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Severe Maternal Morbidity in Michigan: An Investigation of Health Disparities

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Walden University
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Abstract

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MPH, Grand Valley State University, 2015

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Doctoral Study Submitted in Partial Fulfillment

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Doctor of Public Health

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Abstract

Severe maternal morbidity (SMM) rates in Michigan have increased over the past 20 years and continue to affect racial and ethnic women disproportionately. Women experiencing health conditions that complicate pregnancy outcomes have a greater risk of having poor obstetric outcomes that result in a SMM event. To evaluate the distribution of women experiencing health conditions that complicate pregnancy and a SMM event, geographic information systems were utilized in this study. The purpose of this study was to depict trends in the prevalence of 4 health conditions and SMM among women hospitalized for obstetric delivery in Michigan from 2016–2017. The 4 health conditions associated with pregnancy complications were obesity, hypertension, mental health diagnosis, and diabetes. This study was supported by the socio-ecological model and the critical race framework that advance the idea that an individual's health is a consequence of the environment, structural and intrapersonal factors, and the community where they live and seek healthcare services. A retrospective cohort analysis was conducted using the 2016–2017 State Inpatient Database, which is the largest database for delivery hospitalizations with race and ethnicity included. Logistical regression analysis indicated an association with geographic location and race and ethnicity, which were the sociodemographic predictors related to SMM risk. The analysis provided detailed information on the locations with the greatest need for more comprehensive maternal health interventions. This study contributes to social change by focusing on improving the health of women, who are of childbearing age, through equitable interventions that address disparities in SMM.

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Dedication

I would like to dedicate this to each mother that has come before me and paved the way, especially my own mother, Darlene.

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Section 1: Foundation of the Study and Literature Review

Introduction

Maternal health has become a prominent news story due to the recent increases in mortality and morbidity. The World Health Organization estimated that over 300,000 women died globally from pregnancy complications and that the worldwide maternal mortality rate has dropped 44% since 1990; yet, in the United States, the maternal mortality rate has increased during that time. The United States is 1 of 8 countries that has experienced an increase in maternal mortality, ranking at the bottom of all developed countries (Hirshberg & Srinivas, 2017; WHO, 2015b). Maternal mortality is the death of a woman within 1 year of the end of pregnancy related to pregnancy or pregnancy management, whereas morbidity is unexpected outcomes from labor and delivery complications that can result in consequences to a woman's health (Centers for Disease Control and Prevention [CDC], 2017b). Maternal mortality rates proxy the quality and effectiveness of a nation's healthcare overall, and upon further analysis brings to light disparities within the healthcare system.

In the United States, approximately 700 women die per year from pregnancy-related complications, and approximately 60% of those deaths are preventable (Peterson et al., 2019). Maternal mortality rates hover between 21–22 deaths per 100,000 live births (Moaddab et al., 2018). In Michigan, approximately 90 women die each year during the antepartum, intrapartum, or postpartum periods, which translate to about 9 deaths per 100,000 live births (Michigan Maternal Mortality Surveillance Program [MMMS], 2018). While this may be lower than the national rate, it has highlighted disparate outcomes for

racial and ethnic women (Michigan Department of Health and Human Services Division for Vital Records & Health Statistics, 2018).

The most common cause of pregnancy-related deaths in Michigan is cardiomyopathy (21%), followed by infection/sepsis (14%; MMMS, 2018). Less common but significant causes of death include cardiovascular conditions, amniotic fluid embolism, hypertension, and other medical conditions (primarily due to chronic diseases, such as cancer, epilepsy, and diabetes; MMMS, 2018). The most common cause of pregnancy-associated, but not related (i.e., injury), deaths is accidental poisoning/drug overdose (45%; MMMS, 2018). Other common causes of death include motor vehicle accidents (23%), homicide (16%), and suicide (11%; MMMS, 2018). According to the Michigan Pregnancy Risk Monitoring System (PRAMS, 2017) and resident live birth files from the Division for Vital Records and Health Statistics, in 2017, 52.4% of women delivering an infant entered pregnancy overweight or obese. The racial and ethnic disparities seen nationally are also patterned and observed in Michigan. From 2011–2015, Black women were 3 times more likely to die from pregnancy-related causes in Michigan (27.7 versus 8.1 per 100,000 live births, respectively; MMMS, 2018). For the same timeframe, Black women were twice as likely to die from pregnancy-associated, not pregnancy-related, causes compared to White women (MMMS, 2018).

Maternal morbidity and mortality, as well as the accompanying unintended outcomes, have been steadily increasing, gaining global, national, and statewide attention. Maternal mortality and morbidity are representations of the nation's overall health and well-being of its citizens. Providing adequate care to women and children can

indicate how a nation, state, or local community takes care of the population at large. Poor health outcomes and the associated complications have detrimental effects on the mother, infant, and families affected by maternal mortality and morbidity. While it is important to note that the increase in maternal mortality and morbidity is attributed to improved surveillance, it can be linked to increasing prevalence of obesity and chronic health conditions (MacDorman, Declercq, Cabral & Morton, 2016). The CDC (2017b) has documented other potential risk factors such as maternal age (i.e., > 35 years old); women living in medically underserved or rural areas; and cesarean delivery, which may affect women differently (Kilpatrick, Ecker, & American College of Obstetricians and Gynecologists, 2016). Moreover, significant racial and ethnic disparities exist, especially for non-Hispanic Black women, who are 3 to 4 times more likely to die from complications related to pregnancy when compared to non-Hispanic White women (Admon et al., 2018; Creanga, Syverson, Seed, & Callaghan, 2017).

Maternal mortality, although catastrophic, affects fewer women in the United States than severe maternal morbidity (SMM). Maternal morbidity affects more than 60,000 women annually in the United States and is associated with high costs and disability (Chen, Chauhan, & Blackwell, 2018; Silveira et al., 2016). Due to the higher frequency of morbidity, the analysis and review of SMM events have the potential to be more informative for policy and practice. SMM, which is based on a specific set of inclusion criteria outlined by the CDC (discussed later in the study), is defined by any health condition attributed to and/or complication of pregnancy and childbirth that has a negative impact on a woman's well-being and functioning and is described per 10,000

delivery hospitalizations (CDC, 2017b; Chou et al., 2016). The effects of maternal morbidity have a negative impact on a women's well-being, family function, and an infant's trajectory, which highlights the need for a comprehensive evaluation of the maternal morbidity burden. In response to these increasing trends, the WHO created the Maternal Morbidity Working Group to craft standardized definitions and measurement criteria (Machiyama et al., 2017). The mission of this group is to shift the focus from maternal mortality and move upstream to focus on women surviving childbirth with a morbid event (WHO, 2015a). This shift emphasizes the need for more robust systemic changes that focus on the entire life course. Researchers continue to study the collective impact on women's function postmaternal morbid event and, therefore, require better understanding and more innovative analysis (Silveira et al., 2016).

The Michigan Mortality Surveillance Committee, which is the nation's longest standing mortality surveillance committee, has identified priority areas for the reduction of maternal mortality and morbidity (MMMS, 2018). In 2018, the Committee identified access to care, prenatal care, mental health, and a healthy lifestyle as the leading priority areas (Michigan Department of Health and Human Services Division for Vital Records & Health Statistics, 2018). The identification of priority areas within women's health during preconception, perinatal, and postpartum may vary geographically across the state. Due to the striking variation regarding population density and geography across the state of Michigan, the recommendations vary widely due to resources and availability (MMMS, 2018). This became apparent when evaluating existing metrics, such as neonatal abstinence syndrome, resulting from increased opioid use during pregnancy, where

Michigan's rural areas have been disproportionately affected by this epidemic (CMS, 2019; Michigan Department of Health and Human Services Division for Vital Records & Health Statistics, 2018). Enhanced tracking of SMM is one way to identify priority areas for interventions, quality improvement, and effective interventions. This aligns with reports from the CDC; other state's Maternal Mortality Review Committees; and the Preventing Maternal Deaths Act of 2018, which emphasizes the need for identification and analysis of maternal death and morbidity at the state level (CDC, 2016).

Recently, national findings have associated the risk of SMM with geographic location, race and ethnicity, and chronic or preexisting health conditions (Admon et al., 2018; CDC, 2016; Chen et al., 2018; Silveira et al., 2016; Somer, Sinkey, & Bryant, 2017). Black women die from pregnancy-related causes at higher rates when compared to White women, which is reflected in Michigan's SMM rates (MMMS, 2018; Petersen et al., 2019). Those disproportionate rates are aggravated when chronic conditions are added to the analysis and affect racial and ethnic women disproportionately (Admon et al., 2018; Somer et al., 2017). Increasing rates of preexisting, chronic conditions within racial and ethnic women demonstrate inequitable care despite the advances in transportation, medical technologies, and health policy (Creanga et al., 2017; Louis, Menard & Gee, 2015; Somer et al., 2017). Women living in rural communities have experienced greater rates of SMM, including higher rates of eclampsia (Lisonkova et al., 2016). Moreover, it is important to note that the effects of morbidity not only manifest in physical chronic conditions but as a mental and behavioral health risk. Machiyama et al. (2017) found SMM was associated with depression, diabetes, and incontinence among other burdens of

ill health, such as mental, social, economic, marital, and sexual functioning. Maternal depression and anxiety contribute to the rising numbers of maternal morbidity yet has been underreported and often overlooked in current literature. These disproportionate health outcomes have been associated with higher medical costs, extended hospital stays, and excess trauma for women and families (Chen et al., 2018; Silveira et al., 2016). Examining the impact of geographic location, race and ethnicity, and health conditions associated with pregnancy complications have on delivery hospitalization in Michigan will impact the lives of its residents and reduce the healthcare burden on providers and patients.

Problem Statement

While maternal mortality is a sentinel event, SMM affects more than 50,000 women per year, which is 100 times more frequent than maternal mortality (CDC, 2017b). SMM is the unexpected outcome(s) of a delivery hospitalization that has short- and/or long-term complications (CDC, 2017b). The rates of SMM have been steadily increasing in the United States and Michigan for women of color, women living in resource-poor communities, and women living with preexisting health conditions (CDC, 2017b). The burden of maternal morbidity has been discussed as the bottom, larger, and more dangerous part of the public health issue with more complicated pathologies. In 2017, the Michigan SMM rate among all hospital deliveries was 1.7 per 10,000 delivery hospitalizations and affected racial and ethnic populations disproportionately: 1.4 for non-Hispanic White women, 1.42 for Native American women, 1.55 for Hispanic women, Asian women 1.67, and 2.77 for African American women (Michigan Alliance

for Innovation on Maternal Health, 2019). The consequences of increasing SMM rates on a women's health are wide-ranging and complex. Understanding the patterns by geographic locations, race and ethnicity, and health conditions associated with pregnancy complications are essential to reducing the burden of SMM.

Michigan is divided into 10 prosperity regions consisting of 83 counties and more than 1,100 zip codes (PRAMS, 2017). There are gaps in understanding the variability between zip codes and adverse maternal health outcomes, specifically racial and ethnic women living with health conditions that complicate pregnancy. It is important for the development of zip code level interventions to promote optimal health for women. Reliable and up to date zip code level data are essential to monitor widening inequities to inform innovative policies and programs that halt the disparities and manage the increase morbidity burden. In an effort to provide more statewide information, the purpose of this study was to describe SMM by geographic location, racial and ethnic women, and health condition.

Purpose of the Study

The purpose of this exploratory, retrospective cohort study was to describe SMM disparities during delivery hospitalizations in Michigan from 2016–2017. The highest burden of SMM clusters where health systems are weakest, the environment is resource-poor, and individuals are living in the most vulnerable communities; the burden disproportionately falls on the most vulnerable women (Graham et al., 2016). The high-risk conditions are generally undiagnosed or mismanaged chronic conditions that contribute to poor obstetric conditions (CDC, 2016). The variation in the prevalence of

chronic conditions, by race and ethnicity, has not been comprehensively examined in a statewide sample of delivering women. The health disparities among racial and ethnic groups experiencing poorer health outcomes prompted a deeper analysis into the specific locations these events are occurring to provide access to adequate health care, contraception counseling, prenatal and postpartum care, and improvement in tailored public health interventions.

In this study, I compared maternal morbidity among geographic location, race and ethnicity, and health conditions associated with pregnancy complications associated with SMM outcomes. Using ArcGIS software for geographic, spatial reference and analysis provided a better understanding where persistent maternal and pregnancy related health issues occur in Michigan. This approach was unique insofar as I described the characteristics of the population by (a) SMM, (b) geographic location, (c) race and ethnicity, and (d) health condition impacting pregnancy outcomes. Furthermore, the conditions associated with greater socioeconomic and health-access disparities were explicated.

Makanga, Schuurman, von Dadelszen, and Firoz (2016) urged researchers to develop a spatial analysis that would inform the geographical variation in risk factors on adverse maternal outcomes to better inform practitioners. There is limited Geographic Information Systems (GIS) evidence that exists, and more explicit use of this technology can account for geographical variation in Michigan. The analysis promoted a call to action for those striving to improve access to healthcare services prior to delivery for women living in Michigan's most vulnerable communities. This study provides an

opportunity for public health personnel to understand the health disparities in SMM rates, including preexisting conditions, preconception health, and access to women's health services. The findings of this study may shed light on the geographic variation and disparities for women and provide a unique opportunity for improvement in coordinated services to manage chronic conditions prior to pregnancy.

Currently, geographic disparities in SMM have not been adequately examined; for example, knowing where there are greater rates of obesity and a SMM event in a specific zip code will help prompt public health interventions to become more tailored, timely, and poignant. Addressing SMM after pregnancy is less timely and unlikely to have lasting effects; however, providing care for a preexisting medical condition prior to pregnancy and birth may become more sufficient in preventing an event, considering 50% of pregnancies in the United States are unplanned (Metcalf, Wick, & Ronksley, 2018). Depicting these rates will help notify public health professionals of the areas with the greatest need. The use of GIS to demonstrate geographic patterns through combining various individual level characteristics, indicators, and risk factors that may be associated with SMM can contribute to the identification of high priority areas that need robust maternal health services.

Research Questions and Hypotheses

The central research question guiding this study was: Are there differences in SMM rates among geographic location and racial/ethnic (i.e., non-Hispanic Black, Hispanic, Asian or Pacific Islander, and Native American or Alaska Native) women?

RQ1: Are there geographic variations of SMM across the state of Michigan?

$H_0$1: There are no statistically significant geographic variations in the incidence of severe maternal morbidity across the state of Michigan.

H_A1: There are statistically significant geographic variations in the incidence of severe maternal morbidity across the state of Michigan by race and ethnicity.

RQ2: Are there racial and ethnic variations of SMM across the state of Michigan?

$H_0$2: There are no statistically significant racial and ethnic variations in the incidence of SMM across the state of Michigan.

H_A2: There are statistically significant racial and ethnic in the incidence of SMM across the state of Michigan by race and ethnicity.

RQ3: Are there racial/ethnic variation between women who have a health chronic condition and SMM across the state of Michigan?

$H_0$3: There are no statistically significant variations in the prevalence of a health condition that complicates pregnancy outcomes (i.e., preexisting diabetes, preexisting hypertension, obesity, mental health diagnosis, alcohol use during pregnancy, drug use during pregnancy, tobacco use during pregnancy, gestational diabetes, and gestational hypertension) across the state of Michigan by race and ethnicity.

H_A3: There are statistical significance in the prevalence of a health condition that complicates pregnancy outcomes (i.e., preexisting diabetes, preexisting hypertension, obesity, mental health diagnosis, alcohol use during pregnancy, drug use during pregnancy, tobacco use during

pregnancy, gestational diabetes, and gestational hypertension) across the state of Michigan by race and ethnicity.

Theoretical Foundation

For the theoretical framework of this study, I used the social-ecological model, developed in the 1980s by Urie Bronfenbrenner and the critical race theory developed by a group of researchers including Kimberle Crenshaw, Neil Gotanda, Gary Peller, Kendall Thomas, and Derrick Bell's critical race theory and Arline Geronimus. The social-ecological model introduced human development in the context of an entire ecological system (Bronfenbrenner, 1994). The socio-ecological model suggests that birth outcomes are impacted by the environment into which a child is born and is subsequently influenced by the community and society (Bronfenbrenner, 1994). Maternal and infant health has been studied in the context of the socio-ecological model to provide potential solutions for healthcare disparities. Additionally, the critical race theory conveyed how racism contributed to cultural perceptions and societal norms, as well as how that was represented in the criminal justice system, housing and employment opportunities, and how policies were enacted (Bell, 1995; Gotanda & Peller, 1995)

Socioecological Model

The ecological model posits that a public health program, such as one designed to address SMM, is the result of influences across all levels of the problem (Glanz, Rimer, & Viswanath, 2015). The two specific concepts demonstrated in this model are that individual behaviors are affected by the social environment and that the behaviors are molded to multiple levels of influence, including the microsystem, mesosystem,

exosystem, and macrosystem (Bronfenbrenner, 1994). These terms are more simply understood when expressed at the individual, interpersonal, organizational, community, and societal levels; the different levels represent a unique influence on the individual. Each individual has a unique experience situated within the insidious influences from policies and laws in addition to the different contexts between and within the levels of influence. An examination of these dynamic levels can provide more information on the lived experiences of women. This model can provide consideration for the broader environmental context where, when, and how childbearing women experience SMM. To do so requires acknowledgement of an individual's family values, church, school, lived experiences and peer influences (i.e., microsystem); the community's ambulatory health caresettings, hospitals, and social service offices (i.e., mesosystem); the society's cultural values and norms (i.e., exosystemic); and historical events, such as slavery, segregation, and the attitudes and ideologies of the culture in power (i.e., macrosystemic). In summary, there are multiple, upstream contributing factors at the microsystem, mesosystem, exosystem, and macrosystem levels that must be considered in order to better understand an individual's health outcomes, and for the purposes of this study, specifically that of SMM.

Critical Race Theory

In this research, I took into account the work of Kimberle Crenshaw, Neil Gotanda, Gary Peller, Kendall Thomas, and Derrick Bell's critical race theory and Arline Geronimus's theory of *weathering* (see Bell, 1995; Geronimus, 2001; Gotanda & Peller, 1995). Geronimus (2001) coined the term weathering in *Ethnicity & Disease*, describing

how constant stressors from racism contribute to a premature biologic aging process and poor health outcomes. Weathering is an integral component of the higher SMM rates that disproportionately affect African American pregnancy-related complications, which is displayed in the higher mortality rates from chronic conditions that may contribute to maternal mortality and morbidity (CDC 2017b; Geronimus, 2001). The critical race theoretical framework examines race and racism to understand how victims of systematic racism are affected by cultural perceptions of race and how that effects their lived experiences and world views as well as how that is represented in the United States (Bell, 1995; Gotanda & Peller, 1995). Health outcomes for racial and ethnic women have shown similar poor outcomes across income and education levels, suggesting that racism may contribute to the underlying health disparities; racism has created barriers and also impacted women's access to quality healthcare (Admon et al., 2018; Alio et al., 2010; Howland et al., 2019; Tangel, White, Nachamie, & Pick, 2018).

Utilizing critical race theory in this study helped provide a context for understanding health disparities in maternal morbidity. Bringing awareness to a public health issue within a health equity framework can make an impact on the complex and upstream factors. In order to provide and promote a more equitable impact on women and reduce SMM rates among racial and ethnic women. Incorporating health equity into all research will emphasize the impact systems have on individuals and start to shift the narrative away from individual blame and towards larger systemic responsibility that will improve every pregnant women's healthcare quality.

Nature of the Study

My main priority in this study was to document a population-level analysis of SMM within delivery hospitalizations in Michigan utilizing data from the 2016–2017 Statewide Inpatient Databases (SID). Using an exploratory, retrospective cohort framework, I demonstrated geographic and racial/ethnic variance in SMM across the state of Michigan using demographic, procedural, and diagnosis information. In addition, an examination of health conditions associated with pregnancy complications was documented using GIS. The use of GIS software displayed where racial and ethnic women with SMM and health conditions associated with pregnancy complications reside to document where disparities persist. Overall, the findings of this study elucidate where women with health conditions have the highest rates of SMM to help inform public health decisions concerning targeted, condition-specific interventions and prevention programs.

Secondary Data Types and Sources of Information

The data for this study were retrieved from the Healthcare Cost and Utilization Project (HCUP) due to it being the largest, longitudinal hospital database in the United States, which is funded through the Agency for Healthcare Research and Quality (Healthcare Cost and Utilization Project, 2019). The SID database the largest source of administrative data with race and ethnicity for pregnant women who deliver in a community hospital setting. In the data set, I identified women whose delivery occurred in a Michigan hospital in 2016 and 2017 and excluded deliveries with missing data.

SMM was the primary outcome for this study, which was identified using the CDC's SMM indicators.

The key outcome (i.e., dependent) variable was the SMM indicated by International Statistical Classification of Disease and Related Health Problems (ICD-10-CM) codes. The 21 SMM indicators to identify SMM criteria were outlined by the CDC, 2017b) and are the most common diagnosis codes associated with SMM, including acute myocardial infarction, aneurysm, acute renal failure, adult respiratory distress syndrome, amniotic fluid embolism, cardiac arrest/ventricular fibrillation, disseminated intravascular coagulation, eclampsia, health failure, puerperal cerebrovascular disorders, pulmonary edema, severe anesthesia complications, sepsis, shock, sickle cell disease with crisis, air and thrombotic embolism, blood products transfusion, hysterectomy, and temporary tracheostomy. The independent variables included four health conditions associated with pregnancy complications. Admon et al. (2017) identified the common health conditions associated with obstetric morbidity and mortality among women of childbearing age across socioeconomic predictors of obstetric outcomes. Taking into account these conditions and current literature reviews, the four health conditions analyzed in this study were diabetes; hypertension; obesity; and mental health which included alcohol use during pregnancy, drug use during pregnancy, and tobacco use during pregnancy. Health conditions codes were located in the SID database within the diagnosis upon hospital admission column.

Literature Strategy

I systematically searched the literature in PubMed, SAGE Journals, Google Scholar, and ProQuest databases. Using vocabulary and terms combining maternal health, maternal morbidity, health conditions, chronic conditions, and spatial epidemiology are listed here. The keywords searched were *maternal morbidity, maternal death, maternal mortality, Michigan, spatial epidemiology, geographic information system (GIS), obstetric chronic conditions,* and *multiple chronic conditions*. Searches were conducted between January 1, 2019 and November 1, 2019, with a 10-year data restriction unless a seminal paper was identified.

Literature Review

Historically, maternal mortality has been a traditional sentinel event for monitoring maternal health; however, maternal morbidity occurs more frequently and requires a deeper understanding and a more specific analysis (American College of Obstetricians and Gynecologists, 2015; The Joint Commission, 2015). While maternal mortality is easier to identify (due to a sentinel event), maternal morbidity is more complicated because it is less clearly defined due to reporting, coding, and timing (Main et al., 2016). SMM is a patient safety concern defined as a life-threatening diagnosis or enduring a life-saving procedure during a delivery hospitalization (Admon et al., 2018; Callaghan, Creanga, & Kuklina, 2012). Callaghan et al. (2012) estimated that SMM during delivery and postpartum hospitalizations has increased by 75% and 114%, respectively, since the time period between 2008–2009. Moreover, maternal morbidity has been associated with high levels of preventability, which is fundamental for public

health practitioners (Kilpatrick et al., 2016). The high levels of preventability associated with maternal morbidity provide an opportunity to identify risk factors to improve the health of women and create social change and health policies.

The Joint Commission recognized a maternal morbidity when a woman receives 4 or more units of blood and/or an intensive care unit (ICU) admission; however, due to recent quality improvement efforts at the national level, this may continue to change in order to continue to have clarity and consistency in data reporting (Leonard, Main, Scott, Profit, & Carmichael, 2019; Machiyama et al., 2017). Characterizing SMM events by diagnostic, administrative, and outcome data determine if the morbidity was preventable or avoidable, which help systems change and prompt quality improvement within organizations and, in turn, can guide more strategic public health interventions (Kilpatrick et al., 2016). While there are nuances and complexities to maternal morbidity diagnosis and surveillance, it can provide insight into severe pregnancy and delivery complications because it pertains to upstream risk factors, access to quality care, and racial and ethnic disparities.

SMM has been categorized by some institutions as a near miss for maternal mortality because without proper identification and treatment, the complications could result in a maternal death (Main et al., 2016). Tracking SMM is essential for resource allocation, identification of priorities for researchers and clinicians, and helps create policies and procedures that improve the quality of a woman's life; therefore, focusing research efforts on SMM is an upstream entry point into, ultimately, decreasing the maternal mortality rates. The analysis and subsequent interventions for women who

experience SMM are important for preventing disease and injuries as well as improving healthcare delivery. The CDC (2017b) published 21 SMM indicators based on ICD-10-CM that rely on diagnosis codes from administrative data sources. The identification of SMM in a data set is a combination of diagnostic codes for an outcome of delivery, the diagnosis-related group delivery codes, and procedure codes for delivery-related procedures (Kuklina et al., 2008). The most common diagnoses associated with SMM are blood transfusion, hysterectomy, temporary tracheostomy with and without ventilation, postpartum hemorrhage (PPH), hypertension, stroke, renal failure, sepsis, pulmonary distress, cardiac disease, and an ICU stay (CDC, 2017b; Creanga, Bateman, et al., 2014; Kilpatrick et al., 2016). According to the CDC (2017b), nine SMM indicators have increased by more than 50% since 2014, including blood transfusion (399%), acute myocardial infarction or aneurysm (300%), acute renal failure (300%), adult reparatory distress syndrome (205%), cardiac arrest (175%), shock (173%), ventilation (93%), sepsis (75%), and hysterectomy (55%).

Severe Maternal Morbidity and Race/Ethnicity

SMM has been documented in the literature as an increasing trend that poses concern and draws attention to a widening disparity gap. The Institute of Medicine defined racial and ethnic disparities in obstetric care by the quality of care and health outcomes between groups who have similar health insurance and access (Smedley, Stith, & Nelson, 2003). In the United States, racial disparities in obstetric outcomes have been documented from preterm delivery to life-long debilitating repercussions from postpartum events, such as hemorrhage, stroke, and hypertensive disorders (Admon et al.,

2018). This information has been used to demonstrate disproportionate distribution across racial and ethnic groups, specifically Hispanic, Black, African-American, Native American or Alaska Native, and Asian Pacific Islanders (Admon et al., 2018; Creanga, Bateman, et al., 2014; Howell et al., 2017; Leonard, Main, Scott, et al., 2019; Metcalfe et al., 2018).

Researchers have highlighted the racial disparities in SMM and demonstrated that non-Hispanic Black women have a 3–4 times higher risk of mortality and a 9 times higher risk of morbidity than non-Hispanic White women (Admon et al., 2018; Creanga, Berg, et al., 2014). The U.S. SMM rates for non-Hispanic White women are 139.2 per 100,000, while the SMM rates for non-Hispanic Black women are 231.1 per 100,000 delivery hospitalization (Admon et al., 2018). Admon et al. (2018) estimated that if racial and ethnic women experienced SMM at the same rate as non-Hispanic White women, there would be 8,102 fewer SMM cases per year, resulting in a 28% reduction in SMM cases nationwide.

Grobman et al. (2015) evaluated the differences in severe PPH, peripartum infection, and severe perineal laceration and found that non-Hispanic White women were significantly less likely to experience PPH and perineal laceration than non-Hispanic Black, Hispanic, and Asian women. Bryant et al. (2012) found that Hispanic and Asian/Pacific Islander have greater risk factors for atonic PPH. Similarly, Leonard, Main, Scott, et al. (2019) linked birth certificates to delivery discharge records and found that SMM was highest in non-Hispanic, Black women and lowest in non-Hispanic White women. Compared with non-Hispanic, White women, non-Hispanic Black women have a

greater risk of infections, preterm labor, antepartum hemorrhage, and hypertensive complications (Cabacungan, Ngui, & McGinley, 2012). The prevalence of preexisting diabetes was highest among American Indian/Alaska Native women, and the highest rates of gestational diabetes was highest among non-Hispanic Asian women (Deputy, Kim, Corney, & Bullard, 2018). Moreover, Hispanics, Asian/Pacific Islanders, and Native Americans had a greater likelihood of infection, PPH, and gestational diabetes than non-Hispanic White women (Cabacungan et al., 2012).

The racial and ethnic disparities in the prevalence of SMM associated with preexisting health conditions have been documented in the literature. Women with preexisting health diseases or those who develop a pregnancy-associated disease have increased significantly within non-Hispanic Black and Hispanic populations (Admon et al., 2018; Metcalfe et al., 2018). Racial and ethnic disparities intertwined with a complex history of chronic health conditions and disease progression demonstrate the disparate outcomes in SMM rates. Maternal comorbidities, such as obesity, hypertension, and diabetes, are more frequently identified in racial and ethnic women (Leonard, Main, & Carmichael, 2019; Leonard, Main, Scott, et al., 2019; Robbins et al., 2018). The increase in risk factors prior to pregnancy may contribute to the higher rates of SMM, specifically in racial and ethnic populations that may have previously been marginalized and lacked trust in the healthcare system. This reflects multiple levels of health disparities rooted in a complex history of segregation and unfair clinical trials and treatments (Kennedy, Mathis, & Woods, 2007). One key example was identified by the Institute of Medicine who reported that racial and ethnic women are less likely to receive medically indicated

procedures yet receive more procedures overall that have been shown to be less effective (Smedley et al., 2003). The persistent health disparities may be due to a delay in treatment due to distrust in the healthcare system from a history of slavery, segregation, racism, and the lack of cultural competence and compassion by some providers (Corbie-Smith, Thomas, & George, 2002). In order to develop a meaningful analysis, health disparities were attended to in this SMM study.

Severe Maternal Morbidity and Health Conditions

Complications from preexisting health conditions account for one third of all maternal deaths (Admon et al., 2018). The emergence of pregnancy-related death due to cardiovascular disease, cardiomyopathy, and other chronic conditions has increased (Creanga, Bateman, et al., 2014). Similarly, maternal morbidity trends have increased across the United States, providing more information about women's health prior to and during pregnancy (CDC, 2019). A woman's health before pregnancy can impact the future health of mother and child. Admon et al. (2017) found that rates of women with a chronic condition delivering in a hospital have increased from 66.9 per 1,000 delivery (in 2005–2006) to 91.8 per 1,000 (in 2013–2014).

The CDC (2017a) reported that nearly half of women are overweight or obese before pregnancy, which has been associated with delivery complications and severe morbidity. The rate of obesity and diabetes have been greatest in Black women, and those rates have been on the rise for the past decade for Hispanic women (CDC, 2017a). Creanga, Bateman, et al.(2014) found that the presence of chronic heart disease, chronic renal disease, and chronic liver disease was associated with higher rates of severe

morbidity and that the presence of HIV/AIDS infection doubled the rates of severe morbidity. Deputy et al. (2018) found that diabetes prevalence increased an infant's risk of congenital anomalies and still birth. Diabetes can have serious and long-term effects on overall health, and elevated blood sugar has been associated with severe complications, including perinatal loss, preeclampsia, and macrosomia (American Diabetes Association, 2019). Metcalf et al. (2018) established that that maternal mortality review committees report that women who have died during pregnancy had one or more poorly managed health conditions. Overall, SMM among women with chronic health conditions, specifically multiple chronic health conditions, were significantly higher than women without chronic conditions (Admon et al., 2017; Admon et al., 2018). It is important to note that some of the previously mentioned health conditions, such as obesity and heart disease, are preventable (CDC, 2017b).

The SMM classifications have mainly focused on physical health outcomes; however, trauma from an obstetric emergency and poor mental health management can contribute to poor short- and long-term pregnancy outcomes. According to the Michigan PRAMS (2017), half of the women in Michigan reported feeling depressed before, during, or after their pregnancy. Among women, depression and anxiety are the leading pregnancy-related mental health conditions (Creanga, Berg, et al., 2014; Robbins et al., 2018). Women living with depression are more likely to have a chronic medical condition and have an increased risk of substance abuse, domestic violence, and poor long-term health, impacting the mother and infant's overall health (Chang, Tabet, Elder, Kiel, & Flick, 2016; Robbins et al., 2018). This is the most underreported aspect of SMM because

often times the morbidity occurs outside of the hospital walls (Main et al., 2016). Furuta, Sandall, and Bick (2012) found that women who experienced severe preeclampsia had a greater risk of posttraumatic stress disorder. Women living in areas with greater rates of violence are more likely to experience depression or anxiety, which disproportionally affects African American, Hispanic, and Native American women (Chang et al., 2016; Somer et al., 2017). Trauma and mental health are disease burdens that impact women and family's mental health before, during, and after pregnancy (Chang, Tabet, Elder, Kiel, & Flick, 2016; Creanga, Berg, et al., 2014; Robbins et al., 2018).

Severe Maternal Morbidity and Geographic Location

Individual's health experiences can operate differently in different places (Ballas, Clarke, Franklin, & Newing, 2017). Health geographers have documented that health inequalities are a combination of individual characteristics and contextual effects, such as where an individual grew up and lived (MacQuillan, Curtis, Baker, & Paul, 2019; Detres, Lucio, & Vitucci, 2014). GIS can help define a study population by spatial variation in disease risk. Using geospatial maps to analyze spatial health patterns and the social determinants of risk to identify health related clusters can help distribute health care resources. GIS allows public health practitioners the opportunity to ascertain where characteristic of contextual effects contribute to disease or poor health outcomes.

Geographic location is a contributing factor to how and where women receive services. Rural living leaves women with little to no choice where they receive services and large metropolitan areas can lack availability and accessibility. The ability to interpret geographic location, as it relates to healthcare availability and resources, is

limited. Using data visualization techniques provides neighborhoods, regional collaborative, policymakers, and clinicians with an evidence base for important public health programs and funding. Similar analysis have been conducted for income variations, deprivation, and social demographics to help assess coverage and the breadth of services in specific geographic locations, which can facilitate targeting public health services. GIS mapping is an imperative tool for researchers, public health practitioners, and policymakers that should be readily available to combat this public health crisis and improve health equity while eliminating health disparities.

Geographic location has been documented as a predictor of overall health including access to quality care. Different population densities have been associated with an array of complex geographic challenges (Ballas, Clarke, Franklin, & Newing, 2017). For example, fewer than 50% of rural women have access to perinatal care within 30 minutes to their home, which continues to worsen due to the closing of more than 100 rural hospitals since 2010 (Centers for Medicare and Medicaid Services [CMS], 2019). These closures disproportionately affected low-income communities and racial and ethnic women living in resource poor areas; maternal deaths are more common in rural communities worldwide (Makanga, Schuurman, von Dadelszen, & Firoz (2016). The lack of accessible prenatal care contributes to the burden of disease and the high rates of maternal morbidity and mortality.

Women living in rural areas have higher rates of eclampsia, obstetric embolism, and uterine rupture (Lisonkova et al., 2016). In response to the rural health burden, the Centers for Medicare & Medicaid (2019) published an Issue Brief prioritizing health

policy for rural maternal healthcare. Rurality may contribute to inadequate access to services, higher rates of poverty and social isolation, which may impact a woman's experience during the perinatal periods. Women living in rural areas are more likely to experience domestic violence and substance use disorders (Bhandari et al, 2015). Similarly, Admon et al. (2017) found an increasing prevalence of chronic conditions and substance use disorders for women living in rural communities compared to those within an urban residence. These rural challenges persist in Michigan, where more than half of the zip codes have an urban designation (Ratcliffe, Burd, Holder, & Fields, 2016). These issues present a unique opportunity to demonstrate the need for GIS maps indicating where disparities persist. Maternity care providers in rural areas must be aware of the increased burden of disease and how this distresses rural Michigan women.

GIS is most widely used as a visualization tool to explore inequalities of health care outcomes and is a powerful tool for identification of health care facilities and access to quality care. The understanding of geographical aspects of health and health care resources are imperative for health care provisions and location planning and decision support for allocation of services (Ballas et al., 2017). This detailed information equips professionals with the knowledge to integrate additional healthcare services to an area with health inequities. Utilizing GIS to evaluate health and health care from a geographical perspective will play a major role in evaluating Statewide healthcare policy.

Definitions

Disparities: reference a health outcome that disproportionately affects the racial and ethnic women (CDC, 2017).

Maternal Morbidity: is an overarching term that refers to any event that directly relates to pregnancy and childbirth or may be a result of sequalae from the unintended event (Mosley, Koblinsky, Reed, National Research Council, & Committee on Population, 2000).

Maternal Mortality: is the death of a woman while pregnant or within a year of the end of pregnancy from any cause (CDC, 2019).

Near miss: is an event that may have resulted in harm to a patient, but the event did not reach the patient partially due to timely interventions (American College of Obstetricians and Gynecologists, 2015).

Preexisting Health Conditions: are the nine-health condition associated with obstetric complications including: preexisting diabetes, preexisting hypertension, obesity, mental health diagnosis, alcohol us during pregnancy, drug use during pregnancy, tobacco use during pregnancy, gestational diabetes, and gestational hypertension.

Racial and ethnic women: include non-Hispanic Black, Hispanic, Asian or Pacific Islander, and Native American or Alaska Native (CDC, 2017).

Severe Maternal Morbidity: is the unexpected outcomes of labor and delivery that result in significant consequences to a woman's health defined by 21 indicators and is described in a rate per 10,000 delivery hospitalizations (CDC, 2017b).

Sociodemographic: refers to the economic, geographic and social measures of an individual's experience (CDC, 2017).

Social Determinants of Health Inequalities: is used to describe the environmental and societal conditions where individuals are born, live, age, work, grow and can drive health outcomes (Marmont, 2005).

Spatial Epidemiology: is the field of health geography that focuses on the spatial distribution of health outcomes (Ostfeld, Glass & Keesing, 2005).

Assumptions

This study should be interpreted with the assumptions and nature of the data set and study design. First, there is a possibility that each hospital discharge record might not be unique, and that one woman could have delivered twice during the study period due to the de-identified data (Admon et al., 2018). Second, health conditions may contribute to complications during birth and may result in severe maternal morbidity, however, this may not be the case due to misdiagnosis or a lack of adequate code and could be associated with low specificity. Third, the claims-based dataset may not always generate a specific payment for a chronic condition, which may be associated with low sensitivity.

Scope and Delimitations

Each year more than 200 million women become pregnant and many women experience the burden of severe maternal morbidity, which suggests this maternal health issue is not a marginal issue. This study takes cross-sectional data, aggregates women into a cohort and performs an analysis that may underestimate the true SMM rates and decrease the external validity. The burden of SMM may pose a greater threat than previously indicated due to undocumented diagnosis, long term sequala of infection, and may under-reported calculations (Graham et al., 2016; Machiyama et al., 2017). The

CDC published 21 SMM diagnosis codes, however this is not inclusive of all morbid events. Main et al. (2016) recommends the inclusion of the CDC's criteria, as well as including a prolonged postpartum length of stay, maternal ICU admission, and/or an administration of any blood product would be a more sufficient measure. Lazariu, Nguyen, McNutt, Jeffrey, & Kacica (2017) proposed expanding the CDC measure of severe maternal morbidity to include additional comorbidities and found 3% increase in the number of cases when compared with the CDC measure only. American College of Obstetricians and Gynecologist & Society for Maternal Fetal Medicine (2018) recommend including transfusion of four or more units of blood and an admission into an ICU where there has been a higher positive predictive value for identifying SMM. Expanding on the CDC's measures may provide a more sensitive estimate of the disease burden and provide clarity to the severity of this public health problem. Finally, the lack of a concise definition among systems and organizations implies that adopting an existing screening criterion or creating a document that represents SMM is what most institutions must do in order to identify gaps in care for quality improvement (American College of Obstetricians and Gynecologist & Society for Maternal Fetal Medicine, 2018). Ultimately, the primary and secondary aims of this exploratory study are the description of health disparities across the state of Michigan. This study may be generalizable to the public due to the large sample size and may help foster more tailored interventions based on preexisting health needs.

Significance

The increasing rates of SMM, which disproportionately affect racial and ethnic women, demand a call to action. The data visualization techniques proposed will determine locations where clusters of women experience SMM. Mapping SMM rates and health conditions by race and ethnicity will indicate where higher rates of adverse outcomes occur in Michigan, providing a more granular perspective of the specific needs in those communities. Delivery complications and morbidity identification may provide indicators of quality of care and racial and ethnic disparities that would benefit from an upstream public health intervention. This analysis will help determine areas that would benefit from more robust public health initiatives and interventions. The opportunity to employ SMM analysis to depict where enhanced public health outreach could have the highest impact on women's overall health and well-being is a significant driver for social change.

Severe Maternal Morbidity as a Public Health Concern

SMM is a public health problem affecting an estimate of more than 700 women per year and non-Hispanic Black women and American Indian/Alaska Native women experience the highest rates (42.8 and 32.5, respectively) (Peterson et a., 2019). Unexpected outcomes of labor and delivery affect women of color at 3.3 and 2.5 times higher for non-Hispanic Black, and American Indian/Alaska native, respectively, as the non-Hispanic White women rate (13.0) (Callaghan et al.,2012; Peterson et al., 2019). Racial and ethnic monitories suffer more complications, injuries and disabilities than their White counterpart, which are mostly preventable and often lead to poor maternal

and infant health outcomes. Overall, the burden of SMM disproportionately affects women of color, living with lower socioeconomic status, chronic conditions, and dwelling in rural areas (Admon et al., 2017; Leonard et al., 2019). This increasing trend coupled with unexpected outcomes during labor and delivery can have short- and long-term effects on a woman's health (CDC, 2017b).

SMM is a public health concern that has been demonstrated among racial and ethnic women, chronic disease, rurality, and low socioeconomic status disparities. The disparities in SMM rates demonstrates a call to action for a deeper analysis. Utilizing spatial epidemiology to map the widening disparities affecting the childbearing population will better equip public health professionals' interventions in appropriate zip codes. Public health agencies, clinicians, and nurses interact with women during the prenatal stage throughout the pregnancy and into the postpartum periods. Those interactions occur throughout a variety of clinical and public health services in ambulatory care settings, inpatient and outpatient settings, community programs, public health-funded programs, and home visiting programs. Services provided are usually within the zip code the woman resides, yet many clinicians and health care providers are unfamiliar or do not live within similar neighborhoods or zip codes. Thus, these health professionals may not be accustomed to the community characteristics, nuances, prominent social determinants of health that affect a woman and her perinatal health care needs (Suplee, Bloch, Hillier, & Herbert, 2018).

The rise in community-engagement action initiatives in the public health arena has provided an opportunity for clinicians, public health and nursing to learn more about

the social environments and communities where families reside. GIS has gained momentum for enhancing data visualization that can be used to better understand zip code variations and neighborhood characteristics as it relates to the residents' health. Mapping data can organize and easily depict community characteristics to inform clinicians of barriers and challenges the individuals they serve experience. In this study, public and clinical health care providers can focus on the high rates of health conditions and rates of SMM for ethnic women and how that relates to their service areas.

Severe Maternal Morbidity and Geographic Information Systems (GIS)

GIS is a spatial software tool that displays geographic data at a neighborhood, street, census or zip code level. GIS technology helps capture, analyze and visualize health related data. The commonly used GIS software called ArcGIS is used for creating maps openly on a web application to share geographic information. GIS has been used in public health fields to map disease, health care utilization, and aids in identification of community needs (Detres, Lucio, & Vitucci, 2014). Moreover, on January 12, 2015, the United States Agency for International Development met in Washington, DC to discuss global Maternal and Child Survival Programs. This meeting convened 25 global health organizations, government agencies, donors, and universities advocated for more equitable analysis for those living in rural and hard to reach populations. The recommendations placed a strong emphasis on the application of GIS for maternal and neonatal health data in an effort to reduce preventable maternal and newborn mortality (Molla et al., 2017). Molla et al. (2017) explained that the data visualization and geospatial analysis can address key challenges in poorly resourced areas. Not only can

geospatial analysis be helpful at a global level, but it can help communities identify health related areas including socio-demographic characteristics, health behaviors, health outcomes, and factors influence health (Detres, Lucio, & Vitucci, 2014). The use of maps can engage a wide array of stakeholders from community members to hospital systems and garner support in discussions about programs that affect an individual's health outcomes.

Stopka, Krawczyk, Gradziel, & Geraghty (2014) utilized geographic information systems and cluster analysis to identify locations where Special Supplemental Nutrition Program for Women, Infants, and Children (WIC) Program services were needed. The analysis demonstrated statistically significant clusters of WIC-eligible nonparticipants, which provided a unique approach to determine where public health outreach would help improve enrollment. MacQuillan, Curtis, Baker, & Paul (2019) identified subgroups of women with high rates of gestational diabetes mellitus using birth records and geospatial mapping. Salehi and Ahmadian (2017) mapped women's access to hospitals, which provided a robust identification of high priority areas that needed more access to advanced maternity care. Innovative analysis that yield maps help identify health related and physical barriers that contribute to maternal morbidities such as the built environment, racial segregation, and insufficient housing (Bloch & Cordivano, 2016; Mehra, Boyd, & Ickovics, 2017). The geospatial maps may prompt locations for deeper qualitative analysis such as focus groups and structured interviews to understand the nuances of health behaviors in a specific community. Mapping can be a valuable tool in the synthesis, exchange, and application of community knowledge to stakeholders and

nontraditional partners such as housing and youth programming (Detres, Lucio, & Vitucci, 2014). GIS mapping can accelerate innovation related to health programming for women to prevent complications and SMM. The literature indicates a growing need in making GIS data available to the community stakeholders to empower them to use data in a way that would stratify health problems within an ecological context.

The increasing SMM trends have affected the nation's women, families, and infants and prompts a call for a more innovative analysis with open access to medical journals for public health personnel. The increased incidence of SMM, coupled with clearly demonstrated racial and ethnic disparities, indicates an exploration of where women are more likely to have a negative health outcome. Due to the disparate reporting techniques and urban and rural geographical distribution in Michigan, less is known about precursors to maternal morbidity by regional health disparities. Spatial epidemiological methods could provide an innovative means by which to quantify severe maternal morbidity and pregnancy related health conditions by race and ethnicity. In lieu of the typical numeric tables and graphs, geo-spatial representations of data can provide a simplified means by which public health concerns and interventions can be understood and utilized by those in the broader community.

Conclusion

One of the most influential outcomes reflective of a country's overall health and well-being is its maternal and child health outcomes, specifically maternal and infant mortality. The United States is ranked in the bottom quartile for maternal morbidity and Michigan rates reflect those national trends. This ranking is due in large part to racial and

ethnic disparities and pre-existing health conditions. While mortality is the most tragic event, morbidity plays a close second. High rates of maternal morbidity reflect the gaps in the healthcare system that can be addressed to reduce the chance of mortality taking place. The causes of maternal morbidity are diverse, including multiple chronic conditions, demographic, epidemiological, socioeconomic, and system-level factors. Despite technological advancements these rates persist and have recently increased over the past decade.

Healthy People 2020 declared the elimination of health disparities, an improvement in health equity and overall health for all groups (HealthyPeople.gov, 2017). Researchers have established that racial and ethnic health disparities persist and are associated with living environments, poverty, unemployment, crime, and racial segregation (Somer et al., 2017). Yet, the identification of specific, demographic, socioeconomic, environmental and behavioral factors to explain racial and ethnic disparities as it relates to health outcomes has not demonstrated the type of success that Healthy People posed 10 years prior. Understanding the scope of social determinants of health that occur within zip code can better guide the development of feasible and relevant interventions to reduce rates of health conditions and racial and ethnic health disparities. The use of spatial epidemiology and geospatial mapping can demonstrate the areas in Michigan with a higher level of deprivation, which can prompt tailored and specific geographical interventions, which is outlined in the next section.

Section 2: Research Design and Data Collection

Introduction

The purpose of this exploratory study was to describe SMM disparities during delivery hospitalizations in Michigan from 2016–2017. I used an exploratory cohort design to demonstrate geographic and racial/ethnic variance in SMM across the state of Michigan using demographic, procedural, and diagnosis information. In addition, I documented an examination of health conditions associated with pregnancy complications using GIS. GIS software was used to display where racial and ethnic women with SMM and health conditions reside to document where disparities persist. Overall, the findings of this study elucidate where women with health conditions have the highest rates of SMM to help inform public health decisions concerning targeted, condition-specific interventions and prevention programs.

Research Design and Rationale

In this exploratory study, I pooled, cross-sectional, 2016–2017 data from the SID to create a retrospective cohort of delivery hospitalizations in Michigan. The cohort consisted of women who were admitted into a Michigan hospital between the years 2016–2017. Obstetric deliveries were stratified out of the larger data set and utilized as the denominator for the analysis. The primary outcome was the number of women who experienced a SMM event out of all of the delivery hospitalizations in Michigan between 2016–2017. The covariates controlled in the analysis included age, race/ethnicity, insurance, and geographic dwelling (i.e., location).

The dependent variable was SMM as it was defined by the CDC. The independent variables were the health conditions associated with pregnancy complications; diabetes; hypertension; obesity; and mental health, including alcohol use during pregnancy, drug use during pregnancy, and tobacco use during pregnancy. I identified these variables through all ICD-10-CM diagnostic codes in the discharge record (i.e, 1–30) that indicated conditions complicating the pregnancy, childbirth, and puerperium outlined in the O-chapter codes. The O-chapter includes all codes related to the perinatal period. I chose to focus on these conditions rather than pregnancy-related conditions to better inform prevention and upstream interventions for the greatest impact on women and families in Michigan. Admon et al. (2018) posited that there is a lack of information on the prevalence of health conditions by socioeconomic predictors, geographic location, income, and insurance status. The understanding of the prevalence of health conditions and its association with SMM is essential for healthcare providers, policy makers, and public health professions to identify populations that would benefit from evidence-based interventions to reduce the rates of maternal morbidity and the inequitable health outcomes for racial and ethnic women.

Currently, most analyses conclude with tables and graphics that show which variables are statically significant. In this study, I took the analysis a step forward and mapped the significant existing health conditions by race and ethnicity to depict the communities with the greatest need to inform where targeted interventions and more resources are needed. For the purposes of this study, the data were used to depict health outcomes for racial and ethnic women by geographic location. Current research has

underutilized geospatial epidemiology to display areas of highest need. The practical application of GIS provides the capacity to identify where there are high priority communities, significant health disparities, and poorer health outcomes (Salehi & Ahmadian, 2017). These geographic characteristics helped provide context for the social determinants of health, including rural or urban dwellings, to provide a fundamental understanding of the communities with the greatest disparities. Finally, through this analysis, I provided critical emphasis on racial disparities, which may impact resource allocation for equitable perinatal healthcare.

Methodology

Population

I performed the retrospective, pooled, cross-sectional analysis on a sample of all delivery hospitalization discharges in Michigan between 2016-2017 using the HCUP in the SID. The total number of hospitalizations accounted for in the SID in Michigan for 2016–2017 was over 2.4 million; HCUP (2019) houses the largest nationally representative sample of hospital discharges in the United States. The SID contains discharges from 97% of all U.S. community hospital discharges that includes discharges from specialist facilities (HCUP, 2019). This database contains a set of clinical and nonclinical information and includes uninsured individuals. Data for each hospitalization includes diagnostic and procedure codes, patient demographic characteristics, insurance status, and information pertaining to the individual's zip code.

The study population included delivery hospitalizations from 2016–2017 in Michigan. I identified deliveries by ICD-10-CM codes by converting Kuklina et al.'s

(2008) enhanced method for identifying obstetric deliveries to the updated ICD-10 codes. The updated list of obstetric deliveries included Z37 Outcome of delivery diagnosis related group(DRG 767,768,774,775, 795, 797,798, 805, 806, 807, 951), O80 (DRG 998) encounter for full-term uncomplicated delivery, O82 (DRG 998) encounter for cesarean delivery without indication, and excluded O00–O08 ICD-10 codes for pregnancy with abortive outcomes.

Sampling Procedure

Gaining access to the SID required a Data Use Agreement Training Course and signed HCUP Data Use Agreement before the data were sent. After the completion of the training course, the SID required me to provide a Statement of Intended Use, which was sent to the HCUP Central Distributor and reviewed for approval by the AHRQ team. Upon receiving approval, the SID sent me the requested data, via U.S. Postal Services, on a CD-ROM, which was transferred into the Statistical Package for the Social Sciences (SPSS), Version 25 software. SPSS was used to calculate the sample size in order to test the research questions and hypotheses of the study. All delivery hospitalizations that fit the inclusion criteria were utilized.

The identification of SMM as the primary outcome helped test the first hypothesis. SMM events were identified during delivery hospitalizations using an algorithm developed by the CDC that uses hospital discharge data, diagnosis, and procedure codes (i.e., ICD-10 Codes). The original list of SMM indicators was developed utilizing ICD-9 codes; however, the United States transitioned to the 10th Revision of ICD codes in October 2015 (CDC, 2017b). The CDC, along with their clinical and public

health partners, took into account prior validated studies to review this new set of indicators; Main et al. (2016) found that the previous SMM algorithm had 77% sensitivity, which was then adapted for ICD-10 coding and this set of indicators.

To identify delivery hospitalizations with SMM in 2016–2017, I used the ICD-10 codes. These codes include 21 indicators of SMM that represent serious complications during the hospital stay, such as eclampsia and health failure, as well as lifesaving procedures to manage serious health conditions, such as blood transfusions (CDC, 2017b). The ICD-10 codes associated with SMM were indicated in the discharge field in the data set. A delivery hospitalization was included in the study population if any of the 21 indicators were present on the discharge summary; the complete list of codes is available in Appendix A. I identified women with a health condition by searching all ICD-10-CM diagnostic codes associated with pregnancy complications. The list of preexisting chronic conditions along with the ICD-10 code is publicily available information available on the ICD webpage.

Table 1

Health Conditions ICD 10-CM Codes

Pregnancy Related Health Condition	Type	ICD-10-CM Code
Diabetes	Preexisting diabetes	Codes within O24.3
	Gestational diabetes	Codes within O24.410
Hypertension	Preexisting hypertension	Codes within O10 and O11
	Gestational hypertension	Codes within O10 and O11
Obesity	Obesity	Codes within O99.210
Mental health diagnoses	Mental health diagnoses	Codes within O99.340
	Alcohol use during pregnancy	Codes within O99.310
	Drug use during pregnancy	Codes within O99.320
	Tobacco use during pregnancy	Codes within O99.330

Imputing the data from the aforementioned analysis into ArcGIS, I analyzed racial and ethnic women who experienced preexisting health conditions and a SMM event. The unit of analysis was the patient's zip code. Location of residence was defined by the National Center for Health Statistics' (2017) Classification and Urban Influence Codes into four categories: large metro, medium metro, small metro, and micropolitan/urban. The graphical display for the third aim of my study helped fulfill the practical application of this research and inform policies for social change.

I used these variables to answer the research questions, along with avoiding Type II errors (probability = β) related to the power of the test. Using G*Power 3 (Version 3.1.9.4), a power analysis was conducted to determine the sample size and strength of the

power of the significance among the variables. Due to the large sample size (i.e., over 2.4 million records between 2016–2017), the input parameters for the a priori power analysis were set to an effect size of .80, alpha level of .05, power of .95, odds ratio of 1.2, and a two-tailed test (see Faul, Erdfelder, Buchner, & Lang, 2013; Field, 2013). G*Power generates a sample size for the logistic regression analysis that was utilized to address the research questions. Based on the assumptions listed previously, the desired sample size was 2,451 cases (see Faul et al., 2013).

Instrumentation and Operationalization of Constructs

I conducted the descriptive statistics, chi-square, and univariate logistic regression analysis SPSS, Version 25 (see IBM Corp, 2017). The zip code data were analyzed utilizing GIS to display data geographically. The robust software utilized to depict epidemiological trends was created by the Environmental Systems Research Institute (2019), and I used the ArcGIS Desktop: Release 10.7.1 Version. This tool was used to visualize and analyze spatial relationships by importing and aggregating data. In this exploratory study, I demonstrated salient variation between geography and depicted where health disparities occur as well as clusters of highly vulnerable communities persist. The initial descriptive and inferential statistics helped address the three research questions. The GIS analysis generated maps that show SMM by racial and ethnic women who experienced obesity, diabetes, mental health diagnosis, or hypertension.

Data Analysis Plan

I used the cross-sectional SID to extract all delivery hospitalizations during the study timeframe. The data were pooled into a 2-year time period to increase the sample

size and precision of the analysis. The sampling strategy included the identification of all hospital deliveries occurring between 2016–2017 using an adaptation of Kuklina et al.'s (2008) standard methods. The first step was to identify the cohort of women who had a SMM outcome, and the second step was to identify women who experienced SMM and had one or more health chronic conditions associated with pregnancy complications (see Table 1). The data sets included deliveries occurring among non-Hispanic White, Hispanic, non-Hispanic Black, Asian or Pacific Island; and Native American women. Other variables of interest were age, location, race/ethnicity, and insurance.

The categorization of variables was performed utilizing previous literature reviews. Payment sources were grouped into Medicaid and other. Age was categorized into three distinct subgroups reflecting the study populations (i.e., younger than 19, 19-34, 35 and older). Race was categorized into three groups Black (non-Hispanic Black), White (non-Hispanic White), and other (Hispanic, Asian or Pacific Islander, and Native American or Alaska Native). Geographic location was divided into four meaningful groups that reflect Michigan's population, which include large metropolitan, small metropolitan, micropolitan, and not metropolitan or micropolitan (National Center for Health Statistics, 2017). Any duplicate cases were excluded from the data, only complete cases were analyzed.

The central research question guiding this study was: Are there differences in SMM rates among geographic location and racial/ethnic (i.e., non-Hispanic Black, Hispanic, Asian or Pacific Islander, and Native American or Alaska Native) women?

RQ1: Are there geographic variations of SMM across the state of Michigan?

$H_0$1: There are no statistically significant geographic variations in the incidence of severe maternal morbidity across the state of Michigan.

H_A1: There are statistically significant geographic variations in the incidence of severe maternal morbidity across the state of Michigan by race and ethnicity.

RQ2: Are there racial and ethnic variations of SMM across the state of Michigan?

$H_0$2: There are no statistically significant racial and ethnic variations in the incidence of SMM across the state of Michigan.

H_A2: There are statistically significant racial and ethnic in the incidence of SMM across the state of Michigan by race and ethnicity.

RQ3: Are there racial/ethnic variation between women who have a health chronic condition and SMM across the state of Michigan?

$H_0$3: There are no statistically significant variations in the prevalence of a health condition that complicates pregnancy outcomes (i.e., preexisting diabetes, preexisting hypertension, obesity, mental health diagnosis, alcohol use during pregnancy, drug use during pregnancy, tobacco use during pregnancy, gestational diabetes, and gestational hypertension) across the state of Michigan by race and ethnicity.

H_A3: There are statistical significance in the prevalence of a health condition that complicates pregnancy outcomes (i.e., preexisting diabetes, preexisting hypertension, obesity, mental health diagnosis, alcohol use during pregnancy, drug use during pregnancy, tobacco use during

pregnancy, gestational diabetes, and gestational hypertension) across the state of Michigan by race and ethnicity.

Characteristics of the Study Population

The total population of 2016-2017 hospital deliveries from the SID was used to demonstrate descriptive statistics for deliveries by maternal characteristics age, race, insurance type, and geographic location, as well as health conditions associated with a pregnancy complication. The demographics tables show the percent of delivery hospitalizations for each sociodemographic characteristic of the mother (age, race, insurance, geographic location), and well as the percent of women in each category demonstrates the relative number of delivery hospitalizations for each demographic variable. The characteristics of the population are also detailed by the percent of delivery hospitalization with a health condition known to complicate pregnancy (diabetes, hypertension, obesity, and mental health conditions) from 2016-2017. These descriptive analyses help frame subsequent work for the severe maternal morbidity analysis.

Chi-Square Analysis

In total, 21 indicators were used to demonstrate the incidence of Severe Maternal Morbidity in the total population of 2016-2017 hospital deliveries. The data were entered into IBM SPSS Statistics Version 25 and analyzed using chi-square tests (IBM Corp, 2017). Utilizing SPSS and testing each covariate separately, a simple chi-square contingency table indicated that all sociodemographic variables were significant at the $p = 0.05$ level. The sociodemographic variables and the percent of deliveries with SMM, as

well as the percent of deliveries with a SMM event were used to find statistical significance.

The second analysis tested whether diabetes, mental health, hypertension or obesity was significantly significant with a SMM diagnosis, independently. Each health conditions was analyzed independently with 95% CI. This represents the percent of deliveries with SMM, according to health conditions of the mother. I tested for significance at the .05 level to indicate which health conditions indicators were statistically significant.

Logistic Regression

I analyzed the health conditions and the sociodemographic indicators for an adjusted odds ratio (OR) associated with severe maternal morbidity, 2016-2017. To compare women with health conditions, I performed two logistic regression models. The partial logistic regression model included only sociodemographic variables and the second full logistic regression model included sociodemographic variables and health conditions. Both models were tested for an OR with a 95% confidence interval and lower and upper bounds. The procedure was based on Wald statistics produced significant variables.

Geospatial Analysis

The final analysis was entered into ArcGIS to demonstrate where racial and ethnic women who experienced a health condition and an SMM event were located. The unit of analysis was zip code; each zip code was coded large metro, medium-small metro, micropolitan/urban. The figures depict women who had any SMM event and a health

condition that complicated pregnancy to portray the most vulnerable population. The prevalence of these health conditions associated with obstetric morbidity are diabetes, hypertension, obesity, and mental health diagnosis. This highlights where women living with the highest risks and who could benefit from community public health efforts to ameliorate the deleterious effects of these compound problems.

Threats of Validity

Statewide administrative data is validated before final submission into the HCUP however, these diagnosis and procedure codes do not provide information on prenatal care, the severity of a condition or follow-up outside of the hospital setting. The cross-sectional nature of the data limits our knowledge of whether the conditions have changed over time or led to mortality. Moreover, this analysis only accounted for the CDC's definition of severe maternal morbidity, which includes 21 indicators that correspond with ICD-10 codes identified only during the hospitalization of record. The indicators do not specify length of stay or units of blood transfused during the delivery hospitalization, which might impact the level of morbidity.

Ethical Procedures

Regarding ethical considerations, the patient's information was deidentified and remained confidential. Ethical approval was received from Walden University with the International Review Board (IRB) Approval Number 01-03-20-0667638.

Summary

The analysis of SMM for maternal demographics and maternal health conditions demonstrates the distribution for all delivery hospitalizations from 2016-2017 in

Michigan. The significant predictors of SMM for the maternal characteristics were age, race, location, and Medicaid insurance. For this analysis, the health conditions associated with SMM were hypertension, obesity, diabetes, and a mental health diagnosis. The logistic regression model will demonstrate differences between races, location, insurance, and health conditions. The GIS analysis depicts SMM rates with either obesity, hypertension, mental health diagnosis, or diabetes. This analysis will show the geographic variation of maternal health outcomes across the state of Michigan. Finally, this contribution will further the knowledge on health inequities to inform public health professionals residing in those communities to improve preventative programs, health access, and eliminate health disparities within the results section.

Section 3: Presentation of the Results and Findings

Introduction

Increasing rates of maternal mortality and morbidity are well documented in the United States, but there is limited state-specific documentation of disparities. Disparities in complications from pregnancy-related health conditions are the leading causes of maternal mortality and morbidity in the United States and similar issues occur in Michigan (Michigan Maternal Mortality Surveillance Program, 2018). State-level analysis can identify risk for delivery-related morbidity among women with health conditions, including those with diabetes, hypertension, mental health diagnosis, and obesity. The prevalence of those four conditions has increased over time; yet, less is known about the prevalence of the aforementioned conditions and SMM. It is unclear whether the prevalence of these conditions are associated with an SMM event and if the rates have stabilized, decreased, or worsened in recent years. Moreover, it is unclear how the prevalence of these conditions varies by patient's location. This information is necessary for healthcare providers and policy makers to identify populations that would benefit from evidence-based interventions to reduce maternal morbidity in Michigan.

To address these gaps in knowledge, the objective of this study was to estimate 2016–2017 trends in the prevalence of conditions that may exacerbate SMM among delivery hospitalizations in Michigan. This included evaluating SMM and women who have experienced a health condition that may exacerbate her condition during pregnancy. The health conditions associated with pregnancy include hypertension, diabetes, obesity, and mental health diagnosis, which are generally undiagnosed (i.e., mental health) or

mismanaged conditions that contribute to poor obstetric conditions. The purpose of this analysis was to convey the prevalence of health conditions by geographic location that have not been comprehensively examined in a statewide sample of delivering women. Additionally, depicting those disparities by race and ethnicity may help clinicians provide adequate and culturally competent care to women with 1 of the 4 conditions. The rates of maternal morbidity and the association with health inequities by race and ethnicity for women experiencing SMM provided rationale for geospatial analysis to more accurately pinpoint where disparities exist. The final geospatial mapping depicted the geographic areas of women experiencing a SMM event and 1 of the 4 health conditions in order to provide healthcare professionals the information they need to improve maternal health outcomes.

In this study, I provided analysis of SMM among geographic location, race and ethnicity, and the four health conditions, using ArcGIS software spatial reference and analysis to present geographical awareness to this persistent problem. In this study, I describe (a) SMM in Michigan from 2016–2017, (b) depict the geographic locations where women experience SMM who present with a health condition affecting pregnancy, and (c) examine the differences between race and ethnicity and SMM.

The overarching research question was: Are there differences in SMM rates among geographic location and racial/ethnic (i.e., non-Hispanic black, Hispanic, Asian or Pacific Islander, and Native American or Alaska Native) women. The specific research questions addressed in this study were:

RQ1: Are there geographic variations of SMM across the state of Michigan?

RQ2: Are there racial and ethnic variations of SMM across the state of Michigan?

RQ3: Are there racial/ethnic variations between women who have 1 of the 4 health conditions and SMM across the state of Michigan?

The results section includes the findings and how the secondary data were collected. In this section, I report on baseline descriptive, demographic characteristics, population, and univariate analysis. The results also include statistical assumptions, statistical analysis, findings, and summary. The data are displayed using tables, graphs, and maps because they are appropriate for the study design.

Data Collection of Secondary Data Set

Using the SID to conduct this analysis, I extracted all delivery hospitalization discharges in Michigan from 2016–2017, which included 94% of all Michigan hospitals, and totaling 2,474,118 hospital discharges. The SID is the largest nationally represented state sample of hospital discharges in the United States. Each hospitalization encompasses clinical and nonclinical data, including diagnosis and procedure codes, payment source, patient and hospital location, and patient demographic variables that include race and ethnicity (HCUP, 2019). I identified 202,514 delivery hospitalizations in Michigan from 2016–2017. Deliveries were identified using the ICD-10-CM codes provided by the Michigan Department of Health and Human Services. The data were cleaned to include delivery hospitalizations with a race/ethnicity indicator; abortion, abortive outcomes, and any duplicate medical record numbers were excluded from the dataset.

In order to construct the SMM data set, I utilized the CDC's SMM ICD-10 codes, diagnosis codes (i.e., 1–30), and procedure codes (i.e., 1–15). I identified 2,460 SMM events between 2016–2017 in the data. Next, the prevalence of diabetes (i.e., preexisting and gestational); hypertension (i.e., preexisting and gestational); obesity (i.e., a body mass index ≥30); and mental health conditions that were associated with pregnancy, including tobacco, drug, and alcohol use. Each delivery hospitalization was flagged for one or more of the health condition diagnosis codes. If the delivery hospitalization did not indicate a SMM with diabetes, hypertension, obesity, or mental health diagnosis, the case was included into the data set. I focused the analysis on pregnancy-related conditions rather than preexisting conditions, which were defined using the ICD-10-CM codes listed in Appendix B.

I controlled for four covariates: age, patient location, Medicaid insurance, and race/ethnicity. Patient location was defined using the Urban Influence Codes, which include large metropolitan areas with at least 1 million residents, small metropolitan areas with less than 1 million residents, micropolitan areas that are distinguished by nonmetro size and adjacency to other metro areas, and neither metropolitan nor micropolitan. Payment was grouped into Medicaid and other, which included self-pay, Medicare, and private; this was pertinent because about half of births are covered by Medicaid in Michigan (MDHHS, 2018). Race was categorized into three categories: non-Hispanic White, non-Hispanic Black, and Other, which included Hispanic, Asian or Pacific Islander, Native American or Other. Cases without race were excluded.

I used logistic regression models and cross tabulations to obtain estimates of pregnancy-related health conditions to estimate the rates at which any one delivery hospitalization had any of the health conditions. Data were pooled into a 2-year period to increase precision in the analysis. Prevalent conditions were compared with age, race, patient location, and payer with an adjusted odds ratio associated with SMM. Two models were used for all subgroups to generate the differences between women experiencing SMM and women experiencing SMM and a health condition. Two-tailed *p* values ($p < .001$) were considered statically significant using SPSS. The SMM data were uploaded into the ArcGIS system to map the percentage of the four health conditions and SMM by zip code as well as race and ethnicity and SMM.

Results

The total number of women delivering in a hospital setting from 2016–2017 was 202,514 unique cases. The cohort consisted of delivery hospitalizations among non-Hispanic White (*n* = 138,937); non-Hispanic Black (*n* = 39,485); and Hispanic, Asian or Pacific Islander, Native American or Other (*n* = 24,092). Medicaid paid for approximately 41.5% of all deliveries; among non-Hispanic Black deliveries, Medicaid covered 67.6% (CI 67.1–68.0); among non-Hispanic White 32.8% (CI 32.6–33.1) of deliveries; and Hispanic, Asian or Pacific Islander, Native American, or Other 48.9% (CI (48.3–49.6) of deliveries. Women were predominately 19–34 years old between all races, with the non-Hispanic Black age at 26.49 (CI 26.43–26.55); non-Hispanic White age at 28.86 (CI 28.83–28.89); and Hispanic, Asian or Pacific Islander, Native American, or Other age at 28.85 (CI 28.78–28.92). Non-Hispanic Black women had the highest rate of

teen pregnancy (5.0%), and Hispanic, Asian or Pacific Islander, Native American, or Other had the highest rate of deliveries over the age of 35 years old (17.6%).

Table 2

Sociodemographic Characteristics of Delivery Women by Race and Ethnicity, Michigan, 2016-2017

Characteristics	Non-Hispanic White *N* % (95% CI)	Non-Hispanic Black *N* % (95% CI)	Hispanic, Asian or Pacific Islander, Native American or Other *N* % (95% CI)
Age	138,937 28.86 (28.83-28.89)	39,485 26.49 (26.43-26.55)	24,092 28.85 (28.78-28.92)
Insurance			
Medicaid	45,627 32.8 (32.6-33.1)	26,671 67.6 (67.1-68.0)	11,790 48.9 (48.3-49.6)
Other	93,300 67.2 (66.9-67.4)	12,810 32.4 (31.2-32.9)	12,301 51.1 (50.4-51.7)
Geographic location			
Large metro	53,156 38.3 (38.0-38.5)	26,822 68.0 (67.5-68.5)	12,229 50.8 (50.2-51.4)
Small metro	58,026 41.8 (41.5-42.1)	12,271 31.1 (30.7-31.6)	9,909 41.2 (40.6-41.8)
Micropolitan	58,026 12.8 (12.6-12.95)	270 0.68 (0.61-0.77)	1,465 6.09 (5.8-6.4)
Neither	9,939 7.16 (7.0-7.3)	83 0.21 (0.17-0.26)	467 1.94 (1.8-2.1)

Note. N = 202,514.Table 3 includes all delivery hospitalizations

The largest number of patient's reside in a large metro geographic location (45.5%). The racial and ethnic distribution for large metro area was non-Hispanic White (57.6%); non-Hispanic Black (29.1%); and Hispanic, Asian or Pacific Islander, Native American, or Other (13.3%). However, Table 2 indicates the proportion of non-Hispanic Black women living in large metro areas, such as inner cities, was highest 68% (CI 67.5–

68.5), whereas the highest proportion of non-Hispanic White women live in small metropolitan areas (41.8%; CI 41.5–42.1), such as suburbs.

Among all delivery hospitalizations, mental health diagnosis was the most frequent diagnosis (17.7%), followed by obesity (15.8%), diabetes (8.1%), and hypertension (3.3%). Compared with deliveries among non-Hispanic White women, deliveries among non-Hispanic Black and Hispanic, Asian or Pacific Islander, Native American, or Other had higher prevalence of nearly every health condition examined, including diabetes, obesity, and hypertension with the exception of a mental health diagnosis. Proportionally, racial and ethnic women experienced these health conditions more frequently than their non-Hispanic, White counterparts when comparing within race (see Table 3).

The highest proportion of women living with diabetes was Hispanic, Asian or Pacific Islander, Native American, or Other at 12.6% (CI 12.2–13.0). The highest proportion of women living with obesity was non-Hispanic Black women at 17.9% (CI 17.5–18.3) compared with non-Hispanic White women at 15.3% (CI 15.1–15.4) and Hispanic, Asian or Pacific Islander, Native American, or Other women at 15.8% (CI 15.4–16.3). Mental health diagnosis was most common in non-Hispanic White women with 19.7% (CI 19.5-19.9). The highest percentage of diabetes was found in the Hispanic, Asian or Pacific Islander, Native American, or Other population with 12.6% (CI 12.2–13.0).

Table 3

Pregnancy Conditions that Complicate Pregnancy and Race/Ethnicity, Michigan, 2016-2017

Health Conditions that Complicate Pregnancy	Non-Hispanic White *N* % (95% CI)	Non-Hispanic Black *N* % (95% CI)	Hispanic, Asian or Pacific Islander, Native American or Other *N* % (95% CI)
Diabetes			
No	128,192 92.3 (92.1-92.4)	36,785 93.5 (92.9-93.4)	21,060 87.4 (87.0-87.8)
Yes	10,745 7.7 (7.6-7.9)	2,700 6.8 (6.6-7.1)	3,032 12.6 (12.2-13.0)
Hypertension			
No	135,252 97.3 (97.3-97.4)	37,036 93.8(93.6-94.0)	23,578 97.9 (97.7-98.0)
Yes	3,685 2.65 (2.6-2.7)	2,449 6.2 (6.0-6.4)	514 2.1 (2.0-2.3)
Mental heealth			
No	111,561 80.3 (80.1-80.5)	33,150 84.0 (83.6-84.3)	21,869 90.7 (90.4-91.1)
Yes	27,376 19.7 (19.5-19.9)	6,335 16.0 (15.7-16.4)	2,223 9.2 (8.9-9.6)
Obesity			
No	117,740 84.7 (84.6-84.9)	32,416 82.1 (81.7-82.5)	20,275 84.2 (83.7-84.6)
Yes	21,197 15.3 (15.1-15.4)	7,069 17.9 (17.5-18.3)	3,817 15.8 (15.4-16.3)

Note. N = 202,514. All univariate analysis between race and the four health conditions were significant ($p < .05$)

Severe Maternal Morbidity

In total I identified 2,460 delivery hospitalizations with a SMM indicator, representing 1.2% of all delivery hospitalizations in Michigan, which is a rate of 121.5 per 10,000 deliveries. The highest number of women with SMM were non-Hispanic White (n = 1,334), followed by non-Hispanic Black (n = 800) and Hispanic, Asian or

Pacific Islander, Native American or Other (n = 326), which trended with the overall proportion of each race/ethnicity. However, the rates varied across race and ethnicity; the SMM rate for non-Hispanic White was (1%) 100 per 10,000 deliveries, non-Hispanic Black was (2%) 200 per 10,000 deliveries and Other was (1.4%) 140 per 10,000 deliveries, all were significant $p < .05$. The sociodemographic model in Table 5 depicts the SMM and age, location, and race. The patient's location was the greatest predictor of SMM ($p < .001$), followed by race and ethnicity ($p < .001$).

Medicaid insurance covered about half of the deliveries for women who experienced an SMM event (49.9%). Although insurance type was statically significant, women who had Medicaid insurance (OR 1.20, 95% CI:1.1–1.3) had similar odds of having an SMM event with women who had Medicaid without a health condition (OR 1.23, 95% 1.1-1.3). Non-Hispanic Black women who experienced a SMM had a higher rate of Medicaid insurance coverage (67.6%), compared to non-Hispanic White women (32.8%) and Hispanic, Asian or Pacific Islander, Native American, or Other (49%).

Severe Maternal Morbidity, Health Conditions and Race/Ethnicity

For the women who had a SMM event, the percentages of the four health conditions associated with pregnancy complications were diabetes (10%), obesity (20%), mental health diagnosis (19.6%), and hypertension (6.3%). In total, across all racial and ethnic groups, 56% of women with an SMM outcome experienced one or more health conditions. Table 5 depicts the sociodemographic model with health outcomes where diabetes was the only health condition not statistically significant with SMM as an outcome (p = 0.086). Women with hypertension had the highest risk associated with

SMM (OR 1.56, 95% CI:1.3–1.8), followed by obesity (OR 1.23, 95% CI:1.1–1.4), and mental health diagnosis (OR 1.19, 95% CI:1.1–1.3). Women with hypertension had the highest chance of SMM (OR 1.56, 95% CI:1.3–1.8), with non-Hispanic Black women experiencing hypertension more frequently than non-Hispanic White and Hispanic, Asian or Pacific Islander, Native American, or Other. Women with at least one health condition were anywhere from 1.20—1.50 (95% CI:1.1–1.8) times likely to experience SMM compared to women without these conditions.

Table 4

Adjusted Odds Ratio (OR) associated with severe maternal morbidity in Michigan, 2016-2017

	Sociodemographic Model				Sociodemographic Model with Health Conditions			
Age at Delivery	ChiSquare	OR	LB	UB	ChiSquare	OR	LB	UB
19-34 years vs under 18 years	0.07	0.82	0.66	1.01	0.03	0.78	0.63	0.97
Over 35 years vs under 18 years	0.32	1.13	0.89	1.43	0.87	1.02	0.80	1.29
Over 35 years vs 19-34 years	<.0001*	1.38	1.24	1.53	<.0001*	1.30	1.17	1.45
Patient Location								
Large metro vs small metro	<.0001*	1.81	1.65	1.99	<.0001*	1.84	1.67	2.02
Large metro vs micropolitan	<.0001*	1.42	1.21	1.67	<.0001*	1.43	1.22	1.68
Small metro vs micropolitan	0.0049*	0.78	0.67	0.93	0.0004*	0.78	0.67	0.92
Payment								
Medicaid vs other (private, medicare, self-pay)	<.0001*	1.23	1.12	1.34	<.0001*	1.20	1.09	1.30
Race								
Non-Hispanic Black vs non-Hispanic White	<.0001*	1.78	1.62	1.97	<.0001*	1.76	1.59	1.94

Hispanic, Asian or Pacific Islander, Native American or Other vs non-Hispanic White	<.0001*	1.31	1.15	1.48	<.0001*	1.34	1.78	1.51
Hispanic, Asian or Pacific Islander, Native American or Other vs non-Hispanic Black	<.0001*	0.73	0.64	0.84	<.0001*	0.75	0.67	0.87
Chronic conditions Associated with Pregnancy								
Diabetes (Yes vs No)					0.09	1.13	0.98	1.29
Obesity (Yes vs No)					<.0001*	1.23	1.11	1.36
Mental Health/ Substance use (Yes vs No)					<.0008*	1.19	1.08	1.32
Hypertension (Yes vs No)					<.0001*	1.55	1.31	1.85

Note. N = 202,514. Stastical significance was demonstrated by * ($p < .05$)

Severe Maternal Morbidity, Health Conditions, and Geographic Location

Spatial distribution of risk factors for maternal ill-health (SMM) were modeled by adverse maternal health conditions indicated as independent variables. The use of geographic methods for modeling the effect of risk factors on SMM was minimal; logistic regression portrayed geographic location as the greatest predictor of SMM and GIS was utilized as a means to describe the analysis. The statistical modeling assumes that the statistical associations were affected by geography. These results portray the number, percent, and density of SMM with health conditions across Michigan. Counts and percentages were categorized by natural breaks and quartiles, respectively. Results provided three sets of maps; each analysis was depicted by the zip code where the patient lived or where the patient indicated during their hospital stay.

The SMM 2016-2017 map depicts the number of SMM during the time period 2016-2017. The highest number of SMM cases occurred in three different zip codes in Southeast Michigan, which had 33-45 SMM cases between 2016-2017. The zip codes with the highest SMM were Pontiac (33), Taylor (39), Dearborn (37), and the highest in Detroit (45). The areas with the lowest SMM rates were in rural parts of Michigan, likely due to population density. The highest number of disease diagnosis for the four health conditions were as follows; SMM and diabetes was Dearborn, Inkster, Belleville; SMM and hypertension was Detroit and Saginaw; SMM and obesity was Detroit; SMM and mental health diagnosis was Lapeer, Saginaw, Lansing, Pontiac, Warren, Taylor, Wayne, Ypsilanti, and Jackson. The second set of maps was a collection of three maps depicting SMM by the percent of race/ethnicity groups per zip code. The third set portrays the percent of each health condition associated with SMM per zip code.

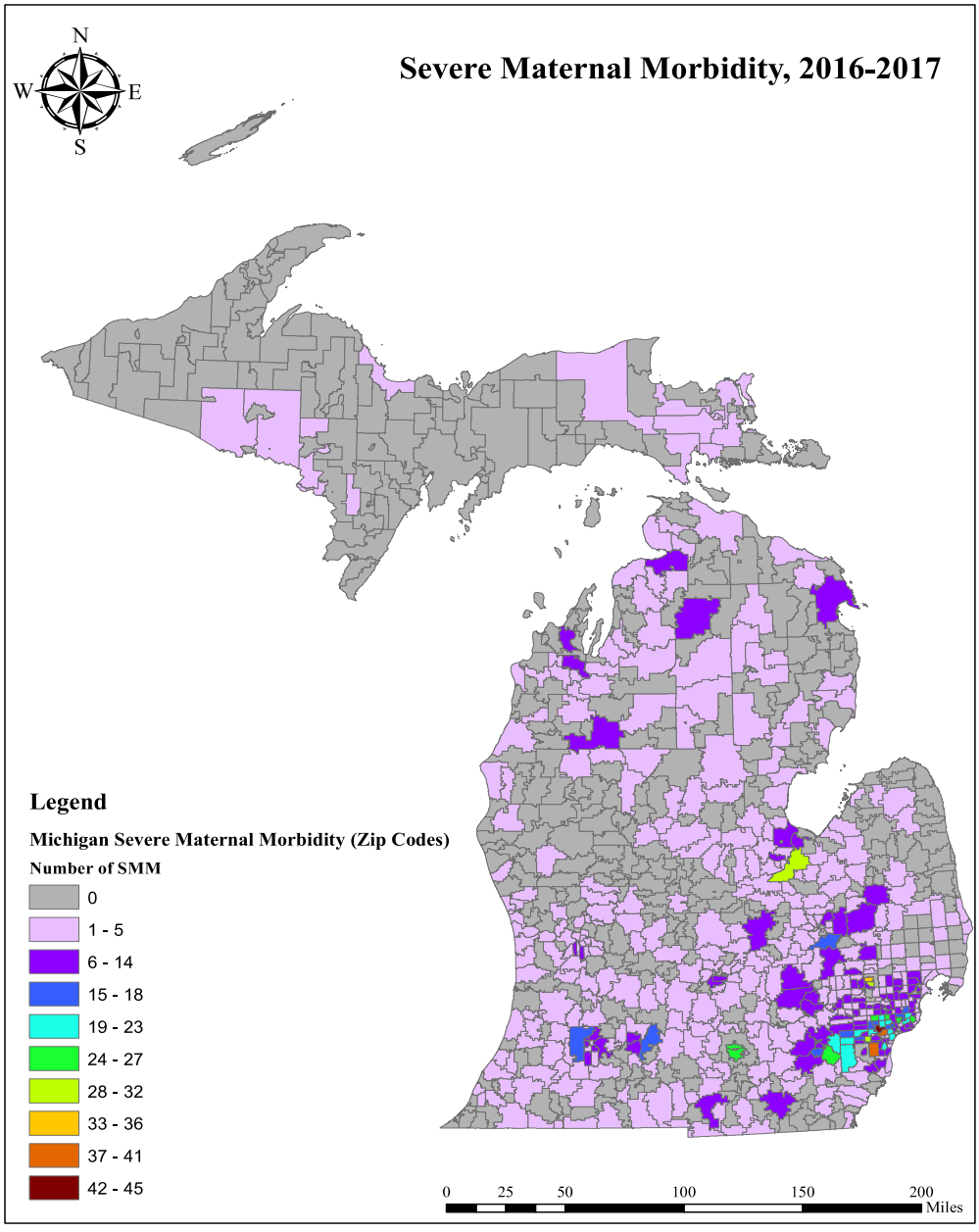

Figure 1. Severe maternal morbidity in Michigan from 2016-2017.

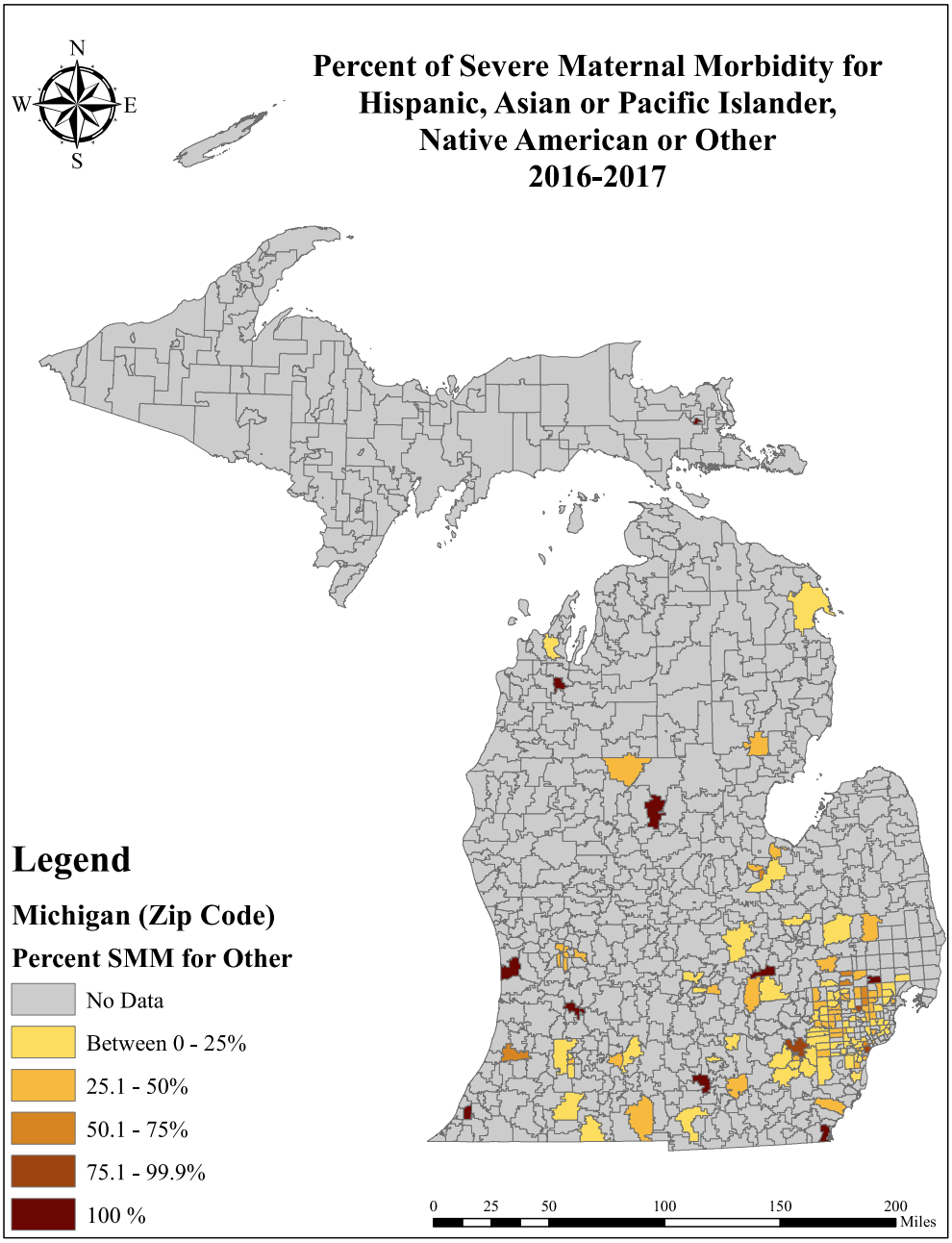

Figure 2. Percent of severe maternal morbidity for hispanic, asian or pacific islander, native american, or other in Michigan 2016-2017.

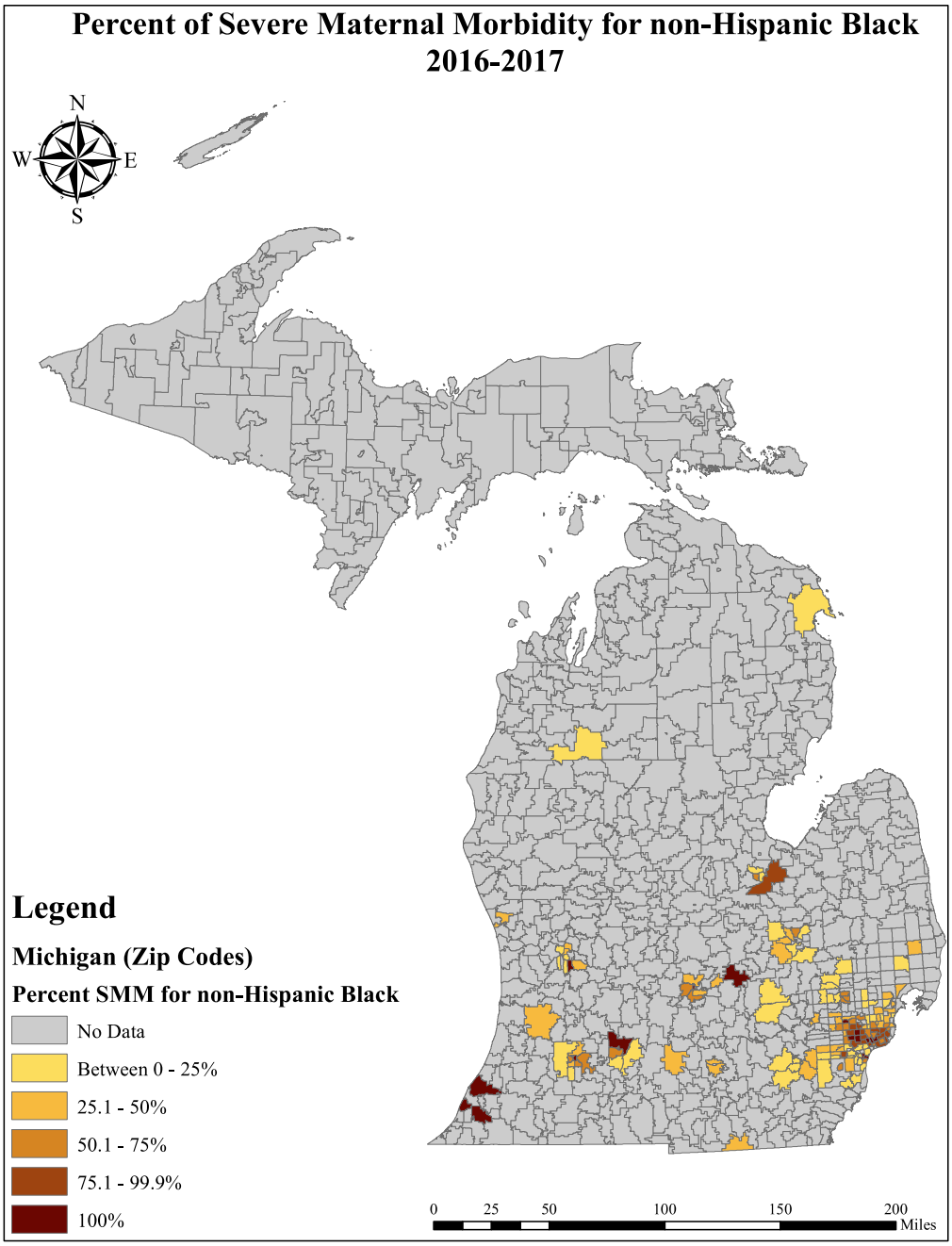

Figure 3. Percent of severe maternal morbidity for non-hispanic Black in Michigan 2016-2017.

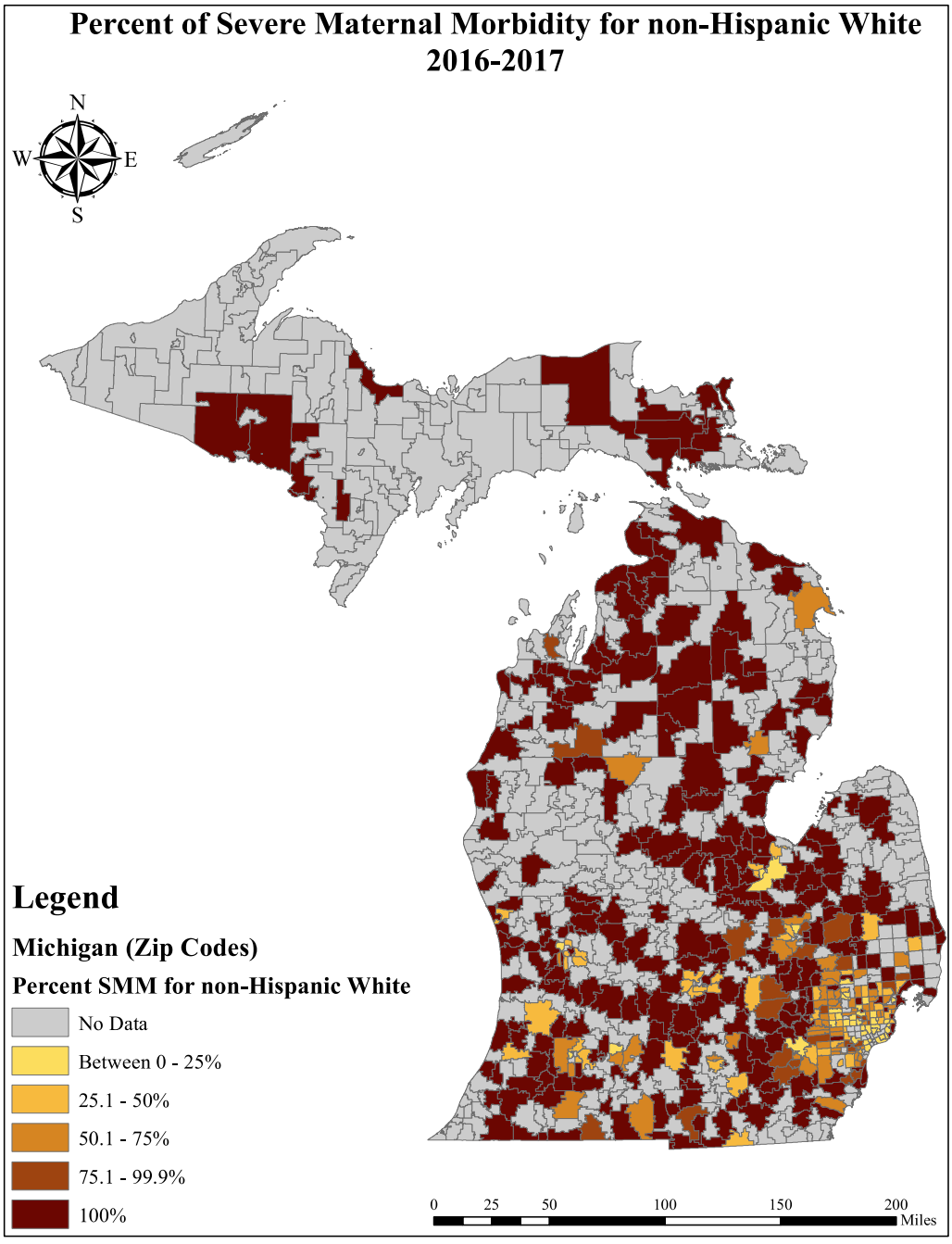

Figure 4. Percent of severe maternal morbidity for non-hispanic White in Michigan 2016-2017.

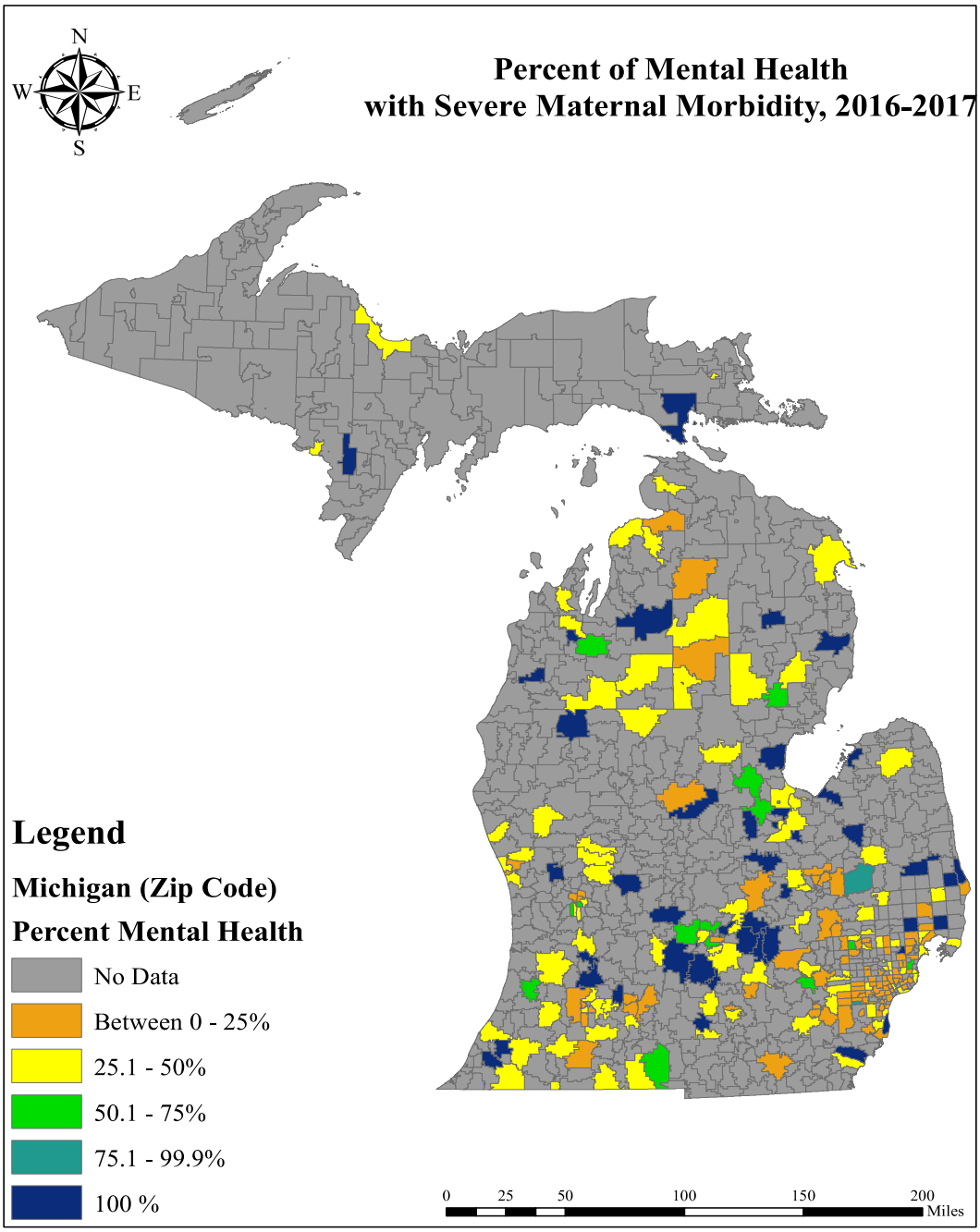

Figure 5. Percent of mental health diagnosis with severe maternal morbidity in Michigan 2016-2017.

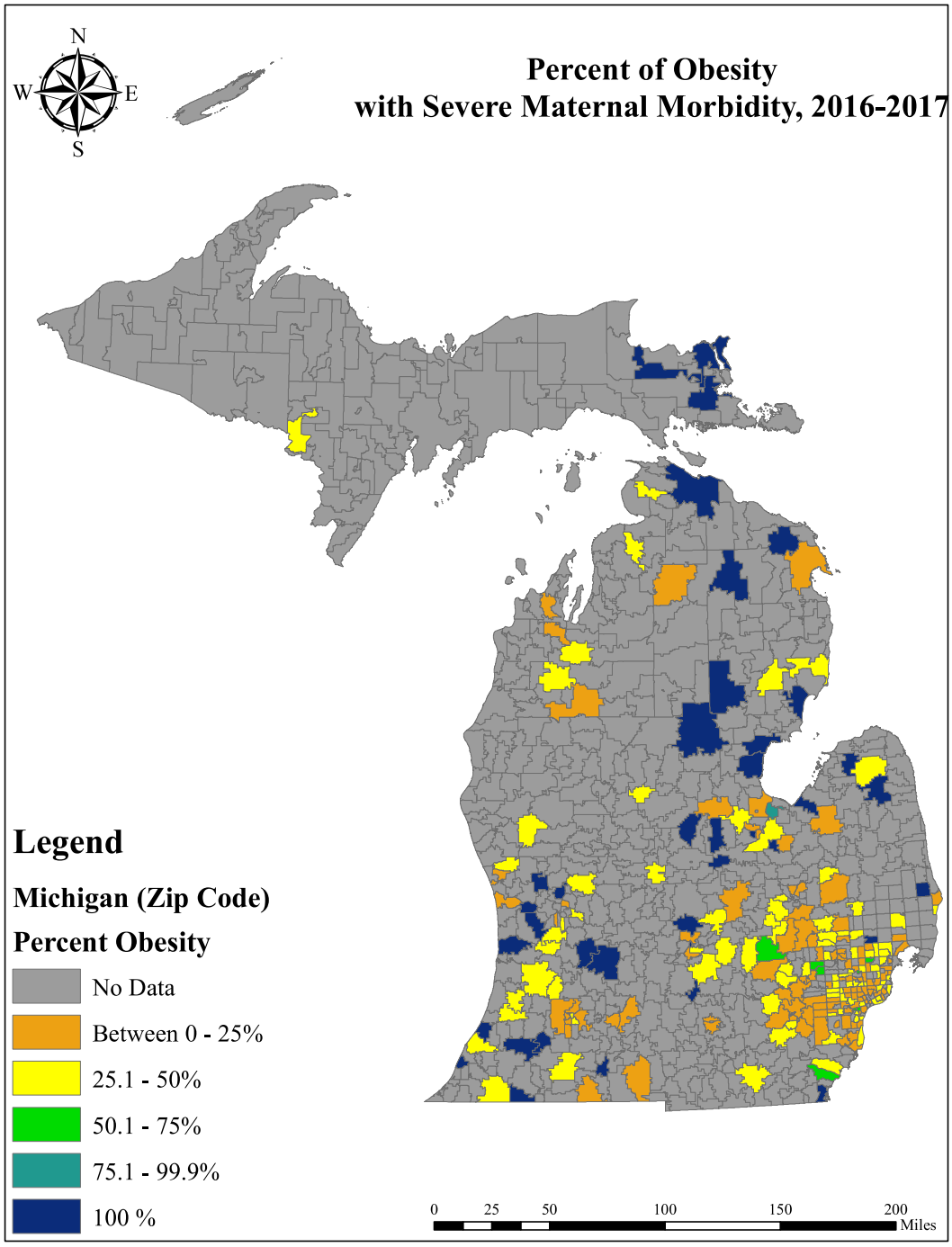

Figure 6. Percent of obesity diagnosis with severe maternal morbidity, 2016-2017.

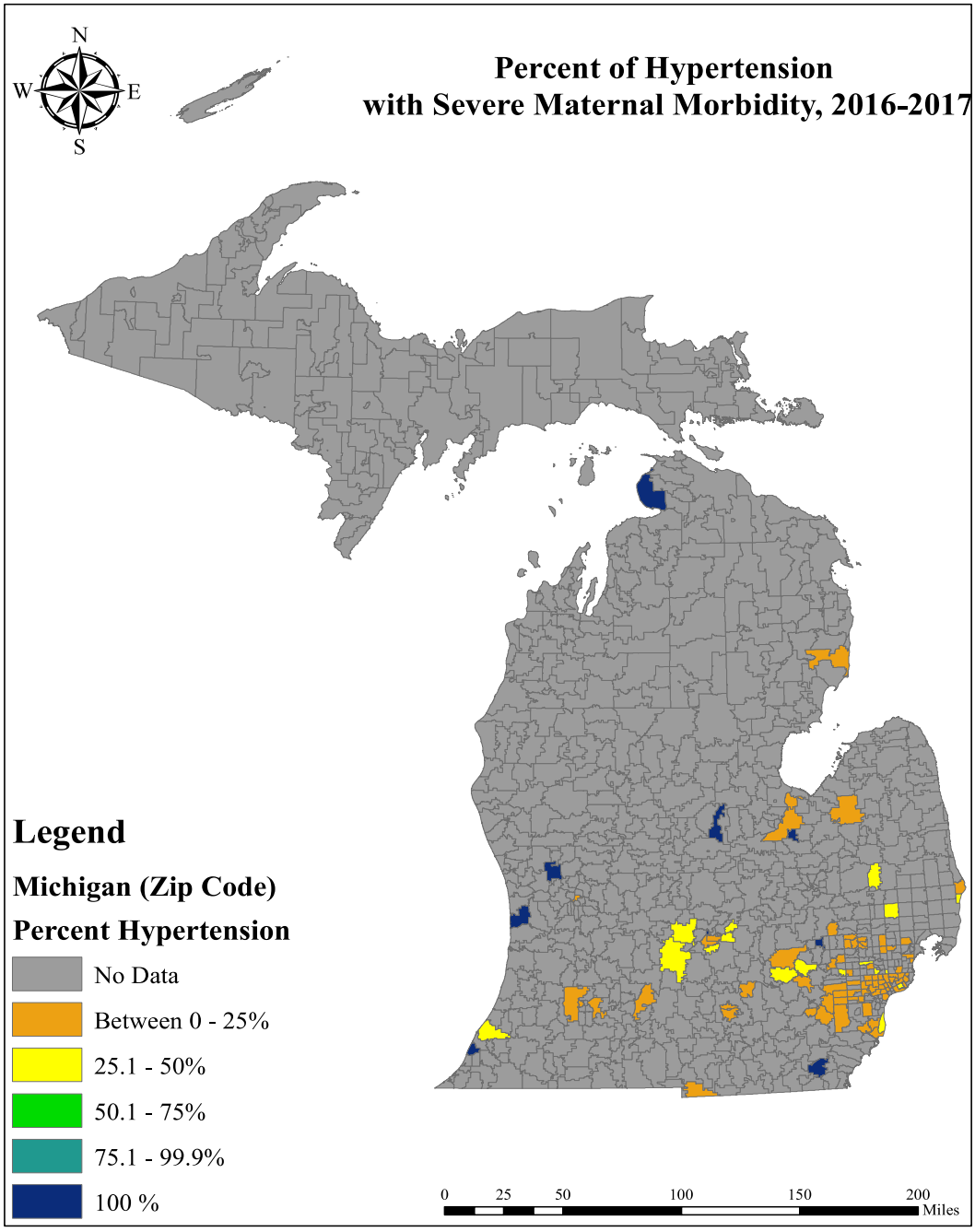

Figure 7. Percent of hypertension diagnosis with severe maternal morbidity, 2016-2017.

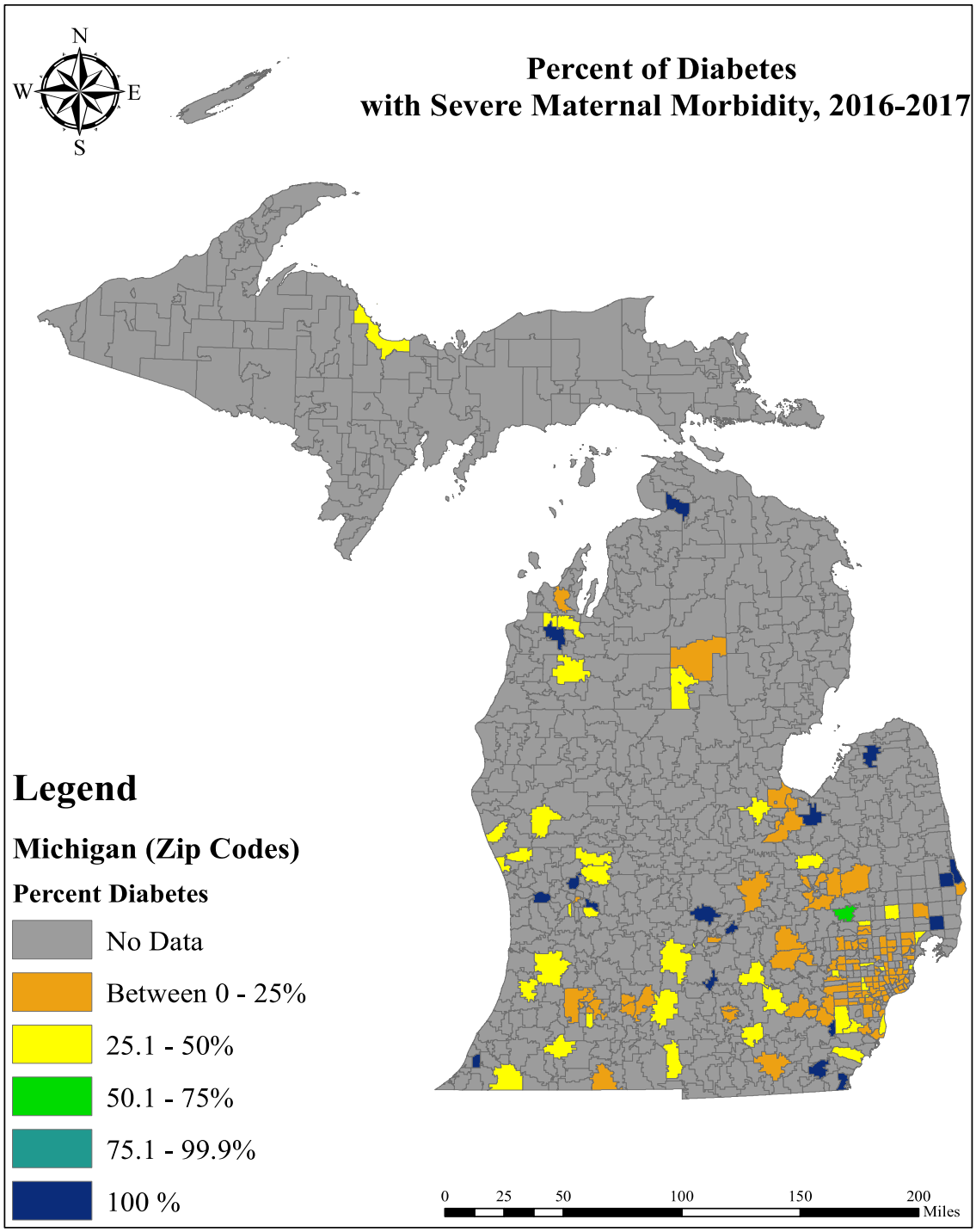

Figure 8. Percent of diabetes diagnosis with severe maternal morbidity, 2016-2017.

Summary

The full logistic regression model indicated that geographic location was the greatest predictor of SMM and health conditions associated with pregnancy complication. The second greatest predictor was race, followed by hypertension diagnosis, age, insurance (payer), obesity, and mental health diagnosis. For the first study hypothesis, I rejected the null hypothesis that there are no differences in severe maternal morbidity rates among geographic location and racial/ethnic (non-Hispanic Black, Hispanic, Asian or Pacific Islander, and Native American, or Alaska Native) women. I rejected the null hypothesis that there are no geographic variations of severe maternal morbidity across the state of Michigan. I rejected the null hypothesis that there are no racial and ethnic variations of severe maternal morbidity across the state of Michigan. I rejected the null hypothesis that there are no racial/ethnic variation between women who have experience hypertension, obesity or mental health diagnosis. Finally, I failed to reject the null hypothesis that there are no racial/ethnic variation between women who have a diabetes diagnosis and SMM outcome.

We found that the average SMM rate for Michigan residents was (1.2%) 121.5 per 10,000 deliveries. However, the rates varied across race and ethnicity with the non-Hispanic Black population having the highest rate of SMM (200 per 10,000 deliveries). In order to better understand these associations, specifically geographic location variation, I used data visualization techniques. I used spatial analysis to determine the location of areas where women had a health condition and experienced SMM during their delivery hospitalization. The set of maps that depicts the percent of health conditions with

an SMM outcome to accurately inform which disease interventions would help women in a specific zip code.

The third set of maps demonstrated the four health conditions by zip code that were most prevalent during the SMM events. For example, the highest number of obesity diagnosis and SMM were located in Detroit. However, the highest percentage of obesity occurred in more rural and small metro locations such as Sault Saint Marine, Pickford, Kinross, Hawks, Atlanta, Alger, Gladwin, Hastings, Holland, Decatur, Coloma, Minden City, Elkton, and more; that is where 100% of the cases were obese on admission. Similarly, the highest number of diabetes diagnosis was in Dearborn, Inkster, Belleville, but the highest percentage of diabetes was located in small metros or rural locations like Dewitt, Alanson, Bad Axe, Casco, Dundee, and more.

These findings present a review of delivery hospitalizations in Michigan from 2016-2017, severe maternal morbidity as an outcome, and four health conditions associated with pregnancy complications that may exacerbate the chances of an SMM event. Secondly, the racial and ethnic variation in disease outcome, as well as the variation in health conditions across the State, was identified. The geographical variation in both health conditions and racial and ethnic diversity was depicted via GIS technologies. Evaluating geographic patterns in the association between four health conditions and SMM introduced more detailed descriptions of where women are experiencing poor health outcomes. Although geographical representation remains on the periphery of many maternal health analysis, these results demonstrate need for visualization techniques for the association between geographic location and SMM to

pinpoint areas of greatest need that inform public health professionals to make social changes, which is outlined in the following section.

Section 4: Application to Professional Practice and Implications for Social Change

Introduction

SMM is an ongoing problem that affects more than 50,000 women annually (Callaghan et al., 2012). There is a public health need to improve reproductive health services with the intent to improve health equity while increasing the number of healthy pregnancies and deliveries. In a response to this public health issue, during the past decade, reducing poor maternal health outcomes has been a leading priority with the U.S. Department of Health and Human Services, declaring the reduction of pregnancy-related complications and illness a Healthy People 2020 objective (HealthyPeople, 2017). However, there is still work to be done. The physical and psychological ailments that directly and indirectly affect women's health contribute to a myriad of consequences, including ill-health, loss of workdays, inability to bond with baby, sleeplessness, and trauma (Mazul et al., 2017). Since SMM occurs 100 times more frequently than maternal mortality (Admon et al., 2017), SMM surveillance is impactful for monitoring maternal outcomes while providing population-level context and geographical differences for public health interventions.

Defining methods for identifying SMM at the population-level utilizing ICD-10-CM diagnosis and procedure codes for delivery hospitalizations to describe trends and health disparities will help states inform maternal morbidity interventions. While there are maternal health impacts, there are challenges navigating the correct diagnosis and procedure codes as well as trying to understand the diverse data systems to examine the patterns and risk factors to implement upstream interventions (Conrey et al., 2019). There

is limited published information that establishes how states are tracking SMM, what data they are using, and the subsequent policy and interventions based on the findings. The purpose of this study was to describe SMM in Michigan, depict where SMM and health conditions related to pregnancy complications occur, and address the infrastructure to improve health equity while focusing on efforts to reduce maternal morbidity.

Interpretation of the Findings

I used spatial epidemiology to advance the assessment of risk factors for SMM, obesity, hypertension, mental health diagnosis, and diabetes. These health conditions, described in the literature as risk factors that fall within social determinants of risk, were examined as characteristics in a complex pathway leading to poor maternal health outcomes. However, the differences in SMM rates are complex, and researchers have examined patient characteristics, systems, healthcare professional, and facility because they contribute to obstetrical care (Hirshberg & Srinivas, 2017). Access to adequate perinatal care aiding in prevention against maternal morbidities and mortalities has been found as a protective factor; yet, researchers have identified barriers and challenges to preconception, prenatal, and postpartum care due to unplanned pregnancies, competing priorities, and limited time in the clinic setting, respectively (Khan, Boyle, Lang, & Harrison, 2019; Mazul, Ward, & Ngui, 2017). The findings of this study added to that current knowledge while identifying geographic disparities in Michigan as well as pinpointing specific gaps for disease-specific interventions.

Socioecological Model, Critical Race Theory, and Severe Maternal Morbidity

Each SMM is unique and poses its own set of risk factors, systemic barriers, and health outcomes for each individual. Each woman lives within a complex socioecological framework, where each interaction with public policy, their community, the organizations they frequent and interact within, as well as their social networks and individual experiences impact their daily lives. Generational trauma and exposure to chronic stress has shaped the socioecological system women are born into and grow accustom to. Different lived experiences contribute to how an individual may access preconception, perinatal, and postpartum health services as well as the number of interactions with the healthcare system (Cabacungan, Ngui, & McGinley, 2012). This may be due to monetary resources, implicit or explicit bias from providers, geographic location, or insurance type (Khan, Boyle, Lang, & Harrison, 2019). It is important to note that the individual differences in health status, as well as healthcare access, should be taken into consideration when analyzing data based on health outcomes on the basis that healthcare access, insurance, and availability is not equal across the state; moreover, racial and ethnic disparities persist across the Michigan for SMM rates.

Analyzing health data is only one step towards providing intervention recommendations and rationale for resources and funding, so it is critical to include a historical context for more accurate findings and subsequent recommendations. Sharing these racial and ethnic disparities while framing this analysis around the socioecological theory alone was inadequate. It was vital to introduce the critical race theory due to an U.S. history of White privilege, where White individuals have been protected by the

government, financial institutions, policy forces, and have been prioritized for safety and resources. The racial and ethnic health disparities, perpetuated by structural barriers, are still heavily documented in the literature; college-educated, Black women are 3 times more likely to experience maternal complications than White women without a high school education, and women living in geographically underserved areas present with more health conditions (New York City Department of Health and Mental Hygiene, 2016). The structural barriers persist for racial and ethnic women and contribute to higher rates of poor health. Bohren et al. (2015) found that mistreatment of women during childbirth in a healthcare setting contributes to morbidity and mortality. Therefore, the multifaceted interactions of a history of racial inequities and individual and environmental networks contribute to health outcomes, and when coupled with intergenerational trauma, women's lives are completely altered.

The exposure to chronic stress and lack of trust in the healthcare system is now understood be to a reason why marginalized ethnic women have greater rates of poor health outcomes and other chronic illnesses compared to non-Hispanic White women (McKinnon et al., 2016). This has been an ongoing public health issue for more than 40 years; from 1979 to 2010, Black women had a twofold higher rate of chronic hypertension than White women (Ananth et al., 2019). Not only do health conditions contribute to ill-health, but unfair treatment by the society at large has led to detrimental effects on pregnancy outcomes, often leading to SMM or sequalae of an adverse risk during delivery (Williams, Priest, & Anderson, 2016). Greater attention to understanding risks and resources in the social environment that are linked to geographic location;

race/ethnicity; and how that accumulation of innate, environmental, and acquired factors across the life course perpetuates or remedies health outcomes to influence SMM rates is necessary in making a social change.

Health Conditions

In addition to the racial and ethnic disparities, many women who have chronic, mismanaged, or underdiagnosed health conditions experiences higher rates of SMM (Creanga, Syverson, Seed & Callaghan, 2017). Providing targeted interventions for women experiencing these conditions is especially important, but the interventions are often inadequately delivered. The prevalence of diabetes among women during reproductive years has increased, disproportionately affecting racial and ethnic women further perpetuating poor health outcomes (Bardenheier et al., 2015; Deputy et al., 2018). When these health conditions are diagnosed before pregnancy, healthcare providers can counsel on interventions that may postpone, delay, treat, or manage any additional harm to the mother and infant. However, when these health conditions are not established before conception or during the perinatal period, severe maternal and infant complications can occur. In fact, only about half of postpartum women with existing diabetes report receiving preconception care (Kim, Deputy, & Robbins, 2018). Treating women with respect and dignity by managing health conditions associated with pregnancy complications is one way to interpret these findings and create social impact.

Lastly, the mental health diagnosis and increased contribution of behavioral health conditions linked to cases of SMM has been identified as an emerging concern. The findings of this study reveal higher prevalence of mental health diagnosis for non-

Hispanic White women. However, underreporting for racial and ethnic women may contribute to a disparity in screening and referral to treatment. The possibility of racial and ethnic women receiving less adequate care by way of underdiagnosed and understudied mental health conditions requires a deeper analysis across healthcare services. Universal screening and referral to evidence-based treatment may benefit women and remedy a systematic barrier. Similarly, other health conditions may showcase system-level disparities for current screening and referral practices.

In this study, I quantified the magnitude of racial and ethnic disparities as well as geographic location and the prevalence of SMM among women who deliver in Michigan. My two main interpretations of this data are: (a) racial and ethnic inequities persist and (b) there is a relationship between geography and health conditions. Identifying the areas where healthcare services are needed is imperative for the fair and just distribution of these services. Healthcare systems can provide powerful resources, such as preventative initiatives to reduce the burden of disease. Shifting the responsibility to healthcare systems, instead of individual responsibility, by equipping health systems with surveillance and effective monitoring, such as GIS, will help identify the needs of vulnerable communities to address individual needs and systematic problems.

Limitations of the Study

Statewide administrative data are validated before final submission into the HCUP; however, these diagnosis and procedure codes do not provide information on prenatal care, the severity of a condition, or follow-up outside of the hospital setting; the cross-sectional nature of the data limits the knowledge of whether the conditions have

changed over time, between racial groups, or led to a mortality. Administrative databases that lack patient characteristics, such as age and body mass index, may lack necessary information (Grobman et al., 2015).

The data lack some socioeconomic fields, smoking status, primary language, and other demographics that may contribute to inadequate health care services and potentially SMM (Metcalfe et al., 2018). It is also possible that an increased SMM rate may reflect rigorous coding practices over time (Admon et al., 2017). Moreover, I only accounted for the CDC's definition of SMM, which includes 18 indicators that correspond with ICD-10 codes identified only during the hospitalization of record, in this study.

I examined four of the health conditions associated with pregnancy complications and did not do a full analysis of all health-related complications. There are other leading diagnosis-based indicators of SMM that include adult respiratory distress syndrome and acute renal failure (CDC, 2018; New York City Department of Health and Mental Hygiene, 2016). Finally, this study lacks information regarding preconception obstetric care received that has benefits to reduce maternal morbidity and poor health outcomes. The findings should be interpreted considering the limitations of the data source, study design, and geographic visualization methodology. Expanding inclusive maternity care management programs that integrate preconception health through the first year postpartum, particularly among racial and ethnic women with a prior health conditions, are mechanisms to reduce SMM.

Recommendations

In this study, geographic location was the greatest predictor of SMM with race and ethnicity being a close second. This geographic and racial SMM analysis presented opportunities to examine these disparities more closely. Poor health conditions contribute to the health disparities across Michigan, and the number of racial and ethnic women living with a health condition is higher when compared with their White counterparts. I recommend a deeper analysis into the four health conditions related to pregnancy outcomes examined in this study (i.e., mental health diagnosis, diabetes, obesity, and hypertension) and the relationship with sociodemographic factors, such as poverty, neighborhood resources, and social support. While there is evidence of increased focus on describing patterns of maternal morbidity, the collective impact of morbidity and the extent to which it effects women is poorly understood. The varying effects SMM has on women can be exacerbated by the environment and conditions in which they live; living with poverty, racial inequalities, multiple health conditions, and inadequate resources during pregnancy compound and can result in poor mental health and a litany of other physical diagnoses. The physical and psychological function of a woman experiencing a SMM event may dissipate after childbirth; however, the sequelae of poor birth experiences in addition to health conditions, fatigue, pain, depression, anxiety, and restful sleep may continue to impact a woman's day-to-day functioning and disproportionately effect racial and ethnic women.

The nuances prompt another layer of exploration. In addition to other analysis, collecting qualitative data to examine the lived experiences and world views of women

and families impacted by SMM could provide more information into the overall trends and why certain zip codes experience disparities. The daily structural and social barriers women face can be detrimental to their health and can contribute to poor pregnancy outcomes. Conducting a mixed methods approach to SMM could help elucidate the social determinants of disease and potentially identify modifiable risk factors that contribute to one area more than another.

Each health condition is uniquely complex in relationship to pregnancy, thus a deeper analysis into the interplay between health conditions, sociodemographic risk factors, and SMM may provide richer results. Each of the four health conditions present vastly different upstream interventions effecting women differently depending on where they live and the resources easily available to them, especially mental health, hypertension, and diabetes diagnosis. These health conditions have more granular information that may provide more definitive results. This is due, in part, to the mental health diagnosis including alcohol, tobacco and substance use during pregnancy, while hypertension and diabetes include preexisting and gestational diagnosis. Moreover, these health conditions, coupled with a history of unfair treatment, effect racial and ethnic groups disproportionately and, as a result, have led to disparate health outcomes. Thus, it is our recommendation that each health condition associated with pregnancy complications be studied in its relationship to severe maternal morbidity and what that means for women living in geographically diverse areas. Finally, an exploration on cost savings pertaining to the different health conditions and SMM interventions may provide useful. Comparing intervention costs, health care costs, childcare costs, and the societal

costs including lost workdays, long-term rehabilitation, and mental health services may provide reason to explore more upstream interventions. Estimating cost savings could help resources and policy interventions to create sustainable social change for all effected by SMM.

Implication for Professional Practice and Social Change

The higher rates of SMM for non-Hispanic Black, Hispanic, Asian or Pacific Islander, Native American, and/or Other races and ethnicities have been the subject of considerable attention. The persistent gaps in risk between non-Hispanic White women and other races and ethnicities has plagued the public health realm. Yet, the inequities continue. In the February 2020 issue of *Obstetrics and Gynecology,* Dr. William M Callaghan states,

> "Health and medical care exist in the context of the larger society, and our failure to address the needs of women and the inequities borne by marginalized populations is a reflection of reconciling what we say we value and what we do to achieve our valued goals (Callaghan, 2020)."

Addressing the SMM problem with changes to the professional field, first by focusing on health equity and systems change, is the only acceptable way to tackle this public health problem. The changes in practice will require social change within organizations, clinical practices, local health departments, schools, governmental bodies and anywhere women seek services, treatment, and support.

There are three main implications resulting from the findings. The first is that among all four health conditions explored, three of those conditions emerged as

important risk factors associated with SMM. Second, the results support an emphasis on preconception health and access to pregnancy services that aligns with statewide and national strategies. Finally, these implications shared with stakeholders in Michigan may help prioritize strategies to prevent the increased maternal morbidity rates.

Professional Practice

This analysis prompts a call to action for those striving to improve access to healthcare services prior to delivery for women living in Michigan. It is evident that adverse pregnancy and health outcomes persist among racial and ethnic health women who live in large metropolitan zip codes. These findings suggest interventions based on the patient's location may prove an innovative way to tailor resources for specific healthcare needs. For example, focusing efforts on reducing SMM geographically has been shown to be effective for women living in in resource-poor areas (Suplee, Bloch, Hillier, & Herbert, 2018).

For professionals working with women and children, providing GIS maps of SMM with information regarding the health conditions that complicate pregnancy may help providers engage with community organizations to modify interventions for the greatest needs. Enhanced surveillance of SMM can help identify preventability and outline actionable recommendations to mitigate poor maternal health outcomes and optimize maternal health service delivery. Sharing population-level data with public health and clinical health providers will improve their understanding of factors that contribute to health disparities. Understanding the zip codes where women return, after a delivery hospitalization, and the related patterns of health in those areas, as well as

recurring health outcomes can impact perinatal health care interventions to tailor specific needs.

GIS maps assist in targeted implementation interventions that impact women to positively impact her health throughout her life course. This includes contraception access and family planning services, preconception health that helps manage health conditions, and providing accessible perinatal care and education across the state (Robbins et al., 2018). Importantly, enrolling women in insurance programs before they become pregnant and ensuring that women and infants have insurance until one year after birth may impact SMM rates (Ranji, Gomez, & Salganicoff, 2019). Finally, providing wrap around services by creating relationship with women prior to pregnancy, assisting her while pregnant, and supporting her in the recovery after childbirth and during the postpartum period is an opportunity to reduce health disparities and feelings of fear of the healthcare system. Providing long-term care for women prior to pregnancy, throughout pregnancy and postpartum would remedy the social barriers of geographic isolation, problematic health conditions, and offer hope for lasting social change in the maternal healthcare delivery system.

Social Impact

Geospatial analysis has grown in popularity to advance precision public health initiatives. Precision public health focuses on the use of technologies (such as GIS) to deliver the correct intervention at the right time to the right population (Khoury, Iademarco, & Riley, 2016). This would guide public health practice to individually tailored interventions and policies that may benefit the public with more precise

interventions and medicine. Moreover, this approach leads to social change and disease treatment because it takes into consideration the individual variability, environment and lifestyle.

The data demonstrates that specific zip codes and neighborhoods have higher rates of SMM than others and clinical, public health, and policy interventions can be directed to those areas. The findings of this study support the need for enhanced screening and timely treatment for racial and ethnic women. While the graphs in the results do not demonstrate the exact location of disease, they pinpoint areas with greater risk. Taking into consideration precision public health, these maps may be a helpful tool in beginning the alignment of resources for the greatest need. Moreover, GIS allows local government to consider policy changes to be considered for lasting social change. By utilizing precision public health, localities can provide context for additional efforts among populations with limited resources, greater risk of a health condition, and have the greatest social impact. Professional practice can have a great deal of impact on social well-being. When a woman seeks care from a professional, they trust the professional will pose the least amount of harm on them. Identifying opportunities to change deeply rooted professional practices will ultimately create a compound of social change benefiting women and their families. When professionals advocate for women and their health, families, and societies benefit for a more harmonious lived experience.

Conclusion

Increases in maternal mortality rates over recent years has prompted more national attention on women's health. Maternal morbidity is a continuum of short-term

adverse effects to long-term life-altering events and are 100 times more common than maternal mortality. However, defining maternal morbidity as the unintended outcomes of pregnancy that results in a significant short or long-term consequence to a women's health may overlook some of the environmental, societal, or delayed onsets of SMM. The prevalence of death remains low overall, however maternal death only showcase the more obvious aspects of healthcare delievery with respect to the number of pregnancies and pregnancy complications. Complications due to health conditions and maternal mental health have not been examined as closely, leading many to explore risk factors, health disparities, and access to quality healthcare in SMM. This research is an important step in understanding the precursors to morbidity and the remaining, less obvious, 90% of healthcare delivery.

SMM was identified at significantly higher frequency across racial and ethnic women, which are consistent with findings identified in Admon et al. (2017) nationwide analysis. The data suggests that racial and ethnic women have a significant proportion of obstetric complications, many of which are preventable, and improved quality of healthcare interventions are a considerable key factor in the prevention of maternal morbidity. The implementation of precision public health interventions for health condition management, as well as hospital centric interventions including the Alliance for Innovation safety bundles and racial and ethnic disparities bundles are actionable steps that can be taken to reduce disparities in poor obstetric outcomes. Disparities will not be eliminated by improved public health interventions or hospital safety bundles alone.

Implicit bias trainings, cultural sensitivity and health literacy trainings are also needed to create social change in healthcare environments.

In summary, we found racial and ethnic disparities in overall severe maternal morbidity among non-Hispanic Black, Hispanic, Asian or Pacific Islander, and Native American compared with non-Hispanic White women. The prevalence of health conditions associated with SMM varied geographically and provided insight into identifying opportunities for public health interventions. It is clear that within zip codes and between zip codes there are health inequalities in morbidity rates. Whether those differences in morbidity rates are related to access to quality healthcare, hospital services, or perinatal care is unclear. However, within the broader health context, there continues to be a debate around the relationship between health and place, as well as the bases of health inequities (Ballas et al., 2017). Health is qualified at an individual level, but healthcare issues are geographical in nature. Individual health is determined by a multitude of predisposing factors, but also personal geographic. Where an individual was raised, where they live, work, play, and all of which affect health outcomes, ill-health and access to healthcare, as well as the quality of treatment available.

In closing, exposure to environmental factors are spatially clustered but behaviors are also inherently linked to geographic locations such as zip codes. Health behaviors, access to quality care, social environmental, and stressors tend to spatially cluster effecting individuals similarly in specific areas. There is a clear correlation between geographic ill-health and health needs. Tools to identify health conditions by underlying demographic and indicators have been identified. I have identified GIS as an important

tool for visualizing health disparities and evaluating areas where improved interventions are necessary. Thus, I must strive for deeper analysis, and consistent levels of care relative to geographic need in order to protect and promote women's health for generations to come.

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Appendix A: Center for Disease Control and Preventions Severe Maternal Morbidity Indicators

Center for Disease Control and Preventions Severe Maternal Morbidity Indicators (ICD-10-CM)

DIAGNOSIS	ICD-10	Descriptions
	1. Acute myocardial infarction	
	I21.01	ST elevation (STEMI) myocardial infarction involving left main coronary artery
	I21.02	ST elevation (STEMI) myocardial infarction involving left anterior descending coronary artery
	I21.09	ST elevation (STEMI) myocardial infarction involving other coronary artery of anterior wall
	I21.11	ST elevation (STEMI) myocardial infarction involving right coronary artery
	I21.19	ST elevation (STEMI) myocardial infarction involving other coronary artery of inferior wall
	I21.21	ST elevation (STEMI) myocardial infarction involving left circumflex coronary artery
	I21.29	ST elevation (STEMI) myocardial infarction involving other sites
	I21.3	ST elevation (STEMI) myocardial infarction of unspecified site
	I21.4	Non-ST elevation (NSTEMI) myocardial infarction
	I21.9	Acute myocardial infarction, unspecified
	I21.A1	Myocardial infarction type 2
	I21.A9	Other myocardial infarction type
	I22.0	Subsequent ST elevation (STEMI) myocardial infarction of anterior wall
	I22.1	Subsequent ST elevation (STEMI) myocardial infarction of inferior wall
	I22.2	Subsequent non-ST elevation (NSTEMI) myocardial infarction
	I22.8	Subsequent ST elevation (STEMI) myocardial infarction of other sites
	I22.9	Subsequent ST elevation (STEMI) myocardial infarction of unspecified site
	2. Acute Renal Failure diagnosis	

N17.0	Acute kidney failure with tubular necrosis
N17.1	Acute kidney failure with acute cortical necrosis
N17.2	Acute kidney failure with medullary necrosis
N17.8	Other acute kidney failure
N17.9	Acute kidney failure, unspecified
O90.4	Postpartum acute kidney failure

3. Adult Respiratory Distress Syndrome diagnosis

J80	Acute respiratory distress syndrome
J95.1	Acute pulmonary insufficiency following thoracic surgery
J95.2	Acute pulmonary insufficiency following nonthoracic surgery
J95.3	Chronic pulmonary insufficiency following surgery
J95.821	Acute postprocedural respiratory failure
J95.822	Acute and chronic postprocedural respiratory failure
J96.00	Acute respiratory failure unspecified whether with hypoxia or hypercapnia
J96.01	Acute respiratory failure with hypoxia
J96.02	Acute respiratory failure with hypercapnia
J96.20	Acute and chronic respiratory failure unspecified whether with hypoxia or hypercapnia
J96.21	Acute and chronic respiratory failure with hypoxia
J96.22	Acute and chronic respiratory failure with hypercapnia
R09.2	Respiratory arrest

4. Amniotic fluid embolism

O88.111	Amniotic fluid embolism in first trimester
O88.112	Amniotic fluid embolism in second rimester
O88.113	Amniotic fluid embolism in third trimester
O88.119	Amniotic fluid embolism in pregnancy
O88.12	Amniotic fluid embolism in childbirth
O88.13	Amniotic fluid embolism in puerperium

5. Aneurysm

I71.00	Dissection of unspecified site of aorta
I71.01	Dissection of thoracic aorta
I71.02	Dissection of abdominal aorta

I71.03	Dissection of thoracoabdominal aorta
I71.1	Thoracic aortic aneurysm, ruptured
I71.2	Thoracic aortic aneurysm, without rupture
I71.3	Abdominal aortic aneurysm, ruptured
I71.4	Abdominal aortic aneurysm, without rupture
I71.5	Thoracoabdominal aortic aneurysm, ruptured
I71.6	Thoracoabdominal aortic aneurysm, without rupture
I71.8	Aortic aneurysm of unspecified site, ruptured
I71.9	Aortic aneurysm of unspecified site, without rupture
I79.0	Aneurysm of aorta in diseases classified elsewhere

6. Cardiac arrest/ventricular fibrillation

I49.01	Ventricular fibrillation
I49.02	Ventricular flutter
I46.2	Cardiac arrest due to underlying cardiac condition
I46.8	Cardiac arrest due to other underlying condition
I46.9	Cardiac arrest, cause unspecified

7. Disseminated Intravascular Coagulation

D65	Disseminated intravascular coagulation [defibrination syndrome]
D68.8	Other specified coagulation defects
D68.9	Coagulation defect, unspecified
O72.3	Postpartum coagulation defects

8. Eclampsia

O15.00	Eclampsia complicating pregnancy, unspecified trimester
O15.02	Eclampsia in pregnancy, second trimester
O15.03	Eclampsia in pregnancy, third trimester
O15.1	Eclampsia in labor
O15.2	Eclampsia in the puerperium
O15.9	Eclampsia, unspecified as to time period

9. Heart failure/arrest during procedure or surgery

I97.120	Postprocedural cardiac arrest following cardiac surgery
I97.121	Postprocedural cardiac arrest following other surgery
I97.130	Postprocedural heart failure following cardiac surgery

I97.131	Postprocedural heart failure following other surgery

10. Internal injuries of thorax, abdomen, and pelvis

Not carried forward (either very low frequency or imprecise usage)

11. Intracranial injuries

Not carried forward (either very low frequency or imprecise usage)

12. Puerperal Cerebrovascular Disorder

I60.00	Nontraumatic subarachnoid hemorrhage from unspecified carotid siphon and bifurcation
I60.01	Nontraumatic subarachnoid hemorrhage from right carotid siphon and bifurcation
I60.02	Nontraumatic subarachnoid hemorrhage from left carotid siphon and bifurcation
I60.10	Nontraumatic subarachnoid hemorrhage from unspecified middle cerebral artery
I60.11	Nontraumatic subarachnoid hemorrhage from right middle cerebral artery
I60.12	Nontraumatic subarachnoid hemorrhage from left middle cerebral artery
I60.2	Nontraumatic subarachnoid hemorrhage from anterior communicating artery
I60.20	Nontraumatic subarachnoid hemorrhage from unspecified anterior communicating artery
I60.21	Nontraumatic subarachnoid hemorrhage from right anterior communicating artery
I60.22	Nontraumatic subarachnoid hemorrhage from left anterior communicating artery
I60.30	Nontraumatic subarachnoid hemorrhage from unspecified posterior communicating artery
I60.31	Nontraumatic subarachnoid hemorrhage from right posterior communicating artery
I60.32	Nontraumatic subarachnoid hemorrhage from left posterior communicating artery
I60.4	Nontraumatic subarachnoid hemorrhage from basilar artery
I60.50	Nontraumatic subarachnoid hemorrhage from unspecified vertebral artery
I60.51	Nontraumatic subarachnoid hemorrhage from right vertebral artery

I60.52	Nontraumatic subarachnoid hemorrhage from left vertebral artery
I60.6	Nontraumatic subarachnoid hemorrhage from other intracranial arteries
I60.7	Nontraumatic subarachnoid hemorrhage from unspecified intracranial artery
I60.8	Other nontraumatic subarachnoid hemorrhage
I60.9	Nontraumatic subarachnoid hemorrhage, unspecified
I61.0	Nontraumatic intracerebral hemorrhage in hemisphere, subcortical
I61.1	Nontraumatic intracerebral hemorrhage in hemisphere, cortical
I61.2	Nontraumatic intracerebral hemorrhage in hemisphere, unspecified
I61.3	Nontraumatic intracerebral hemorrhage in brain stem
I61.4	Nontraumatic intracerebral hemorrhage in cerebellum
I61.5	Nontraumatic intracerebral hemorrhage, intraventricular
I61.6	Nontraumatic intracerebral hemorrhage, multiple localized
I61.8	Other nontraumatic intracerebral hemorrhage
I61.9	Nontraumatic intracerebral hemorrhage, unspecified
I62.00	Nontraumatic subdural hemorrhage, unspecified
I62.01	Nontraumatic acute subdural hemorrhage
I62.02	Nontraumatic subacute subdural hemorrhage
I62.03	Nontraumatic chronic subdural hemorrhage
I62.1	Nontraumatic extradural hemorrhage
I62.9	Nontraumatic intracranial hemorrhage, unspecified
I63.00	Cerebral infarction due to thrombosis of unspecified precerebral artery
I63.011	Cerebral infarction due to thrombosis of right vertebral artery
I63.012	Cerebral infarction due to thrombosis of left vertebral artery
I63.013	Cerebral infarction due to thrombosis of bilateral vertebral arteries
I63.019	Cerebral infarction due to thrombosis of unspecified vertebral artery

I63.02	Cerebral infarction due to thrombosis of basilar artery
I63.031	Cerebral infarction due to thrombosis of right carotid artery
I63.032	Cerebral infarction due to thrombosis of left carotid artery
I63.033	Cerebral infarction due to thrombosis of bilateral carotid arteries
I63.039	Cerebral infarction due to thrombosis of unspecified carotid artery
I63.09	Cerebral infarction due to thrombosis of other precerebral artery
I63.10	Cerebral infarction due to embolism of unspecified precerebral artery
I63.111	Cerebral infarction due to embolism of right vertebral artery
I63.112	Cerebral infarction due to embolism of left vertebral artery
I63.113	Cerebral infarction due to embolism of bilateral vertebral arteries
I63.119	Cerebral infarction due to embolism of unspecified vertebral artery
I63.12	Cerebral infarction due to embolism of basilar artery
I63.131	Cerebral infarction due to embolism of right carotid artery
I63.132	Cerebral infarction due to embolism of left carotid artery
I63.133	Cerebral infarction due to embolism of bilateral carotid arteries
I63.139	Cerebral infarction due to embolism of unspecified carotid artery
I63.19	Cerebral infarction due to embolism of other precerebral artery
I63.20	Cerebral infarction due to unspecified occlusion or stenosis of unspecified precerebral arteries
I63.211	Cerebral infarction due to unspecified occlusion or stenosis of right vertebral arteries
I63.212	Cerebral infarction due to unspecified occlusion or stenosis of left vertebral arteries
I63.213	Cerebral infarction due to unspecified occlusion or stenosis of bilateral vertebral arteries
I63.219	Cerebral infarction due to unspecified occlusion or stenosis of unspecified vertebral arteries

I63.22	Cerebral infarction due to unspecified occlusion or stenosis of basilar arteries
I63.231	Cerebral infarction due to unspecified occlusion or stenosis of right carotid arteries
I63.232	Cerebral infarction due to unspecified occlusion or stenosis of left carotid arteries
I63.233	Cerebral infarction due to unspecified occlusion or stenosis of bilateral carotid arteries
I63.239	Cerebral infarction due to unspecified occlusion or stenosis of unspecified carotid arteries
I63.29	Cerebral infarction due to unspecified occlusion or stenosis of other precerebral arteries
I63.30	Cerebral infarction due to thrombosis of unspecified cerebral artery
I63.311	Cerebral infarction due to thrombosis of right middle cerebral artery
I63.312	Cerebral infarction due to thrombosis of left middle cerebral artery
I63.313	Cerebral infarction due to thrombosis of bilateral middle cerebral arteries
I63.319	Cerebral infarction due to thrombosis of unspecified middle cerebral artery
I63.321	Cerebral infarction due to thrombosis of right anterior cerebral artery
I63.322	Cerebral infarction due to thrombosis of left anterior cerebral artery
I63.323	Cerebral infarction due to thrombosis of bilateral anterior arteries
I63.329	Cerebral infarction due to thrombosis of unspecified anterior cerebral artery
I63.331	Cerebral infarction due to thrombosis of right posterior cerebral artery
I63.332	Cerebral infarction due to thrombosis of left posterior cerebral artery
I63.333	Cerebral infarction to thrombosis of bilateral posterior arteries
I63.339	Cerebral infarction due to thrombosis of unspecified posterior cerebral artery
I63.341	Cerebral infarction due to thrombosis of right cerebellar artery
I63.342	Cerebral infarction due to thrombosis of left cerebellar artery
I63.343	Cerebral infarction to thrombosis of bilateral cerebellar arteries

I63.349	Cerebral infarction due to thrombosis of unspecified cerebellar artery
I63.39	Cerebral infarction due to thrombosis of other cerebral artery
I63.40	Cerebral infarction due to embolism of unspecified cerebral artery
I63.411	Cerebral infarction due to embolism of right middle cerebral artery
I63.412	Cerebral infarction due to embolism of left middle cerebral artery
I63.413	Cerebral infarction due to embolism of bilateral middle cerebral arteries
I63.419	Cerebral infarction due to embolism of unspecified middle cerebral artery
I63.421	Cerebral infarction due to embolism of right anterior cerebral artery
I63.422	Cerebral infarction due to embolism of left anterior cerebral artery
I63.423	Cerebral infarction due to embolism of bilateral anterior cerebral arteries
I63.429	Cerebral infarction due to embolism of unspecified anterior cerebral artery
I63.431	Cerebral infarction due to embolism of right posterior cerebral artery
I63.432	Cerebral infarction due to embolism of left posterior cerebral artery
I63.433	Cerebral infarction due to embolism of bilateral posterior cerebral arteries
I63.439	Cerebral infarction due to embolism of unspecified posterior cerebral artery
I63.441	Cerebral infarction due to embolism of right cerebellar artery
I63.442	Cerebral infarction due to embolism of left cerebellar artery
I63.443	Cerebral infarction due to embolism of bilateral cerebellar arteries
I63.449	Cerebral infarction due to embolism of unspecified cerebellar artery
I63.49	Cerebral infarction due to embolism of other cerebral artery
I63.50	Cerebral infarction due to unspecified occlusion or stenosis of unspecified cerebral artery
I63.511	Cerebral infarction due to unspecified occlusion or stenosis of right middle cerebral artery

I63.512	Cerebral infarction due to unspecified occlusion or stenosis of left middle cerebral artery
I63.513	Cerebral infarction due to unspecified occlusion or stenosis of bilateral middle arteries
I63.519	Cerebral infarction due to unspecified occlusion or stenosis of unspecified middle cerebral art
I63.521	Cerebral infarction due to unspecified occlusion or stenosis of right anterior cerebral artery
I63.522	Cerebral infarction due to unspecified occlusion or stenosis of left anterior cerebral artery
I63.523	Cerebral infarction due to unspecified occlusion or stenosis of bilateral anterior arteries
I63.529	Cerebral infarction due to unspecified occlusion or stenosis of unspecified anterior cerebral a
I63.531	Cerebral infarction due to unspecified occlusion or stenosis of right posterior cerebral artery
I63.532	Cerebral infarction due to unspecified occlusion or stenosis of left posterior cerebral artery
I63.533	Cerebral infarction due to unspecified occlusion or stenosis of bilateral posterior arteries
I63.539	Cerebral infarction due to unspecified occlusion or stenosis of unspecified posterior cerebral
I63.541	Cerebral infarction due to unspecified occlusion or stenosis of right cerebellar artery
I63.542	Cerebral infarction due to unspecified occlusion or stenosis of left cerebellar artery
I63.543	Cerebral infarction due to unspecified occlusion or stenosis of bilateral cerebellar arteries
I63.549	Cerebral infarction due to unspecified occlusion or stenosis of unspecified cerebellar artery
I63.59	Cerebral infarction due to unspecified occlusion or stenosis of other cerebral artery
I63.6	Cerebral infarction due to cerebral venous thrombosis, nonpyogenic
I63.8	Other cerebral infarction
I63.81	Other cerebral infarction due to occlusion or stenosis of small artery
I63.89	Other cerebral infarction
I63.9	Cerebral infarction, unspecified
I65.01	Occlusion and stenosis of right vertebral artery
I65.02	Occlusion and stenosis of left vertebral artery
I65.03	Occlusion and stenosis of bilateral vertebral arteries

I65.09	Occlusion and stenosis of unspecified vertebral artery
I65.1	Occlusion and stenosis of basilar artery
I65.21	Occlusion and stenosis of right carotid artery
I65.22	Occlusion and stenosis of left carotid artery
I65.23	Occlusion and stenosis of bilateral carotid arteries
I65.29	Occlusion and stenosis of unspecified carotid artery
I65.8	Occlusion and stenosis of other precerebral arteries
I65.9	Occlusion and stenosis of unspecified precerebral artery
I66.01	Occlusion and stenosis of right middle cerebral artery
I66.02	Occlusion and stenosis of left middle cerebral artery
I66.03	Occlusion and stenosis of bilateral middle cerebral arteries
I66.09	Occlusion and stenosis of unspecified middle cerebral artery
I66.11	Occlusion and stenosis of right anterior cerebral artery
I66.12	Occlusion and stenosis of left anterior cerebral artery
I66.13	Occlusion and stenosis of bilateral anterior cerebral arteries
I66.19	Occlusion and stenosis of unspecified anterior cerebral artery
I66.21	Occlusion and stenosis of right posterior cerebral artery
I66.22	Occlusion and stenosis of left posterior cerebral artery
I66.23	Occlusion and stenosis of bilateral posterior cerebral arteries
I66.29	Occlusion and stenosis of unspecified posterior cerebral artery
I66.3	Occlusion and stenosis of cerebellar arteries
I66.8	Occlusion and stenosis of other cerebral arteries
I66.9	Occlusion and stenosis of unspecified cerebral artery
I67.0	Dissection of cerebral arteries, nonruptured
I67.1	Cerebral aneurysm, nonruptured
I67.2	Cerebral atherosclerosis

I67.3	Progressive vascular leukoencephalopathy
I67.4	Hypertensive encephalopathy
I67.5	Moyamoya disease
I67.6	Nonpyogenic thrombosis of intracranial venous system
I67.7	Cerebral arteritis, not elsewhere classified
I67.81	Acute cerebrovascular insufficiency
I67.82	Cerebral ischemia
I67.83	Posterior reversible encephalopathy syndrome
I67.841	Reversible cerebrovascular vasoconstriction syndrome
I67.848	Other cerebrovascular vasospasm and vasoconstriction
I67.89	Other cerebrovascular disease
I67.9	Cerebrovascular disease, unspecified
I68.0	Cerebral amyloid angiopathy
I68.2	Cerebral arteritis in other diseases classified elsewhere
I68.8	Other cerebrovascular disorders in diseases classified elsewhere
O22.51	Cerebral venous thrombosis in pregnancy unspecified trimester
O22.52	Cerebral venous thrombosis in pregnancy second trimester
O22.53	Cerebral venous thrombosis in pregnancy third trimester
O87.3	Cerebral venous thrombosis in the puerperium
I97.810	Intraoperative cerebrovascular infarction during cardiac surgery
I97.811	Intraoperative cerebrovascular infarction during other surgery
I97.820	Postprocedural cerebrovascular infarction during cardiac surgery
I97.821	Postprocedural cerebrovascular infarction during other surgery

13. Acute Heart Failure / Pulmonary edema

J81.0	Acute pulmonary edema
I50.1	Left ventricular failure
I50.20	Unspecified systolic (congestive) heart failure
I50.21	Acute systolic (congestive) heart failure
I50.23	Acute on chronic systolic (congestive) heart failure

I50.30	Unspecified diastolic (congestive) heart failure
I50.31	Acute diastolic (congestive) heart failure
I50.33	Acute on chronic diastolic (congestive) heart failure
I50.40	Unspecified combined systolic (congestive) and diastolic (congestive) heart failure
I50.41	Acute combined systolic (congestive) and diastolic (congestive) heart failure
I50.43	Acute on chronic combined systolic (congestive) and diastolic (congestive) heart failure
I50.9	Heart failure, unspecified

14. Severe anesthesia complications

O74.0	Aspiration pneumonitis due to anesthesia during labor and delivery
O74.1	Other pulmonary complications of anesthesia during labor and delivery
O74.2	Cardiac complications of anesthesia during labor and delivery
O74.3	Central nervous system complications of anesthesia during labor and delivery
O89.01	Aspiration pneumonitis due to anesthesia during the puerperium
O89.09	Other pulmonary complications of anesthesia during the puerperium
O89.1	Cardiac complications of anesthesia during the puerperium
O89.2	Central nervous system complications of anesthesia during the puerperium

15. Sepsis

O85	Puerperal sepsis
O86.04	Sepsis following an obstetrical procedure
T80.211A	Bloodstream infection due to central venous catheter, initial encounter
T81.4XXA	Infection following a procedure, initial encounter
T81.44XA	Sepsis following a procedure, initial encounter
T81.44XD	Sepsis following a procedure, subsequent encounter
T81.44XS	Sepsis following a procedure, sequela
T81.44	Sepsis following a procedure
R65.20	Severe sepsis without septic shock
A40.0	Sepsis due to streptococcus, group A

A40.1	Sepsis due to streptococcus, group B
A40.3	Sepsis due to Streptococcus pneumoniae
A40.8	Other streptococcal sepsis
A40.9	Streptococcal sepsis, unspecified
A41.01	Sepsis due to Methicillin susceptible Staphylococcus aureus
A41.02	Sepsis due to Methicillin resistant Staphylococcus aureus
A41.1	Sepsis due to other specified staphylococcus
A41.2	Sepsis due to unspecified staphylococcus
A41.3	Sepsis due to Hemophilus influenza
A41.4	Sepsis due to anaerobes
A41.50	Gram-negative sepsis, unspecified
A41.51	Sepsis due to Escherichia coli
A41.52	Sepsis due to pseudomonas
A41.53	Sepsis due to serratia
A41.59	Other gram-negative sepsis
A41.81	Sepsis due to Enterococcus
A41.89	Other specified sepsis
A41.9	Sepsis, unspecified
A32.7	Listerial sepsis

16. Shock

O75.1	Shock during or following labor and delivery
R57.0	Cardiogenic shock
R57.1	Hypovolemic shock
R57.8	Other shock
R57.9	Shock, unspecified
R65.21	Severe sepsis with septic shock
T78.2XXA	Anaphylactic shock, unspecified
T88.2XXA	Shock due to anesthesia
T88.6XXA	Anaphylactic reaction due to adverse effect of correct drug or medicament properly administered
T81.10XA	Postprocedural shock unspecified, initial encounter
T81.11XA	Postprocedural cardiogenic shock, initial encounter
T81.19XA	Other postprocedural shock, initial encounter

17. Sickle Cell Disease with Crisis

D57.00	Hb-SS disease with crisis, unspecified

D57.01	Hb-SS disease with acute chest syndrome
D57.02	Hb-SS disease with splenic sequestration
D57.211	Sickle-cell/Hb-C disease with acute chest syndrome
D57.212	Sickle-cell/Hb-C disease with splenic sequestration
D57.219	Sickle-cell/Hb-C disease with crisis, unspecified
D57.411	Sickle-cell thalassemia with acute chest syndrome
D57.412	Sickle-cell thalassemia with splenic sequestration
D57.419	Sickle-cell thalassemia with crisis, unspecified
D57.811	Other sickle-cell disorders with acute chest syndrome
D57.812	Other sickle-cell disorders with splenic sequestration
D57.819	Other sickle-cell disorders with crisis, unspecified

18. Air and thrombotic embolism

I26.01	Septic pulmonary embolism with acute cor pulmonale
I26.02	Saddle embolus of pulmonary artery with acute cor pulmonale
I26.09	Other pulmonary embolism with acute cor pulmonale
I26.90	Septic pulmonary embolism without acute cor pulmonale
I26.92	Saddle embolus of pulmonary artery without acute cor pulmonale
I26.99	Other pulmonary embolism without acute cor pulmonale
O88.011	Air embolism in pregnancy, first trimester
O88.012	Air embolism in pregnancy, second trimester
O88.013	Air embolism in pregnancy, third trimester
O88.019	Air embolism in pregnancy, unspecified trimester
O88.02	Air embolism in childbirth
O88.03	Air embolism in the puerperium
O88.211	Thromboembolism in pregnancy, first trimester
O88.212	Thromboembolism in pregnancy, second trimester
O88.213	Thromboembolism in pregnancy, third trimester
O88.219	Thromboembolism in pregnancy, unspecified trimester
O88.22	Thromboembolism in childbirth
O88.23	Thromboembolism in the puerperium

O88.311	Pyemic and septic embolism in pregnancy, first trimester
O88.312	Pyemic and septic embolism in pregnancy, second trimester
O88.313	Pyemic and septic embolism in pregnancy, third trimester
O88.319	Pyemic and septic embolism in pregnancy, unspecified trimester
O88.32	Pyemic and septic embolism in childbirth
O88.33	Pyemic and septic embolism in the puerperium
O88.811	Other embolism in pregnancy first trimester
O88.812	Other embolism in pregnancy second trimester
O88.813	Other embolism in pregnancy third trimester
O88.819	Other embolism in pregnancy, unspecified trimester
O88.82	Other embolism in childbirth
O88.83	Other embolism in the puerperium

PROCEDURE	**ICD-10**	Descriptions
19. Blood transfusion		
	30230H0	Transfusion of Autologous Whole Blood into Peripheral Vein, Open Approach
	30230K0	Transfusion of Autologous Frozen Plasma into Peripheral Vein, Open Approach
	30230L0	Transfusion of Autologous Fresh Plasma into Peripheral Vein, Open Approach
	30230M0	Transfusion of Autologous Plasma Cryoprecipitate into Peripheral Vein, Open Approach
	30230N0	Transfusion of Autologous Red Blood Cells into Peripheral Vein, Open Approach
	30230P0	Transfusion of Autologous Frozen Red Cells into Peripheral Vein, Open Approach
	30230R0	Transfusion of Autologous Platelets into Peripheral Vein, Open Approach
	30230T0	Transfusion of Autologous Fibrinogen into Peripheral Vein, Open Approach
	30230H1	Transfusion of Non-autologous Whole Blood into Peripheral Vein, Open Approach
	30230K1	Transfusion of Non-autologous Frozen Plasma into Peripheral Vein, Open Approach
	30230L1	Transfusion of Non-autologous Fresh Plasma into Peripheral Vein, Open Approach

30230M1	Transfusion of Non-autologous Plasma Cryoprecipitate into Peripheral Vein, Open Approach
30230N1	Transfusion of Non-autologous Red Blood Cells into Peripheral Vein, Open Approach
30230P1	Transfusion of Non-autologous Frozen Red Cells into Peripheral Vein, Open Approach
30230R1	Transfusion of Non-autologous Platelets into Peripheral Vein, Open Approach
30230T1	Transfusion of Non-autologous Fibrinogen into Peripheral Vein, Open Approach
30233H0	Transfusion of Autologous Whole Blood into Peripheral Vein, Percutaneous Approach
30233K0	Transfusion of Autologous Frozen Plasma into Peripheral Vein, Percutaneous Approach
30233L0	Transfusion of Autologous Fresh Plasma into Peripheral Vein, Percutaneous Approach
30233M0	Transfusion of Autologous Plasma Cryoprecipitate into Peripheral Vein, Percutaneous Approach
30233N0	Transfusion of Autologous Red Blood Cells into Peripheral Vein, Percutaneous Approach
30233P0	Transfusion of Autologous Frozen Red Cells into Peripheral Vein, Percutaneous Approach
30233R0	Transfusion of Autologous Platelets into Peripheral Vein, Percutaneous Approach
30233T0	Transfusion of Autologous Fibrinogen into Peripheral Vein, Percutaneous Approach
30233H1	Transfusion of Non-autologous Whole Blood into Peripheral Vein, Percutaneous Approach
30233K1	Transfusion of Non-autologous Frozen Plasma into Peripheral Vein, Percutaneous Approach
30233L1	Transfusion of Non-autologous Fresh Plasma into Peripheral Vein, Percutaneous Approach
30233M1	Transfusion of Non-autologous Plasma Cryoprecipitate into Peripheral Vein, Percutaneous Approach
30233N1	Transfusion of Non-autologous Red Blood Cells into Peripheral Vein, Percutaneous Approach
30233P1	Transfusion of Non-autologous Frozen Red Cells into Peripheral Vein, Percutaneous Approach
30233R1	Transfusion of Non-autologous Platelets into Peripheral Vein, Percutaneous Approach

30233T1	Transfusion of Non-autologous Fibrinogen into Peripheral Vein, Percutaneous Approach
30240H0	Transfusion of Autologous Whole Blood into Central Vein, Open Approach
30240K0	Transfusion of Autologous Frozen Plasma into Central Vein, Open Approach
30240L0	Transfusion of Autologous Fresh Plasma into Central Vein, Open Approach
30240M0	Transfusion of Autologous Plasma Cryoprecipitate into Central Vein, Open Approach
30240N0	Transfusion of Autologous Red Blood Cells into CentralVein, Open Approach
30240P0	Transfusion of Autologous Frozen Red Cells into Central Vein, Open Approach
30240R0	Transfusion of Autologous Platelets into Central Vein, Open Approach
30240T0	Transfusion of Autologous Fibrinogen into Central Vein, Open Approach
30240H1	Transfusion of Non-autologous Whole Blood into Central Vein, Open Approach
30240K1	Transfusion of Non-autologous Frozen Plasma into Central Vein, Open Approach
30240L1	Transfusion of Non-autologous Fresh Plasma into Central Vein, Open Approach
30240M1	Transfusion of Non-autologous Plasma Cryoprecipitate into Central Vein, Open Approach
30240N1	Transfusion of Non-autologous Red Blood Cells into Central Vein, Open Approach
30240P1	Transfusion of Non-autologous Frozen Red Cells into Central Vein, Open Approach
30240R1	Transfusion of Non-autologous Platelets into Central Vein, Open Approach
30240T1	Transfusion of Non-autologous Fibrinogen into Central Vein, Open Approach
30243H0	Transfusion of Autologous Whole Blood into Central Vein, Percutaneous Approach
30243K0	Transfusion of Autologous Frozen Plasma into Central Vein, Percutaneous Approach
30243L0	Transfusion of Autologous Fresh Plasma into Central Vein, Percutaneous Approach
30243M0	Transfusion of Autologous Plasma Cryoprecipitate into Central Vein, Percutaneous Approach

30243N0	Transfusion of Autologous Red Blood Cells into Central Vein, Percutaneous Approach
30243P0	Transfusion of Autologous Frozen Red Cells into Central Vein, Percutaneous Approach
30243R0	Transfusion of Autologous Platelets into Centrall Vein, Percutaneous Approach
30243T0	Transfusion of Autologous Fibrinogen into Central Vein, Percutaneous Approach
30243H1	Transfusion of Non-autologous Whole Blood into Central Vein, Percutaneous Approach
30243K1	Transfusion of Non-autologous Frozen Plasma into Central Vein, Percutaneous Approach
30243L1	Transfusion of Non-autologous Fresh Plasma into Central Vein, Percutaneous Approach
30243M1	Transfusion of Non-autologous Plasma Cryoprecipitate into Central Vein, Percutaneous Approach
30243N1	Transfusion of Non-autologous Red Blood Cells into Central Vein, Percutaneous Approach
30243P1	Transfusion of Non-autologous Frozen Red Cells into Central Vein, Percutaneous Approach
30243R1	Transfusion of Non-autologous Platelets into Central Vein, Percutaneous Approach
30243T1	Transfusion of Non-autologous Fibrinogen into Central Vein, Percutaneous Approach
30250H0	Transfusion of Autologous Whole Blood into Peripheral Artery, Open Approach
30250K0	Transfusion of Autologous Frozen Plasma into Peripheral Artery, Open Approach
30250L0	Transfusion of Autologous Fresh Plasma into Peripheral Artery, Open Approach
30250M0	Transfusion of Autologous Plasma Cryoprecipitate into Artery Vein, Open Approach
30250N0	Transfusion of Autologous Red Blood Cells into Artery Vein, Open Approach
30250P0	Transfusion of Autologous Frozen Red Cells into Artery Vein, Open Approach
30250R0	Transfusion of Autologous Platelets into Artery Vein, Open Approach
30250T0	Transfusion of Autologous Fibrinogen into Artery Vein, Open Approach
30250H1	Transfusion of Non-autologous Whole Blood into Peripheral Artery, Open Approach

30250K1	Transfusion of Non-autologous Frozen Plasma into Peripheral Artery, Open Approach
30250L1	Transfusion of Non-autologous Fresh Plasma into PeripheralArtery, Open Approach
30250M1	Transfusion of Non-autologous Plasma Cryoprecipitate into Peripheral Artery, Open Approach
30250N1	Transfusion of Non-autologous Red Blood Cells into Peripheral Artery, Open Approach
30250P1	Transfusion of Non-autologous Frozen Red Cells into Peripheral Artery, Open Approach
30250R1	Transfusion of Non-autologous Platelets into Peripheral Artery, Open Approach
30250T1	Transfusion of Non-autologous Fibrinogen into Peripheral Artery, Open Approach
30253H0	Transfusion of Autologous Whole Blood into Peripheral Vein, Percutaneous Approach
30253K0	Transfusion of Autologous Frozen Plasma into Peripheral Artery, Percutaneous Approach
30253L0	Transfusion of Autologous Fresh Plasma into Peripheral Artery, Percutaneous Approach
30253M0	Transfusion of Autologous Plasma Cryoprecipitate into Peripheral Artery, Percutaneous Approach
30253N0	Transfusion of Autologous Red Blood Cells into PeripheralArtery, Percutaneous Approach
30253P0	Transfusion of Autologous Frozen Red Cells into Peripheral Artery, Percutaneous Approach
30253R0	Transfusion of Autologous Platelets into Peripheral Artery, Percutaneous Approach
30253T0	Transfusion of Autologous Fibrinogen into Peripheral Artery, Percutaneous Approach
30253H1	Transfusion of Non-autologous Whole Blood into Peripheral Artery, Percutaneous Approach
30253K1	Transfusion of Non-autologous Frozen Plasma into Peripheral Artery, Percutaneous Approach
30253L1	Transfusion of Non-autologous Fresh Plasma into Peripheral Artery, Percutaneous Approach
30253M1	Transfusion of Non-autologous Plasma Cryoprecipitate into Peripheral Artery, Percutaneous Approach
30253N1	Transfusion of Non-autologous Red Blood Cells into Peripheral Artery, Percutaneous Approach

30253P1	Transfusion of Non-autologous Frozen Red Cells into Peripheral Artery, Percutaneous Approach
30253R1	Transfusion of Non-autologous Platelets into Peripheral Artery, Percutaneous Approach
30253T1	Transfusion of Non-autologous Fibrinogen into Peripheral Artery, Percutaneous Approach
30260H0	Transfusion of Autologous Whole Blood into Central Artery, Open Approach
30260K0	Transfusion of Autologous Frozen Plasma into Central Artery, Open Approach
30260L0	Transfusion of Autologous Fresh Plasma into Central Artery, Open Approach
30260M0	Transfusion of Autologous Plasma Cryoprecipitate into Central Artery, Open Approach
30260N0	Transfusion of Autologous Red Blood Cells into Central Artery, Open Approach
30260P0	Transfusion of Autologous Frozen Red Cells into Central Artery, Open Approach
30260R0	Transfusion of Autologous Platelets into Central Artery, Open Approach
30260T0	Transfusion of Autologous Fibrinogen into Central Artery, Open Approach
30260H1	Transfusion of Non-autologous Whole Blood into Central Artery, Open Approach
30260K1	Transfusion of Non-autologous Frozen Plasma into Central Artery, Open Approach
30260L1	Transfusion of Non-autologous Fresh Plasma into Central Artery, Open Approach
30260M1	Transfusion of Non-autologous Plasma Cryoprecipitate into Central Artery, Open Approach
30260N1	Transfusion of Non-autologous Red Blood Cells into Central Artery, Open Approach
30260P1	Transfusion of Non-autologous Frozen Red Cells into Central Artery, Open Approach
30260R1	Transfusion of Non-autologous Platelets into Central Artery, Open Approach
30260T1	Transfusion of Non-autologous Fibrinogen into Central Artery, Open Approach
30263H0	Transfusion of Autologous Whole Blood into Central Artery, Percutaneous Approach
30263K0	Transfusion of Autologous Frozen Plasma into Central Artery, Percutaneous Approach

30263L0	Transfusion of Autologous Fresh Plasma into Central Artery, Percutaneous Approach
30263M0	Transfusion of Autologous Plasma Cryoprecipitate into Central Artery, Percutaneous Approach
30263N0	Transfusion of Autologous Red Blood Cells into Central Artery, Percutaneous Approach
30263P0	Transfusion of Autologous Frozen Red Cells into Central Artery, Percutaneous Approach
30263R0	Transfusion of Autologous Platelets into Centrall Artery, Percutaneous Approach
30263T0	Transfusion of Autologous Fibrinogen into Central Artery, Percutaneous Approach
30263H1	Transfusion of Non-autologous Whole Blood into Central Artery, Percutaneous Approach
30263K1	Transfusion of Non-autologous Frozen Plasma into Central Artery, Percutaneous Approach
30263L1	Transfusion of Non-autologous Fresh Plasma into Central Artery, Percutaneous Approach
30263M1	Transfusion of Non-autologous Plasma Cryoprecipitate into Central Artery, Percutaneous Approach
30263N1	Transfusion of Non-autologous Red Blood Cells into Central Artery, Percutaneous Approach
30263P1	Transfusion of Non-autologous Frozen Red Cells into Central Artery Percutaneous Approach
30263R1	Transfusion of Non-autologous Platelets into Central Artery, Percutaneous Approach
30263T1	Transfusion of Non-autologous Fibrinogen into Central Artery, Percutaneous Approach

20. Cardio monitoring

Not carried forward (either very low frequency or imprecise usage)

21. Conversion of cardiac rhythm

5A2204Z	Restoration of Cardiac Rhythm, Single Cardiac countershock with successful conversion to sinus rhythm ICD-9: 99.61,2,4,9
5A12012	Performance of Cardiac Output, Single, Manual

22. Hysterectomy

0UT90ZZ	Resection of Uterus, Open Approach
0UT94ZZ	Resection of Uterus, Percutaneous Endoscopic Approach
0UT97ZZ	Resection of Uterus, Via Natural or Artificial Opening

0UT98ZZ	Resection of Uterus, Via Natural or Artificial Opening Endoscopic
0UT9FZZ	Resection of Uterus, Via Natural or Artificial Opening With Percutaneous Endoscopic Assistance

23. Operations on heart and pericardium

Not carried forward (either very low frequency or imprecise usage)

24. Temporary tracheostomy

0B110Z4	Bypass Trachea to Cutaneous, Open Approach
0B110F4	Bypass Trachea to Cutaneous with Tracheostomy Device, Open Approach
0B113Z4	Bypass Trachea to Cutaneous, Percutaneous Approach
0B113F4	Bypass Trachea to Cutaneous with Tracheostomy Device, Percutaneous Approach
0B114Z4	Bypass Trachea to Cutaneous, Percutaneous Endoscopic Approach
0B114F4	Bypass Trachea to Cutaneous with Tracheostomy Device, Percutaneous Endoscopic Approach

25. Ventilation

5A1935Z	Respiratory Ventilation, Less than 24 Consecutive Hours
5A1945Z	Respiratory Ventilation, 24-96 Consecutive Hours
5A1955Z	Respiratory Ventilation, Greater than 96 Consecutive Hours

* Centers for Disease Control and Prevention. Reproductive Health. Severe Maternal Morbidity. Retrieved from https://safehealthcareforeverywoman.org/aim-data/

Appendix B: List of Delivery Hospitalization Codes

Delivery Hospitalizations	
MS-DRG	'765', '766', '767', '768', '774', '775'
Diagnosis codes	'Z370', 'Z371', 'Z372', 'Z373', 'Z374', 'Z3750', 'Z3751', 'Z3752', 'Z3753', 'Z3754', 'Z3759', 'Z3760', 'Z3761', 'Z3762', 'Z3763', 'Z3764', 'Z3769', 'O80', 'O82'
Procedure codes	'10D00Z0', '10D00Z1', '10D00Z2', '10D07Z3', '10D07Z4', '10D07Z5', '10D07Z6', '10D07Z7', '10D07Z8', '10E0XZZ'

Exclusions	
Diagnosis codes (Abortion/ectopic/molar pregnancy)	'O000', 'O001', 'O002', 'O008', 'O009', 'O010', 'O011', 'O019', 'O020', 'O021', 'O0281', 'O0289', 'O029', 'O030', 'O031', 'O032', 'O0330', 'O0331', 'O0332', 'O0333', 'O0334', 'O0335', 'O0336', 'O0337', 'O0338', 'O0339', 'O034', 'O035', 'O036', 'O037', 'O0380', 'O0381', 'O0382', 'O0383', 'O0384', 'O0385', 'O0386', 'O0387', 'O0388', 'O0389', 'O039', 'O045', 'O046', 'O047', 'O0480', 'O0481', 'O0482', 'O0483', 'O0484', 'O0485', 'O0486', 'O0487', 'O0488', 'O0489', 'O070', 'O071', 'O072', 'O0730', 'O0731', 'O0732', 'O0733', 'O0734', 'O0735', 'O0736', 'O0737', 'O0738', 'O0739', 'O074', 'O080', 'O081', 'O082', 'O083', 'O084', 'O085', 'O086', 'O087', 'O0881', 'O0882', 'O0883', 'O0889', 'O089'
Procedures codes (Abortion/ectopic/molar pregnancy)	'10A00ZZ', '10A03ZZ', '10A04ZZ', '10A07Z6', '10A07ZW', '10A07ZX', '10A07ZZ', '10A08ZZ'