

Conclusion: Although we did not find that travel time was associated with neonatal mortality among very low birthweight infants, our study identified a few significant correlates for neonatal deaths in this birthweight group. Future studies should investigate the role of geographic access to care on mortality during other periods of infancy and among other birthweight groups.

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LIST OF ABBREVIATIONS

CHC .... Community Health Center

CI...Confidence Interval

ICD..International Classification of Diseases

RHC .... Rural Health Clinic

RPC .... Regional Perinatal Center

VLBW... Very Low Birthweight

CHAPTER 1

INTRODUCTION

Background

Infant Mortality

Infant mortality is commonly denoted as a marker of population health. It is defined as death occurring within the first year of life. The infancy period is divided into two main categories: neonatal and post-neonatal. The neonatal period is characterized as life up to 27 days after birth, while the post-neonatal period focuses on infancy beyond 27 days up to one year. Studies usually differentiate between the two periods when assessing birth outcomes and predictors of health. The social, environmental, and biological factors of the mother during preconception through pregnancy and delivery has the strongest influence on perinatal and neonatal health (Association of Maternal and Child Health Programs [AMCHP], 2013) Morbidity and mortality in the post-neonatal period is primarily attributed to environmental factors following birth such as an infant's sleep environment and access to ongoing health care (AMCHP, 2013).

A recent publication by the National Center for Health Statistics showed that in 2010, 6.14 infants per 1000 live births died within the first year in the United States, ranking the U.S. 26th among other industrialized nations (Matthews & MacDorman, 2013;

National Center for Health Statistics [NCHS], 2014). The neonatal and post-neonatal mortality rates were reported at 4.05 deaths per 1000 live births and 2.10 deaths per 1000 live births, respectively (Matthews & MacDorman, 2013). More than half of all infant deaths occur during the neonatal period of infancy (Matthews & MacDorman, 2013; S.C. Department of Health and Environmental Control [SC DHEC], 2014). For the state of South Carolina (SC), mortality rates for infants are higher than the national average. Infant deaths per 1000 live births were 7.4 in 2010 and 7.6 in 2012 (SC DHEC, 2014). Neonatal and post-neonatal deaths for South Carolina exhibited a similar trend with most deaths occurring within 28 days after birth.

Prematurity and Low Birthweight

Among the reasons for infant death, prematurity, marked by a gestational age of less than 37 weeks, and low birthweight (≤ 2500 grams) remains two of the leading causes (Matthews & MacDorman, 2013; SC DHEC, 2014). Prematurity and low birthweight prevalence have declined in past years but remain higher than national goals outlined in *Healthy People 2020* (U.S. Department of Health and Human Services [US DHHS], 2014). In the United States, 12% of all infants were born prematurely in 2010 (Matthews & MacDorman, 2013). For the same year, the prevalence of infants born low birthweight was 8.2% and 1.47% for very low birth weight (< 1500 grams) nationally (Matthews & MacDorman, 2013). Mortality for infants born very low birthweight is markedly higher than normal birthweight babies at 222.15 deaths per 1000 live births in the United States and 194.7 deaths per 1000 births for the state of SC in 2010 (Matthews & MacDorman, 2013; SC DHEC, 2014).

Gestational age and birthweight are important indicators of child health and recently have been found to be associated with the development of diabetes and cardiovascular diseases in adulthood (Harder, Rodekamp, Schellong, Dudenhausen, & Plagemann, 2007; Leeson, Kattenhorn, Morley, Lucas, & Deanfield, 2001). In infancy, premature and very low birthweight infants commonly suffer from respiratory disorders, heart problems, and brain hemorrhaging (March of Dimes Foundation, 2014). In 2007, the costs associated with prematurity exceeded 26 billion US dollars (March of Dimes Foundation, 2013). For these reasons it is important to study factors associated with increased mortality among infants with very low birth weight.

Health Care Access

Health care access has an important role to play in the health of populations. The Institute of Medicine (IOM) defines access as "the timely use of personal health services to achieve the best possible health outcomes" (Millman, 1993). The IOM also outlines three types of barriers that threaten the timely access of needed health services: structural, financial, and personal (Millman, 1993). Of particular interest to this research study, structural barriers focus on the availability, organization, and transportation components in accessing health services.

A regionalized perinatal system was established by the March of Dimes Committee on Perinatal Health in 1976 (March of Dimes Foundation, 2010). The purpose of this organized system is to increase access to risk-appropriate care for the most vulnerable infants. The perinatal system in the state of South Carolina is divided into four regions – Piedmont, Midlands, Pee Dee, and Low Country (Figure 1.1) (S.C. Department of Health and Environmental Control [SC DHEC], n.d.a). Hospital level designations within perinatal systems are based on the type of specialized care provided to infants and mothers and are divided into three categories – level I (basic), level II (intermediate), and level III (advanced) (Millman, 1993). For high-risk neonates, level III facilities are most capable of providing the necessary services and are recommended for the delivery of all very low birthweight infants (SC DHHS, 2014). There are a total of seven level III perinatal facilities in South Carolina, five of which are regional perinatal centers (SC DHEC, n.d.a). Each perinatal region in South Carolina has at minimum one regional perinatal hospital (Figure 1.2) (SC DHEC, n.d.a). Numerous studies have shown that premature and very low birthweight infants have better health outcomes in advanced care hospitals with high patient volumes (Chung et al, 2011; Cifuentes et al., 2002; Menard, Liu, Holgren, & Sappenfield, 1998; Phibbs et al., 2007; Warner, Musial, Chenier, & Donovan, 2004). Despite these recommendations only 80% of very low birthweight infants born in the state of South Carolina in 2012 were delivered in a level III facility (SC DHEC, n.d.b).

Prenatal care involves a close monitoring of the mother and fetus' health status through the assessment of important risk factors in pregnancy such as weight gain, pregnancy history, infection, family history of diseases, pregnancy-related complications, as well as lifestyle factors (March of Dimes Foundation, 2010). Prenatal care allows for early detection of pregnancy complications that if left untreated can lead to an increase in risk for factors associated with infant death and other adverse birth outcomes such as prematurity and low birthweight (March of Dimes Foundation, 2014; Millman, 1993). Vintzileos, Ananth, Smulian, Scorza, & Knuppel (2002) reported that among infants born preterm and term, the risks of neonatal death were increased among mothers who did not receive prenatal care during pregnancy as compared to those mothers who did receive prenatal care during pregnancy. Alexander and Kotelchuck (2001) present some of the challenges in assessing the role of prenatal care and evaluating its benefit to maternal and infant health outcomes and suggests for the improvement of current definitions on the quality and measurement of this health service for women of varying socioeconomic, cultural, and medical backgrounds. Despite these challenges, prenatal care is regarded as a fundamental preventive tool in affecting maternal and infant health. The utilization of this health service is included in national goals by the U.S. Department of Health and Human Services to improve maternal, infant, and child health (US DHHS, 2014). According to the National Center of Health Statistics, roughly 86% of U.S. mothers received prenatal healthcare from an obstetrician between the years 2009 and 2010 (Uddin, Simon, & Myrick, 2014). Family physicians are also capable of providing the necessary care. It is therefore important to recognize the availability of prenatal care providers and geographic access to perinatal health services as a potential access barrier for mothers and evaluate its impact on birth outcomes among high-risk infants.

Geographic Information System and Health Outcomes

Geographic information systems (GIS) are designed to "map, model, query, and analyze large quantities of data within a single database according to their location" (U.S. Environmental Protection Agency [US EPA], 2014).

When modeling health care access between two points, the most commonly used GIS measures include Euclidean "straight line" distance, road travel distance, and road travel time. Haynes, Jones, Sauerzapf, & Zhao (2006) compared GIS estimates for travel time with actual drive times and straight-line distance to health facilities for cancer patients

(Haynes et al., 2006). They found a strong correlation between GIS estimates of travel time and actual drive time (r = 0.856) as well as straight line distance (r = 0.935), indicating sufficiency of using either measure (Haynes et al., 2006). Phibbs and Luft (1995) reported similar findings in an earlier study but stated that travel time is the preferred measure for hospitals in urban settings or studies with relatively small sample sizes (Phibbs & Luft, 1995). Other studies report Euclidean distances as crude assessments of travel burden. Among rural populations, road travel time based on GIS estimates was found to more closely reflect actual drive time as compared to straight-line distance (Jordan, Roderick, Martin, & Barnett, 2004). When comparing travel distances over larger geographic areas, straight line distance was shown to be a poor approximation for actual journey times (Shahid, Bertazzon, Knudtson, & Ghali, 2009).

Many studies have used GIS to model access to care or health-seeking behaviors. Distance measures are utilized in studies evaluating access to emergency services, primary care, and health services related to disease screening (Carr, Branas, Metlay, Sullivan, & Camargo, 2009; Cervigni, Suzuki, Ishii, & Hata, 2008; Fryer et al., 1999; Huang, Dignan, Han, & Johnson, 2009; Khan et al., 2011; Pedigo & Odoi, 2010; Yamashita & Kunkel, 2010). Some other studies have evaluated the impact of road distance traveled to health facilities on either perinatal, neonatal, or infant mortality in both developed (Lisonkova et al., 2011; Pasquier et al., 2007; Pilkington, Blondel, Drewniak, & Zeitlin, 2014) and developing (Armstrong Schellenberg et al., 2008; Kashima et al., 2012; Lohela, Campbell, & Gabrysch, 2012; Malqvist, Sohel, Do, Eriksson, & Persson, 2010)

countries but with varied results. Very few studies have used a more accurate measure, namely travel time to health care services, and studied its impact on mortality in infancy (Combier et al., 2013; Dummer & Parker, 2004; Grzybowski, Stoll, & Kornelsen, 2011; Moisi et al., 2010; Okwaraji, Cousens, Berhane, Mulholland, & Edmond, 2012; Ravelli et al., 2011; Schoeps, Gabrysch, Niamba, Sie, & Becher, 2011). Of those studies that utilized a distance- or time-based measure of access, there were vast differences in sample size, exclusion/inclusion criteria, and geographic region of study. The outcome and exposure variables were also defined differently between studies. Such differences may have contributed to inconclusive results (see Chapter 2). The objective of this study is to investigate the association between travel time to health services, namely prenatal care providers and delivery hospitals, and neonatal mortality among very low birthweight infants (<1500 grams), a high-risk infant group, born in South Carolina between the years 2010 and 2012.

Aims

Geographic accessibility to health services were measured in the following ways:

1. Travel time from maternal residence to the hospital of delivery
2. Travel time from maternal residence to the closest prenatal care provider (i.e., Obstetrician/Gynecologist, Community Health Center, or Rural Health Clinic)

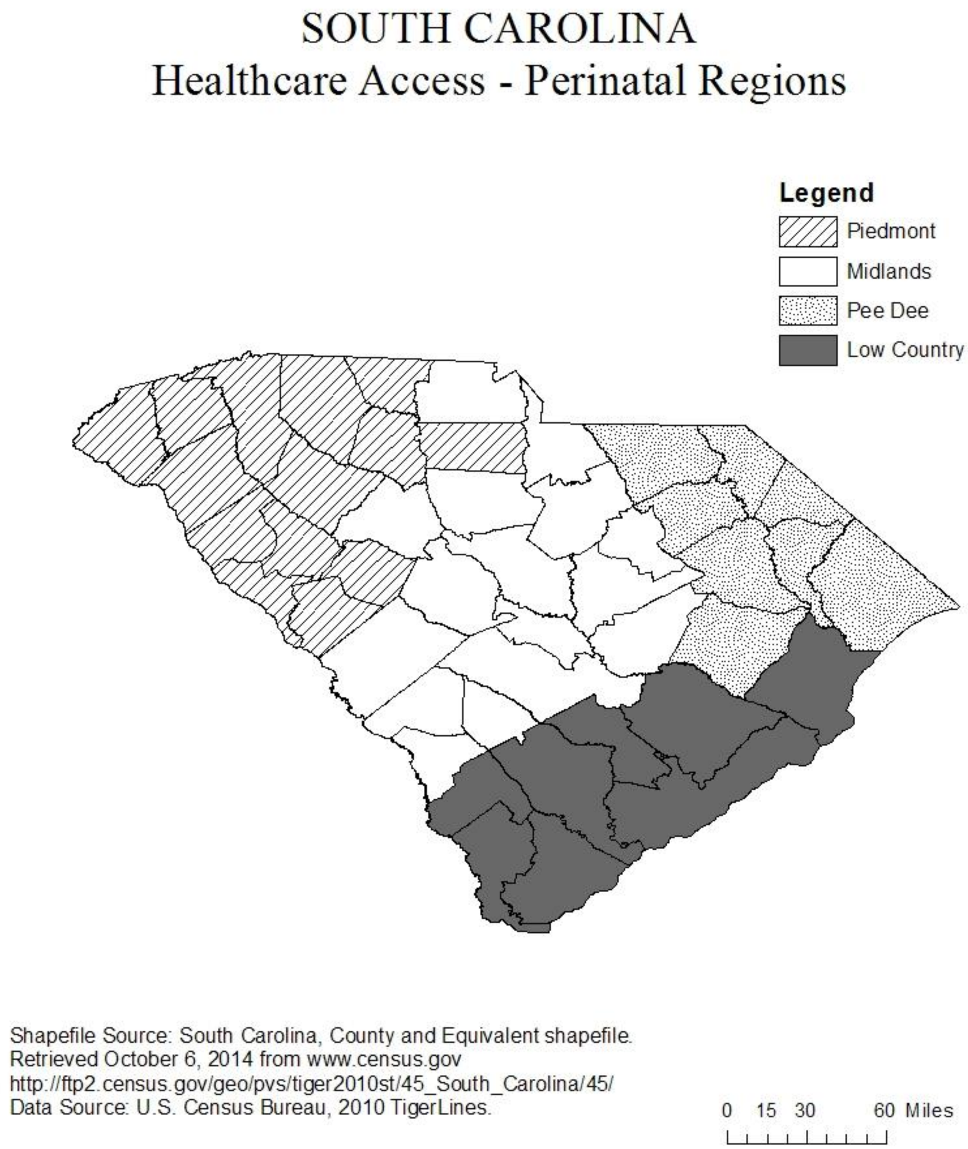

Figure 1.1 South Carolina Health Care Access – Perinatal Regions

CHAPTER 2

LITERATURE REVIEW

Literature Review Search Criteria

The PubMed (Medline) database was utilized to search for previous research studies on travel time to delivery hospital and to the prenatal care provider on neonatal mortality. The search queries are listed in Table 2.1. Each search query included all key terms for travel time, neonatal death, and delivery hospital or prenatal care provider. We included all research studies published between the years 2000 and 2014. The bibliographies of articles selected for further review were additionally scanned for relevant studies.

Prior Studies on Infant Mortality and Travel Time to Delivery Facility

Many studies have evaluated the effect of distance traveled to access health services on perinatal, neonatal, and infant mortality. Not many of those studies have utilized a time-based measure of access, and none have examined its impact on neonatal mortality among a high-risk infant group. Of the seven studies analyzed in this literature review, three concluded a null association (Combier et al., 2013; Dummer & Parker, 2004; Okwaraji et al., 2012) between the travel time to nearest perinatal hospital or actual delivery facility and infant death, while four studies found positive associations (Grzybowski et al., 2011; Moisi et al., 2010; Ravelli et al., 2011; Schoeps et al., 2011) even after adjusting for confounders.

Literature Review

Developed Countries

Dummer and Parker (2004) reported an overall null association between travel time from home to the nearest general or pediatric hospital and risk of infant death in England for all time periods: 1950-1959, 1960-1969, 1970-1979, 1980-1993. This was a population-based cross-sectional study that utilized the Cumbrian Births Database (CBD) which comprises live births, stillbirths, and infant deaths. A total of 4,489 infant deaths occurred in this cohort of 287,993 births. The investigators mentioned that a limitation of theirstudy was the lack of current data. The built environment, such as the development of roadways and the location of services, is always changing. Therefore, it can be difficult to make inferences based on studies that assess geographical barriers to health during differing time periods.

A French population-based cross-sectional study by Combier et al. (2013) reported an insignificant positive association between travel time to closest maternity ward and perinatal mortality (stillbirths and neonatal deaths combined). Data came from hospital discharge summaries of 111,001 deliveries from linked files of mothers and children as well as socioeconomic factors and gestational age provided by the maternity wards. Postal codes served as the geographic unit to define women's residence which impeded the ability to conduct detailed analyses by geographic region. Travel time calculations were based on ambulance drive times which may confound the observed associations. An additional limitation was the potential migration of mothers outside of the study region.

In a population-based Dutch cohort study by Ravelli et al. (2004), a vehicular travel time of at least 20 minutes to the delivery hospital was positively associated with overall infant mortality in both the crude (OR: 1.22; 1.07-1.39) and adjusted (adjusted OR: 1.17; 1.002-1.36) models. Additionally, travel time of at least 20 minutes to the delivery hospital was positively associated with infant deaths within 24 hours of birth (adjusted OR: 1.51; 1.13-2.02) and 0-7 days after birth (adjusted OR: 1.37; 1.12-1.67) but not beyond the first week during the neonatal period (adjusted OR: 1.24; 0.67-2.27). The study was based on linked birth and death files from the perinatal registry of the Netherlands (PRN). A few limitations presented by the authors included the lack of information on cause of death, actual drive times, and place of departure for mothers at the start of labor.

Grzybowski, Stoll, and Kornelsen (2011) developed a hierarchical logistic regression model to evaluate associations between travel time to the nearest referral maternity center and perinatal mortality (stillbirths and early neonatal deaths). A travel time of at least 240 minutes from maternity services was found to be positively associated with perinatal mortality (adjusted OR: 3.17; 1.45-6.95). The study population lived in remote villages and communities in a mountainous area of Canada. The multilevel analysis allowed investigators to control for individual maternal risk factors as well as group level factors such as social vulnerability and the proportion of indigenous groups in their sample. Travel method is not mentioned in the study. [43]

Developing Countries

Moïsi et al. (2010) conducted a prospective cohort study that utilized data collected through interviews as well as the Epidemiological and Demographic

Surveillance System (Epi-DSS) in a predominantly rural area (n=93,216 children) of Kenya. The multivariate proportional-hazards model indicated a slightly insignificant decrease in risk of infant mortality with increasing pedestrian (Hazards Ratio (HR) per 60 minutes: 0.98; 0.95-1.02) and vehicular (HR per 30 minutes: 0.98; 0.93-1.03) travel time to the nearest hospital. A few limitations noted by the authors of this study were potential migration of high-risk pregnancies, the assumption that mothers traveled to the nearest hospital, and the inability to adjust for HIV status and socioeconomic factors.

In a prospective study by Schoeps, Gabrysch, Niamba, Sié, & Becher (2011) travel time (pedestrian) to the closest health facility and risk of under-5 mortality was assessed. The adjusted hazard mortality ratio for children under five years of age was 1.12 (1.07-1.17) for every additional hour spent in walking. This study was conducted in the rural country of Burkina Faso where health facility density is low and there are no forms of emergency or public transportation. Distance measures were based on pedestrian mode of travel and were derived by trained researchers with knowledge of the study area. Alternative weighted distance measures were calculated using ArcView software for sensitivity analyses. Study results are potentially biased if derived estimates do not reflect actual travel times.

A cross-sectional study conducted in Ethiopia by Okwaraji et al. (2011) consisted of rural dwellers from a small city with a single health center. Data were collected by trained staff that conducted in-house interviews with eligible women. Adjusted Poisson regression models showed an increased rate of under-5 mortality for pedestrian travel times of 2.5-3.5 hours (RR: 3.1; 1.3-7.4) and 3.5-6.5 hours (RR: 2.5; 1.1-6.2) to the single health center in Dabat as compared to those that traveled less than 1.5 hours Analyses for the neonatal and post-neonatal period were not possible due to the small sample size of the study population (n = 2,058 households). The investigators mentioned their exclusion of children of women that died. The nature of this selection bias threatens the external validity in populations experiencing high maternal mortality found in many developing countries like Ethiopia (World Health Organization [WHO], 2014).

Limitations

It is important that the exposure and outcome is defined similarly among reviewed studies. Of the studies included in the literature review, none of the studies assessed neonatal mortality strictly but included neonatal deaths in much broader categories classified as under-5 mortality (Okwaraji et al., 2012; Ravelli et al., 2011; Schoeps et al., 2011) perinatal mortality (stillbirths and neonatal deaths) (Dummer & Parker, 2004; Grzybowski et al., 201; Moisi et al., 2010), or total infant mortality (Combier et al., 2013; Okwaraji et al., 2012). Significant associations between travel time to the delivery hospital or closest health facility and perinatal and under-5 mortality were reported by Grzybowski et al. (2011), Okwaraji et al. (2012), Ravelli et al. (2011), and Schoeps et al. (2011). None of the studies that utilized a time-based measure of access evaluated the outcome for a high-risk infant group such as those born very low birthweight.

Most studies included in this literature review consisted of sample sizes between 50,000 and 750,000 births. Mode of travel varied among studies making it challenging to make fair comparisons. Infants born preterm or beyond medical delineations of viability are at increased risk for experiencing adverse health outcomes (March of Dimes Foundation, 2014; Arzuaga & Lee, 2011). The study by Ravelli et al. (2011) only assessed term births (37-42 weeks gestation), while Grzybowski et al. (2011) and

Combier et al. (2013) included births beyond 20 weeks and 22 weeks gestation, respectively. In an attempt to reduce further bias, pregnancies that were complicated or resulted in birth defects, multiples, or stillbirths were excluded (Combier et al. (2013); Dummer & Parker (2004); Grzybowski et al. (2011); Moisi et al., (2010). Most studies included maternal age, parity, and ethnicity for maternal characteristics. Similar constructs for socioeconomic status (SES) were household wealth, social class, and social vulnerability. Maternal education served as a proxy measure for SES in a rural African nation study (Okwaraji et al., 2012). Environmental factors, such as the degree of urbanization, were also controlled for in studies by Ravelli et al. (2011) and Combier et al. (2013). Hospital level and volume have been shown to impact birth outcomes and were additionally adjusted for in the study by Ravelli et al. (2011).

Purpose of Study

According to the U.S. Census Bureau's urban-rural classification, roughly 92% of the total land area of South Carolina met rural standards in 2010 and one third of SC total population reside in rural areas (U.S. Census Bureau, 2011). As compared to other states, South Carolina has the fourth highest rates of both preterm and low birthweight births (Martin, Hamilton, Osterman, Curtin, & Matthews, 2013). The statewide infant mortality rate is consistently higher than the national average (Matthews and MacDorman, 2013; NCHS, 2014). There are clear racial disparities in health outcomes, and with an increasing minority population, the gaps in health achievement will continue to broaden if changes are not made.

The purpose of this research project is to assess geographic access to health services and risk of neonatal death for very low birth weight infants in the state of South

Carolina. To my knowledge, this will be the first study to model neonatal mortality through the evaluation of travel time from home to delivery hospital and the nearest provider of maternity care for very low birth weight infants, a high-risk infant group. In addition to demographic factors, linked birth and death records will allow for the inclusion of other variables such as maternal demographics and risk factors in pregnancy, newborn characteristics, and hospital-level factors. This thesis will seek to explain geographic barriers to health services among very low birthweight infants in South Carolina

Table 2.1 Literature Review Search Terms

Topic	Search Terms
Travel Time	“time factors”, “time factors”, “distance”, “drive”, “driving”, “drive time”, “drive times”, “driving time, “driving times”, “automobile driving”, “proximity”, “geography”, “travel”, “travel time”, “travel times”
Neonatal Death	“infant mortality”, “infant death”, “neonatal mortality”, “neonatal death”, “perinatal mortality”, “perinatal death”, “child mortality”, “child death”
Delivery Hospital	“hospital”, “health service accessibility”, “health services accessibility”, “access to care”, “health care access”, “healthcare access”, “health access”
Prenatal Care Provider	“physicians, primary care” [MESH], “primary health care” [MESH]

CHAPTER 3

METHODS

Study Design and Data Source

We utilized a retrospective cohort study design to analyze the associations between (i) travel time from maternal residence to delivery hospital, and (ii) travel time from maternal residence to the closest prenatal care provider (obstetrician/gynecologist, community health center, or rural health clinic) and neonatal death among very low birthweight infants in South Carolina. The data were obtained from the linked birth and death certificate records provided by the South Carolina Department of Health and Environmental Control (SC DHEC) for all live births who had very low birth weight (<1500 grams) born in the state of South Carolina between the years 2010 and 2012. Birth and death certificate records were linked with provider data for obstetricians/gynecologists, community health center/rural health clinics, and the hospital of delivery. All birth and death records were de-identified by SC DHEC and exported to SAS prior to release to the research investigator.

Study Population

The study population included 3,191 births of very low birthweight infants in South Carolina occurring between the years 2010 and 2012. Among them, an estimated 563 deaths occurred during the neonatal period (< 28 days). For both aims, we excluded infants with a birthweight less than 500 grams (n=303), gestational age less than 20 weeks (n=1), term pregnancies (n=21), home births (n=12), births occurring out of state (n=216), births occurring in a non-licensed perinatal hospital (n=1), and those with missing values for variables included in analyses (n=53). Pregnancies resulting in multiple births violated the assumption of independent observations and were therefore excluded (n=552). The resulting sample size was 2032 live births and 226 neonatal deaths (Figure 3.1). The analytic study sample comprised of all singleton births with pregnancy duration between 20 and 36 weeks.

Measures

Outcome Variable

The outcome variable of interest is all-cause neonatal mortality defined as death within 28 days of birth. The death record will provide cause of death based on International Classification of Diseases, 10^{th} Revision.

Exposure Variable

The exposure of interest for Aim 1 is travel time (minutes) from maternal residence to delivery hospital and for aim 2 is travel time from maternal residence to closest prenatal care provider (obstetrician/gynecologist, community health center, or rural health clinic). Travel time calculations were derived using ArcGis 10.2 (ESRI, Redlands, CA) Network Analyst Extension prepared by South Carolina Department of Health and Environmental Control (SC DHEC) staff.

I. Maternal Residence

The physical address of the mother was based on place of residence provided on the birth certificate record.

II. Perinatal (Delivery) Hospital

The physical address of the perinatal hospital where the delivery took place (n=47) was provided by the South Carolina Hospital Association. Levels of perinatal designations are based on the Division of Health Licensing Regulations at DHEC (Hospital and Institutional General Infirmaries, 2010). There are five hospital-level designations for perinatal hospitals in South Carolina – level I, level II, level II Enhanced, level III, and level III Regional Perinatal Center (RPC) (Figure 3.2). Level II and level II Enhanced perinatal hospitals were combined into one category for analyses (Table 3.1). Level III and level III RPC perinatal hospitals were combined into one category for analysis (Menard et al., 1998) (Table 3.1).

III. Prenatal Care Providers

The physical addresses of all licensed obstetricians/gynecologists (n=519) in 2011 were provided by the South Carolina Revenue and Fiscal Affairs Office. Physicians with missing address (n=11) or P.O. Box listing (n=5) were removed (3%). The final data set included a total of 503 obstetricians/gynecologists. The physical addresses of community health centers and rural health clinics were provided by the South Carolina Primary Health Care Association (SCPHCA) and the South Carolina Office of Rural Health (SCORH), respectively. There were a total of 110 community health centers and 118 rural health clinics in the state of South Carolina between the years 2010 and 2012. Included in our sample were community health centers (n=19) and rural health clinics (n=8) that provided prenatal care to mothers during pregnancy (Figure 3.3). Information on each of the prenatal care providers was linked to birth and death records. Travel time calculations were derived by SC DHEC GIS analysts for each provider type – delivery hospital, obstetrician/gynecologist, community health center, rural health clinic. A final de-identified dataset was released to the research investigator for analyses.

Covariates

The characteristics of the study population were obtained from the birth and death records for each infant. Maternal characteristics were retrieved from the birth record of the newborn which included the maternal race (non-Hispanic White, non-Hispanic Black, Hispanic and others), maternal age (<20 years, 20-24 years, 25-29 years, 30-34 years, and 35 years or more), chronic/gestational hypertension (yes or no), chronic/gestational diabetes mellitus (yes or no), smoking (yes or no). Newborn characteristics retrieved from the birth and death records of the infant included gestational age (very preterm: 20-33 weeks, preterm: 34-36 weeks), birthweight (500-999 grams, 1000-1499 grams), gender (male or female), NICU admission at birth (yes or no), age at death, and cause of death. Hospital characteristics retrieved from the birth record included hospital of delivery.

Statistical Analysis

Neonatal mortality rates were presented by year of birth and neonatal period. Maternal, newborn, and hospital characteristics were described by travel time categories and neonatal death. Associations were tested using the chi-square test for categorical variables and one-way ANOVA for continuous variables. Percentages were presented for categorical variables. The mean and respective standard deviations were presented for continuous variables. Travel time and maternal factors (maternal race, maternal age, chronic/gestational hypertension, chronic/gestational diabetes mellitus, smoking), newborn factors (birthweight, gestational age, gender, NICU admission at birth), and hospital-level factors (birth in a level III delivery hospital) were individually tested for interaction. The interaction model, for instance, included travel time and maternal age and a travel time by maternal age interaction term. The significance was tested with the Wald test. We tested for significant interactions at the 0.05 level. Simple logistic regression models were performed for the crude analysis of the travel time variable with neonatal death (Model I). Model II adjusted for all possible confounding factors. Furthermore, Models III and IV adjusted for variables significant at a p-value of 0.1 and 0.05, respectively. A p-value of <0.05 was considered statistically significant. Odds ratios (ORs) were presented with the 95% confidence intervals (CI) for the travel time variable and all possible confounding factors. All statistical analyses were performed in SAS Version 9.3 (SAS Institute, Cary. NC).

To determine appropriate categories for the travel time variable, we plotted neonatal death against every 10th percentile of travel time. The mortality pattern was evaluated for each percentile. Adjacent travel time categories were combined if the rate of mortality was similar. According to the neonatal mortality pattern by travel time percentile from maternal residence to delivery hospital, the travel time variable was categorized into four classes: less than 10 minutes, 11-30 minutes, 31-50 minutes, and greater than 50 minutes. When analyzing travel time from maternal residence to nearest prenatal care provider, travel time calculations were derived for each provider type. Given we are interested in the access to prenatal care provider in general, we decided to combine obstetrician/gynecologist, community health center, and rural health clinic information into a single provider variable coded as “prenatal care provider.” The shortest travel time among the three provider types served as the measure for all analyses.

The travel time variable was categorized into three classes: 10 minutes or less, 11-20 minutes, and more than 20 minutes. The travel time variable was additionally assessed continuously in all analyses.

Table 3.1 Licensed Perinatal Hospitals in South Carolina

Perinatal Designation (SC DHEC)	Hospital	Perinatal Designation for Analyses
Level I – Community	Chesterfield General Hospital, Clarendon Memorial Hospital, Colleton Medical Center, Greer Memorial Hospital, Hilton Head Hospital, Kershaw Health, Laurens County Hospital, Marlboro Park Hospital, McLeod Medical Center-Dillon, McLeod Loris Hospital, Newberry Memorial Hospital, Oconee Medical Center, Roper – Mt. Pleasant, Upstate Medical Center, Village Hospital, Wallace Thomson Hospital	Level I
Level II – Specialty	Aiken Regional Medical Center, Anmed Health Women's & Children, Baptist Easley Hospital, Beaufort Memorial Hospital, Bon Secours – St. Francis Xavier, Carolina Pines Regional Medical Center, CHS Marion County, Conway, East Cooper Regional Medical Center, Georgetown Memorial Hospital, Grand Strand Regional Medical Center, Lexington Medical Center, Mary Black Memorial Hospital, Providence Hospital North East, Roper Hospital, Springs Memorial Hospital, St. Francis – Eastside Hospital, Summerville Medical Center, Toumey Hospital, Trident Regional Medical Center, The Regional Medical Center-Orangeburg, Waccamaw Community Hospital, Women's Center of the Carolinas Hospital	Level II
Level II – Enhanced Specialty	Piedmont Medical Center	
Level III – Subspeciality	Palmetto Health – Baptist, Self Regional Healthcare	Level III
Level III RPC – Regional Perinatal Center	Greenville Memorial Hospital, McLeod Regional Medical Center, Medical University of South Carolina, Palmetto Health – Richland, Spartanburg Regional Medical Center	

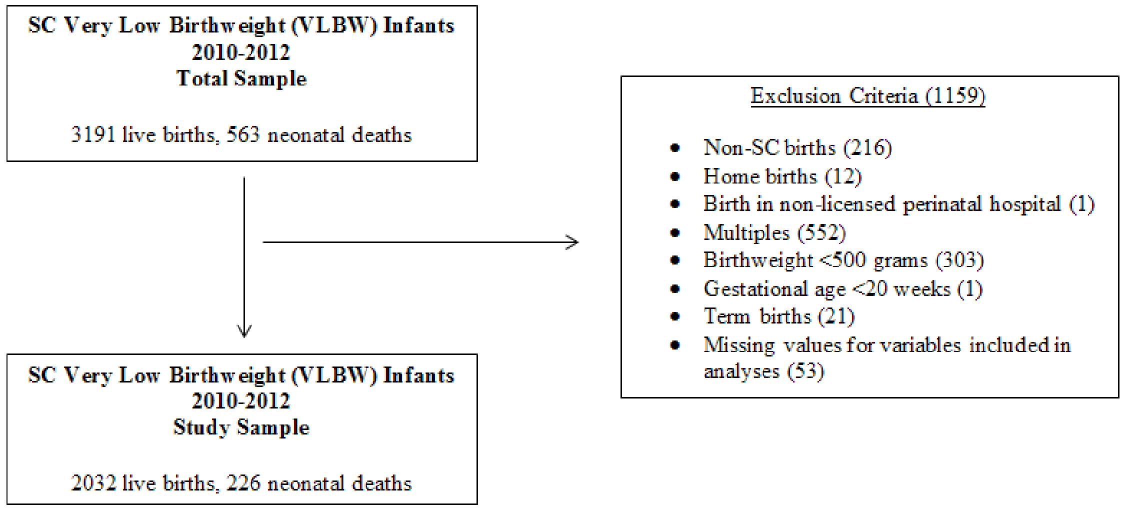

Figure 3.1 Exclusion Criteria

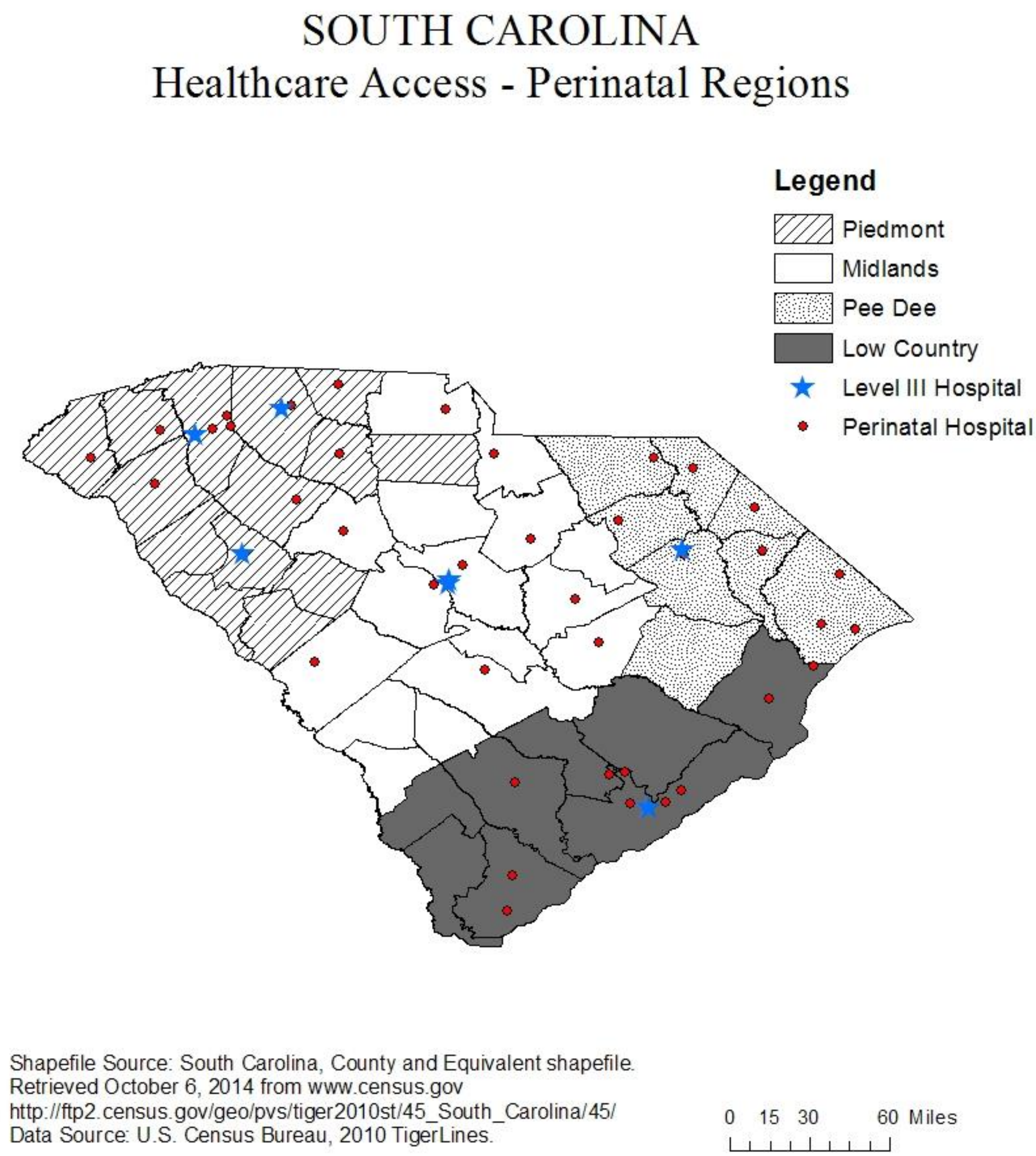

Figure 3.2 South Carolina Health Care Access – Perinatal Hospitals

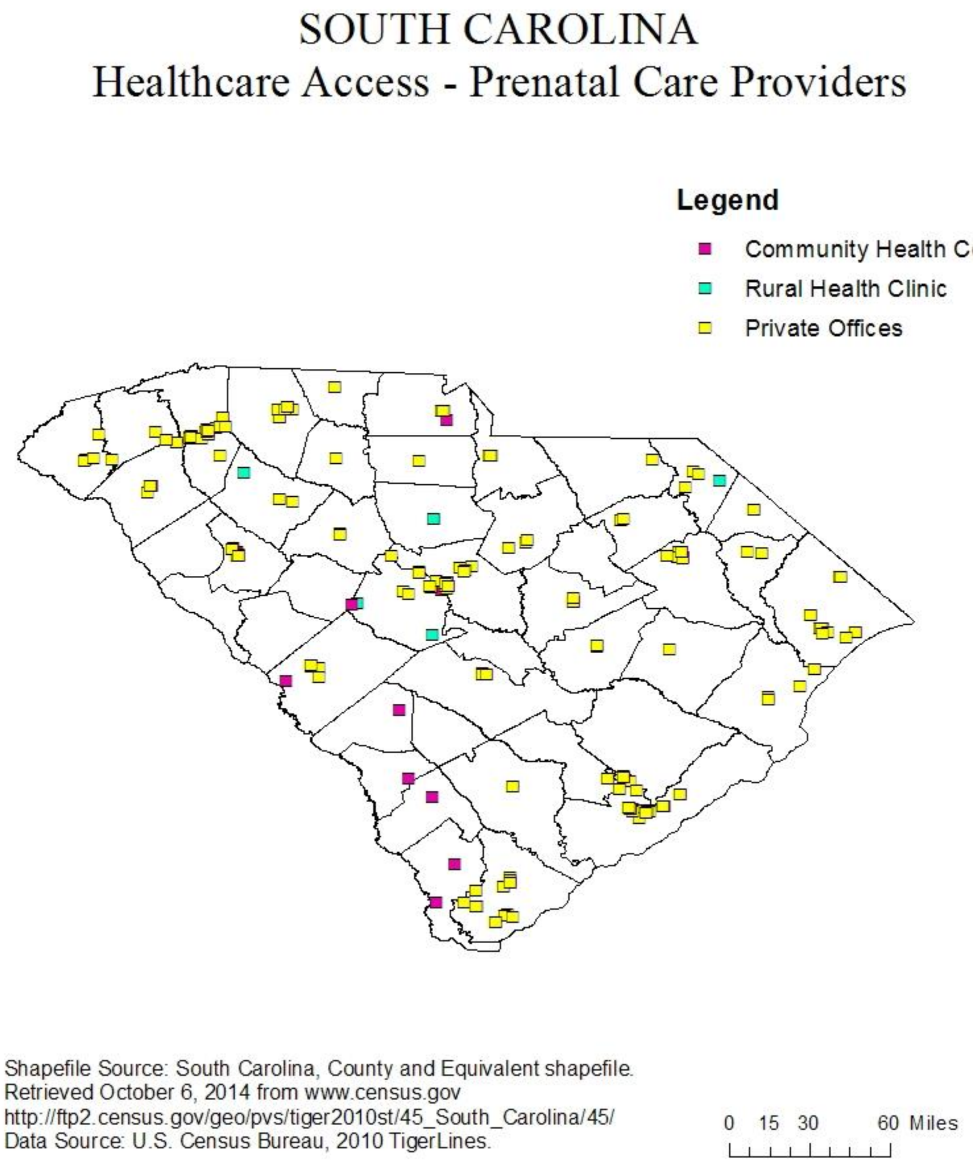

Figure 3.3 South Carolina Health Care Access – Prenatal Care Providers

CHAPTER 4

RESULTS

Neonatal Mortality in Total Population

There were a total of 3,191 live births and 563 deaths among very low birthweight infants in South Carolina between the years 2010 and 2012 (Table 4.1). The overall neonatal mortality rate was 17.64 deaths per 100 live births. The neonatal mortality rate was higher for the years 2011 and 2012 (18.42 and 18.38 deaths per 100 live births, respectively) than that for the year 2010 (16.21 deaths per 100 live births).

Mortality by Neonatal Period

The majority of the neonatal deaths occurred during the early neonatal period (474 deaths) as defined by birth to 7 days (Table 4.2). A total of 412 very low birthweight infants died within 24 hours after birth with a marked neonatal mortality rate of 12.91 deaths per 100 live births. The early neonatal period exhibited a higher neonatal mortality rate than for the late neonatal period (8-27 days) yielding a mortality rate of 14.85 deaths per 100 live births in early neonatal period as compared to 2.79 deaths per 100 live births in the late neonatal period.

Causes of Death

The causes of neonatal death in our sample are outlined in Table 4.3. The majority of all neonatal deaths were attributable to causes originating in the perinatal period

(88.10%) with 9.24% and 2.66% attributed to congenital abnormalities and all other causes, respectively. One-third of all neonates in our sample died due to disorders related to length of gestation and fetal malnutrition (33.04%) while complications of pregnancy and labor and delivery were responsible for one-fifth of all neonatal deaths (21.49%).

Neonatal Mortality in Study Sample

The study sample included 2032 live births with 226 births resulting in neonatal deaths (Table 4.4). The neonatal mortality rate of the study sample was 11.12 deaths per 100 live births. Regarding maternal characteristics, the mean age of mothers in the sample was 26.37 (SD=6.28) and 25.67 (6.41) among mothers whose neonates died. More than half of the mothers in the sample were non-Hispanic Black (58.81%), while non-Hispanic White and Hispanic and others represented 34.15% and 7.04%, respectively. For behavioral factors, 27.90% of mothers had chronic/gestational hypertension, 7.38% had chronic/gestational diabetes mellitus, and 14.81% smoked during pregnancy. With the exception of maternal race, maternal age, and smoking status, the neonatal mortality rate differed by chronic/gestational hypertension status (p-value<0.0001) and chronic/gestational diabetes mellitus status (p-value=0.0191). For newborn characteristics, greater proportions of infants were 20-33 weeks gestation at birth at (96.26%), weighed 1000-1499 grams (56.45%), were males (51.33%), and were admitted to the NICU at birth (86.96%). The neonatal mortality rate was highest for infants with a lower gestational age at birth (p-value=0.0164), lower birthweight (p-value<0.0001), male infants (p-value=0.0164), and for infants not admitted to the NICU at birth (p-value<0.0001). For hospital-level factors, the majority of infants were born in a level III hospital (81.84%). However, the neonatal mortality rate was highest for infants not born in a level III hospital (p-value<0.0001).

Aim 1. Travel time from maternal residence to delivery hospital

In our sample, 20.32% of mothers traveled 10 minutes or less to the hospital of delivery, 37.80% traveled 11-30 minutes, 18.21% traveled 31-50 minutes, and 23.67% traveled more than 50 minutes (Table 4.5). Regarding maternal characteristics, non-Hispanic Black mothers were more likely to travel 10 minutes or less (25.94%) to the delivery hospital or more than 50 minutes (25.94%) to the delivery hospital (p-value<0.0001) than non-Hispanic White mothers (10.95%, 20.32%, respectively) and mothers of Hispanic and other racial/ethnic groups (18.88%, 20.98%, respectively). Mothers with chronic/gestational hypertension were more likely to travel 31-50 minutes (21.16%) or more than 50 minutes (26.46%) to the delivery hospital (p-value=0.0086) than mothers without chronic/gestational hypertension (17.06, 22.59%, respectively). Among characteristics of the newborn, mothers whose neonates were admitted to the NICU at birth were slightly more likely to travel 11-30 minutes (38.20%), 31-50 minutes (18.51%) or more than 50 minutes (23.94%) to the delivery hospital (p-value=0.0475) than mothers whose neonates were not admitted to the NICU at birth. For hospital-level factors, mothers who delivered in a level III hospital were more likely to travel more than 50 minutes (25.86%) to the delivery hospital (p-value<0.0001) than mothers who did not deliver in a level III hospital.. No other significant differences noted by travel time to the delivery hospital.

Logistic Regression Analyses

Interactions with travel time were individually tested for all possible confounders but none were statistically significant at the 0.05 level. Crude and adjusted odds ratios predicting neonatal death among very low birthweight infants are presented in table 4.6. Model I presents results of the crude analysis of travel time from maternal residence to the delivery hospital and neonatal mortality. The adjusted models include all variables (Model II), variables with a p-value=<0.1 (Model III), and variables with a p-value=<0.05 (Model IV). In both the crude and adjusted analyses we found no significant associations between travel time (categorical) from maternal residence to the delivery hospital and neonatal death among very low birthweight infants in South Carolina between the years 2010 and 2012. However, we found that a one-week increase in gestational age (OR: 0.61 [95% CI: 0.57-0.65]) and non-Hispanic Black mothers (versus non-Hispanic White mothers) (OR: 0.65 [95% CI: 0.45-0.94]), were associated with lower odds of neonatal death, while non-NICU admission at birth (OR: 5.99 [95% CI: 4.05-8.84]) was associated with an increased odds of neonatal death. When modeling travel time as a continuous variable, the results of the crude and adjusted did not yield significant results for travel time from maternal residence to the delivery hospital and neonatal death among very low birthweight infants in South Carolina between the years 2010 and 2012 (not shown).

Aim 2. Travel time from maternal residence to nearest prenatal care provider

An obstetrician/gynecologist in a private office setting was the closest prenatal care provider for 80% of mothers while community health centers that provided prenatal care were closest for 15% of mothers and rural health clinics that provided prenatal care were closest for 5% of mothers (not shown). In our sample, 61.81% of mothers traveled

10 minutes or less to the closest prenatal care provider, 24.70% traveled 11-20 minutes, and 13.48% traveled more than 20 minutes (Table 4.7). Regarding maternal characteristics, non-Hispanic Black mothers were more likely to travel 10 minutes or less (67.20%) to the closest prenatal care provider (p-value<0.0001) than non-Hispanic White mothers (49.71%) and less likely than mothers of Hispanic and other racial/ethnic groups (75.52%). As compared to mothers who did not smoke during pregnancy, mothers who smoked were more likely to travel 11-20 minutes (30.23%) and more than 20 minutes (14.95%) to reach the closest prenatal care provider (p-value=0.0210). No other significant differences were noted by travel time to the closest prenatal care provider.

Logistic Regression Analyses

Interactions with travel time were individually tested for all possible confounders but none were statistically significant at the 0.05 level. Crude and adjusted odds ratios predicting neonatal death among very low birthweight infants are presented in table 4.8. Model I presents results of the crude analysis of travel time from maternal residence to the closest prenatal care provider and neonatal mortality. The adjusted models include all variables (Model II), variables with a p-value=<0.1 (Model III), and variables with a p-value=<0.05 (Model IV). In both the crude and adjusted analyses we found no significant associations between travel time (categorical) from maternal residence to the nearest prenatal care provider and neonatal death among very low birthweight infants in South Carolina between the years 2010 and 2012. As with Aim 1, we also found that a one-week increase in gestational age (OR: 0.59 [95% CI: 0.55-0.63]) and non-Hispanic Black mothers (versus non-Hispanic White mothers) (OR: 0.71 [95% CI: 0.51-1.00]), were associated with the lower odds of neonatal death. When modeling travel time as a continuous variable, the results of the crude and adjusted did not yield significant results for travel time from maternal residence to the closest prenatal care provider and neonatal death among very low birthweight infants in South Carolina between the years 2010 and 2012 (not shown).

Table 4.1. Neonatal mortality rates for very low birthweight infants in South Carolina, 2010-2012

	Number of Live Births	Number of Deaths	Neonatal Mortality Rate (per 100 live births)
2010	1104	179	16.21
2011	1064	196	18.42
2012	1023	188	18.38
2010 - 2012	3191	563	17.64

Table 4.2. Neonatal mortality by neonatal period for very low birthweight infants in South Carolina, 2010-2012

Neonatal Period	Number of Live Births	Number of Deaths	Mortality Rate (per 100 live births)
Early (birth-7 days)	3191	474	14.85
Within 24 hours of birth	3191	412	12.91
Late (8-27 days)	3191	89	2.79
Total	3191	563	17.64

Table 4.3. Neonatal mortality by cause of death[a] for very low birthweight infants in South Carolina, 2010-2012 (n=563)

Cause of Death (ICD-10 Code)	Number of Deaths	Proportionate Mortality, %
Originating in Perinatal Period (P00-P96)	**496**	**88.10%**
Length of Gestation and Fetal Malnutrition (P05-P08)	186	33.04%
Complications of Pregnancy, Labor/Delivery (P00-P04)	121	21.49%
Perinatal Infections (P35-P39)	39	6.93%
Respiratory Distress (P22)	34	6.04%
Necrotizing Enterocolitis (P77)	23	4.09%
Hemorrhagic and Blood Disorders (P50-P61)	16	2.84%
Hypoxia and Birth Asphyxia (P20-P21)	13	2.31%
Other Causes[b]	64	11.37%
Congenital Abnormalities (Q00-Q99)	**52**	**9.24%**
All Other Causes[c]	**15**	**2.66%**
Total	**563**	**100%**

[a] Based on International Classification of Diseases (ICD), 10th Edition
[b] Death due to birth trauma (P10-P15), hydrops fetalis not due to hemolytic disease (P83.2), other respiratory conditions in perinatal period (P23-P28), other perinatal conditions (P290,P291,P293,P780,P960,P968)
[c] Diseases of the blood and blood-forming organs (D50-D89), circulatory system (I00-I99), digestive system (K00-K92), genitourinary system (N00-N95), accidents (V01-X59), abnormal clinical and laboratory findings not reported elsewhere (R00-R99)

Table 4.4. Neonatal death by maternal, newborn, and hospital characteristics in SC mothers with VLBW infants, 2010-2012

Study Population	All Women,	Neonatal Deaths	p-value[a]	Neonatal mortality rate per 100 live births
Total	n = 2032	226		11.12
	% (n)	% (n)		
Maternal Characteristics				
Maternal Age, % (n)			0.4663	
< 20 years	12.94 (263)	14.16 (32)		12.17
20-24 years	31.89 (648)	35.40 (80)		12.35
25-29 years	24.11 (490)	24.34 (55)		11.22
30-34 years	19.00 (386)	15.04 (34)		8.81
≥ 35 years	12.06 (245)	11.06 (25)		10.20
Maternal Age, mean (years)	26.37 (6.28)	25.67 (6.41)	0.0741	
Maternal Race			0.1376	
Non-Hispanic White	34.15 (694)	34.07 (77)		11.10
Non-Hispanic Black	58.81 (1195)	55.75 (126)		10.54
Hispanic & Others	7.04 (143)	10.18 (23)		16.08
Chronic/Gestational HTN, % (n)			<0.0001	
Yes	27.90 (567)	11.06 (25)		4.41
No	72.10 (1465)	88.94 (201)		13.72
Chronic/Gestational DM, % (n)			0.0191	
Yes	7.38 (150)	3.54 (8)		5.33
No	92.62 (1882)	96.46 (218)		11.58
Smoking, % (n)				
Yes	14.81 (301)	11.06 (25)	0.0922	8.31
No	85.19 (1731)	88.94 (201)		11.61
Newborn Characteristics				

Gestational Age, % (n)			0.0164	
Very Preterm (20-33 weeks)	96.26 (1956)	99.12 (224)		11.45
Preterm (34-36 weeks)	3.74 (76)	0.88 (2)		2.63
Gestational Age, mean (weeks)	28.14 (3.02)	24.92 (2.87)	<0.0001	
Gender, % (n)			0.0164	
Male	51.33 (1043)	58.85 (133)		12.75
Female	48.67 (989)	41.15 (93)		9.40
NICU Admission, % (n)			<0.0001	
Yes	86.96 (1767)	60.62 (137)		7.75
No	13.04 (265)	39.38 (89)		33.58
Birth in Level III Hospital, % (n)			<0.0001	
Yes	81.84 (1663)	69.47 (157)		9.44
No	18.16 (369)	30.53 (69)		18.70

[a] Based on chi-square test for categorical variables, ANOVA for continuous variables.

Table 4.5. Travel time to delivery hospital by maternal, newborn, and hospital characteristics in SC mothers with VLBW infants, 2010-2012

Study Population	Travel time to delivery hospital (minutes)				p-value[a]
	≤ 10	**11-30**	**31-50**	**> 50**	
Total (n)	413	768	370	481	
% (n)	20.32	37.80	18.21	23.67	
Maternal Characteristics					
Maternal Age, % (n)					0.0853
< 20	24.71 (65)	33.08 (87)	20.15 (53)	22.05 (58)	
20-24	20.37 (132)	34.57 (224)	20.52 (133)	24.54 (159)	
25-29	21.43 (105)	41.22 (202)	16.33 (80)	21.02 (103)	
30-34	18.65 (72)	40.16 (155)	16.06 (62)	25.13 (97)	
≥ 35	15.92 (39)	40.82 (100)	17.14 (42)	26.12 (64)	
Maternal Age, mean (years)	25.64 (5.98)	26.73 (6.18)	25.98 (6.28)	26.72 (6.61)	0.0115
Maternal Race, % (n)					<0.0001
Non-Hispanic White	10.95 (76)	46.54 (323)	22.19 (154)	20.32 (141)	
Non-Hispanic Black	25.94 (310)	32.22 (385)	15.90 (190)	25.94 (310)	
Hispanic & Others	18.88 (27)	41.96 (60)	18.18 (26)	20.98 (30)	
Chronic/Gestational HTN, % (n)					0.0086
Yes	17.11 (97)	35.27 (200)	21.16 (120)	26.46 (150)	
No	21.57 (316)	38.77 (568)	17.06 (250)	22.59 (331)	
Chronic/Gestational DM, % (n)					0.0887
Yes	13.33 (20)	36.67 (55)	21.33 (32)	28.67 (43)	
No	20.88 (393)	37.89 (713)	17.96 (338)	23.27 (438)	
Smoking, % (n)					0.1732
Yes	16.94 (51)	40.20 (121)	21.26 (64)	21.59 (65)	
No	20.91 (362)	37.38 (647)	17.68 (306)	24.03 (416)	

Newborn Characteristics					
Gestational Age, % (n)					0.5572
Very Preterm (20-33 weeks)	20.30 (397)	37.83 (740)	18.40 (360)	23.47 (459)	
Preterm (34-36 weeks)	21.05 (16)	36.84 (28)	13.16 (10)	28.95 (22)	
Gestational Age, mean (weeks)	28.15 (3.01)	28.24 (3.02)	28.01 (2.94)	28.06 (3.09)	0.6151
Gender, % (n)					0.1476
Male	19.27 (201)	40.17 (419)	17.83 (186)	22.72 (237)	
Female	21.44 (212)	35.29 (349)	18.60 (184)	24.67 (244)	
NICU Admission, % (n)					0.0475
Yes	19.35 (342)	38.20 (675)	18.51 (327)	23.94 (423)	
No	26.79 (71)	35.09 (93)	16.23 (43)	21.89 (58)	
Hospital Characteristics					
Birth in Level III Hospital, % (n)					<0.0001
Yes	19.78 (329)	36.32 (604)	18.04 (300)	25.86 (430)	
No	22.76 (84)	44.44 (164)	18.97 (70)	13.82 (51)	

[a] Based on chi-square test for categorical variables, ANOVA for continuous variables

Table 4.6. Association of travel time from maternal residence to delivery hospital and neonatal mortality among very low birthweight infants in South Carolina, 2010-2012 (N = 2032)

	Neonatal Mortality			
	Model I[a]	**Model II[b]**	**Model III[c]**	**Model IV[d]**
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
Travel Time to Delivery Hospital				
≤10 minutes	Reference	Reference	Reference	Reference
11-30 minutes	0.79 (0.54,1.14)	0.78 (0.50,1.23)	0.79 (0.50,1.23)	0.78 (0.50,1.23)
31-50 minutes	1.06 (0.70,1.61)	1.13 (0.68,1.89)	1.11 (0.67,1.83)	1.09 (0.66,1.81)
≥50 minutes	0.75 (0.50,1.14)	0.78 (0.48,1.29)	0.77 (0.47,1.27)	0.74 (0.45,1.21)
Maternal Characteristics				
Maternal Age, years		0.99 (0.97,1.02)		
Maternal Race				
Non-Hispanic White		Reference	Reference	Reference
Non-Hispanic Black		0.62 (0.42,0.90)	0.65 (0.45,0.94)	0.65 (0.45,0.94)
Hispanic & Others		1.17 (0.63,2.17)	1.25 (0.68,2.28)	1.24 (0.68,2.27)
Chronic/Gestational Hypertension				
No		Reference		
Yes		0.84 (0.51,1.37)		
Chronic/Gestational DM				
No		Reference		
Yes		0.62 (0.26,1.50)		
Smoking				
No		Reference		
Yes		0.77 (0.46,1.30)		
Newborn Characteristics				
Gestational Age, weeks		0.62 (0.58,0.66)	0.61 (0.57,0.66)	0.61 (0.57,0.65)
Gender				
Male		Reference		
Female		0.86		

		(0.62,1.20)		
NICU Admission				
No		5.34 (3.56,8.00)	5.43 (3.63,8.14)	5.99 (4.05,8.84)
Yes		Reference	Reference	
Birth in Level III Hospital				
No		1.39 (0.93,2.09)	1.44 (0.96,2.14)	
Yes		Reference	Reference	

[a] Crude model
[b] Adjusted for all possible confounding factors
[c] Adjusted for variables with p-value<0.1
[d] Adjusted for variables with p-value <0.05

Table 4.7. Travel time to closest prenatal care provider by maternal and newborn characteristics in SC mothers with VLBW infants, 2010-2012

Study Population	Travel Time (minutes)			p-value[a]
	≤ 10	**11-20**	**>20**	
Total	1256	502	274	
% (n)	61.81	24.70	13.48	
Maternal Characteristics				
Maternal Age, % (n)				0.1332
< 20 years	60.84 (160)	25.10 (66)	14.07 (37)	
20-24 years	60.34 (391)	24.07 (156)	15.59 (101)	
25-29 years	62.45 (306)	27.55 (135)	10.00 (49)	
30-34 years	65.80 (254)	21.24 (82)	12.95 (50)	
≥ 35 years	59.18 (145)	25.71 (63)	15.10 (37)	
Maternal Age, mean (years)	26.43 (6.22)	26.32 (6.24)	26.21 (6.62)	0.8539
Maternal Race, % (n)				<0.0001
Non-Hispanic White	49.71 (345)	36.89 (256)	13.40 (93)	
Non-Hispanic Black	67.20 (803)	19.08 (228)	13.72 (164)	
Hispanic & Others	75.52 (108)	12.59 (18)	11.89 (17)	
Chronic/Gestational HTN, % (n)				0.5462
Yes	60.67 (344)	24.51 (139)	14.81 (84)	
No	62.25 (912)	24.78 (363)	12.97 (190)	
Chronic/Gestational DM, % (n)				0.8432
Yes	60.00 (90)	26.67 (40)	13.33 (20)	
No	61.96 (1166)	24.55 (462)	13.50 (254)	
Smoking				0.0210
Yes	54.82 (165)	30.23 (91)	14.95 (45)	
No	63.03 (1091)	23.74 (411)	13.23 (229)	
Newborn Characteristics				
Gestational Age, % (n)				0.4882
Very Preterm (20-33 weeks)	62.07 (1214)	24.54 (480)	13.39 (262)	
Preterm (34-36 weeks)	55.26 (42)	28.95 (22)	15.79 (12)	
Gestational Age, mean (weeks)	28.10 (3.00)	28.19 (3.04)	28.20 (3.11)	0.7979
Gender, % (n)				0.3262
Male	60.50 (631)	26.08 (272)	13.42 (140)	
Female	63.20 (625)	23.26 (230)	13.55 (134)	

[a] Based on chi-square test for categorical variables, ANOVA for continuous variables

Table 4.8. Association of travel time from maternal residence to closest prenatal care provider and neonatal mortality among very low birthweight infants in South Carolina, 2010-2012 (N = 2032)

	Neonatal Mortality			
	Model I[a]	**Model II**[b]	**Model III**[c]	**Model IV**[d]
	OR (95% CI)	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
Travel Time to Closest Prenatal Care Provider				
≤10 minutes	Reference	Reference	Reference	Reference
11-20 minutes	1.02 (0.73,1.14)	0.99 (0.68,1.44)	1.02 (0.70,1.48)	1.02 (0.70,1.48)
>20 minutes	1.07 (0.71,1.61)	1.10 (0.69,1.75)	1.11 (0.70,1.76)	1.10 (0.69,1.73)
Maternal Characteristics				
Maternal Age, years		0.99 (0.96,1.01)		
Maternal Race				
Non-Hispanic White		Reference	Reference	Reference
Non-Hispanic Black		0.66 (0.46,0.95)	0.71 (0.51,1.00)	0.71 (0.51,1.00)
Hispanic & Others		1.14 (0.63,2.07)	1.23 (0.69,2.19)	1.24 (0.70,2.22)
Chronic/Gestational Hypertension				
No		Reference	Reference	
Yes		0.70 (0.43,1.12)	0.66 (0.42,1.05)	
Chronic/Gestational DM				
No		Reference		
Yes		0.69 (0.30,1.54)		
Smoking				
No		Reference		
Yes		0.75 (0.46,1.25)		
Newborn Characteristics				
Gestational Age, weeks		0.60 (0.56,0.65)	0.60 (0.56,0.64)	0.59 (0.55,0.63)
Gender				
Male		Reference		
Female		0.82 (0.60,1.11)		

[a] Crude model

[b] Adjusted for all possible confounding factors
[c] Adjusted for variables with p-value<0.1
[d] Adjusted for variables with p-value <0.05

CHAPTER 5

DISCUSSION

Summary

Our study was the first to assess the impact of travel time from maternal residence to delivery hospital and to the closest prenatal care provider among a high-risk infant group. We did not find a significant association between travel time from the maternal residence to the delivery hospital or to the closest prenatal care provider and neonatal mortality among very low birthweight infants in South Carolina between the years 2010 and 2012. Our study found other significant correlates of neonatal mortality in this high risk population. For example, we found an increase in gestational age and admission to a neonatal intensive care unit (NICU) at birth decreases the risk of neonatal death, which was also noted in previous studies that assessed neonatal mortality (Cifuentes et al., 2002; Bacak, Baptiste-Roberts, Amon, Ireland, and Leet (2005). It is important to note that for infants born near the lower gestational age limits of viability, the physician's decision to admit to the NICU at birth may have depended on factors such as the likelihood of survival and the appropriateness of intervention (Arzuaga & Lee, 2011). Therefore, NICU admission at birth may be in favor of neonates born closer to term with promising survivability. Furthermore, our study also study showed decreased odds of neonatal death among non-Hispanic Black mothers as compared to non-Hispanic White mothers after adjusting for maternal and newborn factors. The neonatal mortality rate was also lowest for non-Hispanic Black mothers than for all other racial groups. Bacak et al. (2005)

reported similar findings in their study conducted among extremely low birth weight infants only. In separate studies analyzing racial differences in infant death, non-Hispanic Black mothers exhibited higher rates of neonatal mortality as compared to other racial groups, however, these differences were not significant after adjusting for maternal and newborn characteristics (Hessol & Fuentes-Afflick, 2005; Kitsantas & Gaffney, 2010). Unlike prior studies, our sample did not include infants weighing less than 500 grams or those born before 20 weeks gestation, which we found to have consisted of a higher proportion of births and subsequent deaths to non-Hispanic Black mothers potentially explaining the differences between our study and some previous studies. In terms of all neonatal deaths and not solely among very low birthweight infants, non-Hispanic Black mothers exhibit higher rates of neonatal mortality than mothers of other racial groups, primarily due to a higher prevalence of prematurity and low birthweight among African-American infants (Matthews & MacDorman, 2013; SC DHEC, 2014). Although the leading causes of death are relatively the same for all racial groups, disorders related to short gestation and low birthweight are the leading causes of neonatal death and death under 1-year for infants born to non-Hispanic Black mothers whereas congenital anomalies are reported as the primary cause of death among infants born to non-Hispanic White mothers (Matthews & MacDorman, 2013; SC DHEC, 2014).

This study is consistent with Combier et al. (2013), Dummer and Parker (2004), and Moisi et al. (2010) that travel time is not associated with neonatal mortality, while studies by Gryzbowski et al. (2011), Okwaraji et al. (2012), Ravelli et al. (2011), and Shoeps et al. (2011) found a significant association with under-5 mortality and perinatal mortality (stillbirths and neonatal deaths). However, direct comparisons are not warranted for several reasons. There can be vast difference in travel time by geographic region and mode of transport. It is important to distinguish between industrialized and developing nations as many developing nations do not have the infrastructure in place to provide emergent ambulatory services to a hospital or healthcare facility. In such studies, pedestrian travel was the most common form of transport (Combier et al., 2013; Moisi et al., 2010; Okwaraji et al, 2012). The majority of studies consisted of a much larger sample size (Combier et al., 2013; Dummer & Parker, 2004; Grzybowski et al., 2011; Moisi et al., 2010; Okwaraji et al., 2012; Ravelli et al., 2011). Consistent with Combier et al. (2013), and Grzybowski et al. (2011), we excluded births less than 20 weeks gestation. As with Ravelli et al. (2011), Combier et al. (2013), and Grzybowski et al. (2011), we also excluded pregnancies resulting in multiple births. The outcome variable was defined differently between studies as well which included perinatal (Dummer & Parker, 2004; Grzybowski et al., 2011; Moisi et al., 2010), infant (Combier et al., 2013; Okwaraji et al., 2012), and under-5 mortality (Okwaraji et al., 2012; Ravelli et al., 2011; Schoeps et al., 2011). Beyond maternal and newborn factors, several studies adjusted for social and environmental factors (Combier et al., 2013; Dummer & Parker, 2004; Grzybowski et al., 2011; Moisi et al., 2010; Okwaraji et al., 2012; Ravelli et al., 2011). Unique to our study is the focus on access to care for a high-risk infant group.

Strengths

This research study utilized linked birth and death data files. Linked data is advantageous in that multiple maternal and neonatal characteristics can be assessed concurrently. Linked files presents a more comprehensive picture of the circumstances surrounding preconception and the subsequent birth of an infant. For this reason, detailed analyses can be performed to evaluate neonatal mortality against socio-demographic differences, some behavioral practices, and care at birth. In South Carolina, all infant death records are linked to their corresponding birth records (Matthews & MacDorman, 2013.

Contrary to Euclidean and other road distance measures, travel time is a more accurate assessment of actual journey times (Jordan et al., 2004). In many other studies, travel time is calculated using centroid data, postal code, or other distance algorithms in which averaged or central points serve as the basis for measurements (Combier et al., 2013; Dummer & Parker, 2004; Moisi et al., 2010). Travel time measures in our study are based on the mother's address at the time of birth which would represent a more precise measure of the mother's travel time from home to hospital.

Another strength of our study is the ability to control for maternal, neonatal, and hospital-level factors. Mortality in the neonatal period is most closely associated with demographical characteristics, health behaviors, and environmental factors of the mother during pregnancy. For instance, after adjusting for sample characteristics, we found that important risk factors include gestational age, maternal race, and NICU admission status at birth. We also reported differences in neonatal mortality by chronic/gestational hypertension, chronic/gestational diabetes mellitus, birthweight, gender, and by hospital of birth.

Additionally, we were able to evaluate both access to delivery hospital and to the closest prenatal care provider and its association with neonatal mortality among very low birthweight infants. By linking birth and death records with provider data, we were able to derive travel times to the hospital of delivery and to the closest provider of ongoing prenatal care. This allowed us to examine travel time measures by characteristics of the mother during pregnancy, characteristics present in the newborn at birth, and factors of the delivery hospital.

Limitations

The derived travel time measures in our study may extend or fall short of actual travel times of the mother at the beginning of labor. The trip to the delivery hospital may have been hindered by accidents, detours, or other unexpected vehicular travel circumstances. After reaching the delivery hospital, mothers may have also experienced a delay in receiving medical attention and care.

Longer travel times may not indicate seclusion from health services but the necessity for advanced medical care, in this case, found in level III perinatal hospitals. Tertiary delivery hospitals have the appropriate medical staffing and equipment to care for high-risk neonates like very low birthweight infants. The United States Department of Health and Human Services recommends for all very low birthweights infants to be delivered in a level III perinatal hospital (U.S. DHHS, 2014). Only 82% of all very low birthweight infants included in our study sample were born in a tertiary hospital. In the state of South Carolina there are seven level III delivery hospitals that are capable of handling such deliveries and after-care. These hospitals are regionalized to certain areas of the state. The majority of mothers requiring specialized obstetrical care may not live in close proximity to these facilities and will need to travel long distances or drive to the nearest hospital to be transferred afterwards by way of emergency transport.

Contrarily, primary care is not localized to certain geographic areas. Primary care services are in higher concentrations than hospitals and other emergency care facilities.

Therefore, the nearest provider may not be the actual provider of care. In our assessment of travel time to the nearest prenatal care provider and neonatal death, it was assumed that prenatal care is rendered by the closest prenatal care provider. When it comes to primary care and specialized services, physician density has been utilized to evaluate population outcomes including infant mortality, cancer incidence, and screening behaviors (Campbell, Ramirez, Perez, & Roetzheim, 2003; Shi et al., 2004; Soneji, Armstrong, & Asch, 2012). According to Penchansky and Thomas, healthcare access can be defined in different ways and barriers to uptake in the environment can be explained by the availability, accessibility, affordability, acceptability, and accommodation of services (as cited in Guagliardo, 2004). Penchansky and Thomas notes that physician density reflects service availability while travel time measures reflect service accessibility (as cited in Guagliardo, 2004).

One of the main assumptions of our study is that mothers traveled from their place of residence to the delivery hospital. With the exception of planned deliveries, labor is spontaneous and may begin in a location different from the mother's home. In such cases, actual travel times may be longer or shorter. Both over-estimation and under-estimation of the exposure variable has the capacity to introduce bias into the study. Due to this, this might have led to insignificant findings for the association of travel time and neonatal mortality reported in our study.

Due to sample size, we were not able to perform logistic regression analyses by neonatal period. In our study, we found that most neonatal deaths occurred within 24 hours after birth. Travel time may not be most impactful to birth outcomes in the early neonatal period. The leading causes of neonatal death among very low birthweight infants in our sample were primarily due to short gestation and fetal malnutrition and factors surrounding pregnancy and labor/delivery. Conditions arising from complications of pregnancy and labor/delivery may be most time-sensitive thus placing importance on timely access to care. However, due to sample size limitations, we were also not able to perform additional analyses by cause of infant death.

Conclusion

We did not find travel time from maternal residence to the hospital of delivery and prenatal care provider to be associated with neonatal mortality among very low birthweight infants in South Carolina between the years 2010-2012. It is possible that travel time did not impact neonatal mortality due to a high proportion of neonatal deaths occurring within 24 hours of birth. The underlying causes of death in the early neonatal period may be attributed to reasons not associated with our exposure of interest. It is also possible that the underlying death causes are not sensitive to access to care but are more closely aligned with other maternal, neonatal, or hospital-level factors.

However, in order to make more definitive conclusions, it is better that future studies consist of larger sample sizes that will allow for additional exploration into the impact of travel time on mortality by period of infancy, cause of death, and for other birthweight categories among infants in South Carolina. Statistics regarding the United States infant population show that the majority of very low birthweight infants die during the neonatal period. Future studies should also evaluate neonatal mortality by density of prenatal care providers in South Carolina as another measure of health care access.

In spite of insignificant findings, in agreement with other studies, we have identified similar risk factors for neonatal mortality. The information can be used in support of existing literature that reports the benefits of advanced medical care for very low birthweight infants, to warrant increased study of maternal factors associated with poor birth outcomes, and to prompt additional efforts to evaluate the impact of health care access on total infant health.

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