Associations between Delivery Hospital Obstetric Service Level and Selected Maternal and Perinatal Outcomes for High Risk Women

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Abstract

Despite recent calls for implementation of new definitions of graduated hospital levels of obstetric service to reduce maternal mortality and morbidity, associations between such an intervention and delivery outcomes remain untested. The purpose of this project is to investigate the association between the American Hospital Association's (AHA) graduated levels of obstetric service and delivery outcomes for women at high obstetric risk to provide evidence for policy makers tasked with making decisions about updating regional perinatal systems. Using the three delays framework, this project hypothesized improved outcomes at hospitals with the highest level of obstetric service.

This project first addressed the lack of a gold standard for identifying a sample of women at high obstetric risk in epidemiological data by demonstrating that a recently proposed obstetric comorbidity index allowed creation of a sample resulting in a lower likelihood of misclassification bias. The project then used a sample of women at high obstetric risk to test associations between maternal and perinatal delivery outcomes and delivering at hospitals with different levels of obstetric service as defined by the AHA.

The analyses did not provide evidence to support the hypothesis of improved outcomes for women at high risk delivering at hospitals with the highest level of obstetric service and instead found reduced odds of extended length of stay at hospitals with lower levels of obstetric service. These findings suggest the AHA system of designating levels of obstetric service may not stratify hospitals by resources that improve care and introduces questions about the validity of assumptions that the resources that provide safe

care for women at high risk are limited to hospitals with the highest level of obstetric service. In addition, this project identified problems with using the metric for extended length of stay as a measure of resource use.

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Contents

List of Figures

List of Tables

Abbreviations

AHA	American Hospital Association
DPH	Department of Public Health
ICD-9-CM	International Classification of Diseases, 9th Revision, Clinical Modification
MMRC	Georgia Maternal Mortality Review Committee
NICU	Neonatal Intensive Care Unit
OCI	Obstetric Comorbidity Index

CHAPTER 1: INTRODUCTION

Background

In 1975, the March of Dimes introduced regional systems of obstetric and perinatal care as a strategy to ensure appropriate treatment was available to meet the needs of every patient despite economic constraints (Ryan, 1975). Regional systems involve coordinated resource allocation, risk assessment, and transport to an appropriate service level facility to prevent both the duplication of services and disparities in service allocation (Little & Merenstein, 1993; Rashidian et al., 2014; Simpson, 2011). Though the initial proposal called for integrated maternal and fetal care networks, the maternal component was never fully developed (Hankins et al., 2012). In 2010, the Joint Commission on Accreditation of Healthcare Organizations suggested strengthening obstetric regionalization as an approach to reduce the rising maternal death rate in the United States. To accomplish this goal, the American College of Obstetricians and Gynecologists and the Society for Maternal Fetal Medicine developed detailed definitions of hospital obstetric levels of service and called for implementation of these definitions by delivery hospitals (American College of Obstetricians and Gynecologists et al., 2015).

Inconsistencies in the implementation of levels of service and other state level variations in regionalization hinder research about graduated hospital levels of obstetric service in the United States (Rashidian et al., 2014). Each state defines hospital levels of service differently and only 18 states require outside review to ensure correct identification of a hospital’s level of service (Blackmon, Barfield, & Stark, 2009). Some hospitals report the highest maternal or neonatal level of service despite the absence of any local maternal fetal medicine specialists or neonatologists (Brantley, Davis, Goodman, Callaghan, & Barfield, 2017; Goodman, Fisher, Little, Stukel, & Chang, 2001). Wide variation in hospital resources prevents precise mapping of resources to level of service resulting in defined levels of service that may not reflect the clinical capacity of hospitals (Korst et al., 2015). This confounds determining the associations between delivery outcomes and hospital levels of obstetric service.

In the United States, measurement of hospital levels of obstetric services are independent from the measure of level of neonatal services (Brantley et al., 2017). Only 49% of hospitals with the highest level of neonatal service, a level III neonatal intensive care unit (NICU), also have the highest level of obstetric service, an obstetric critical care unit (Brantley et al., 2017). This may be appropriate because a woman may need a NICU for her infant without needing obstetric critical care for herself (Hankins et al., 2012). However, a woman who needs an obstetric critical care unit likely also requires a NICU, but only 67% of hospitals in the United States with obstetric critical care units have an adjacent level III NICU (Brantley et al., 2017). Discordant levels of service may further confound estimates of benefits.

Another challenge of estimating benefits of hospital levels of obstetric service is due to the complexity of the data needed to evaluate delivery outcomes. Limited linking between vital statistics and medical record data has prevented inclusion of variables that control for bias such as transfer of care, obstetric risk status, and fetal death (Dooley, Freels, & Turnock, 1997; Glance et al., 2014; Lubchenco et al., 1989). For example, studies excluding fetal death, which accounts for approximately 50% of perinatal mortality, are biased against hospitals best equipped to prevent fetal death and thus are likely to underestimate the neonatal benefit a higher level of obstetric service may provide (MacDorman & Gregory, 2015; Phibbs et al., 2007). A recent systematic review found only three studies on perinatal regionalization with a low risk of bias, and only one found a significant decrease in neonatal and infant mortality due to higher levels of neonatal service (Rashidian et al., 2014). To date, the only consistently identified benefit of hospital levels of perinatal service is improved survival for very low birth weight neonates weighing less than 1500 grams at delivery (Lasswell, Barfield, Rochat, & Blackmon, 2010).

Randomized controlled trials for obstetrical levels of service are not possible, so bias and confounding inherent in observational studies challenge accurate estimation of associations. For example, improvements in technology and protocol changes may confound study designs using before and after implementation data to compare outcomes (Heller et al., 2002). Studies that include multiple states may also fail to account for differences in measuring hospital level of service or may include confounding from other differences in the regionalization system (Lorch, Baiocchi, Ahlberg, & Small, 2012; Nowakowski et al., 2012). To overcome these state level differences, researchers use proxies such as hospital size or deliveries per annum, though these measures may not necessarily correlate with level of service (Heller et al., 2002; Moster, Lie, & Markestad, 1999; Tracy et al., 2006; Wright et al., 2010). Sociodemographic characteristics such as race and income are associated with both delivery at specific hospitals regardless of level of service and poor delivery outcomes, resulting in confounding that must be controlled (Dukhovny et al., 2012; Janssens, Holtslag, van Beeck, & Leenen, 2012; Richardson, Gabbe, & Wind, 1984; Viisainen, Gissler, & Hemminki, 1994).

Limitations and Benefits of Levels of Service

As an intervention strategy, designation of delivery hospital level of obstetric service may have a limited potential for improving maternal outcomes. One-third of maternal deaths occur outside the hospital and may not be addressed by designating risk-appropriate delivery hospitals (Costello, Azad, & Barnett, 2006; Geller et al., 2014). Improved definitions of levels of obstetric service also cannot address unintended pregnancy or inadequate prenatal care, two issues associated with maternal mortality (Moaddab et al., 2016). All hospitals must be prepared for unpredictable conditions, such as hemorrhage and sepsis, which account for a disproportionately large amount of maternal mortality and severe maternal morbidity (Pilkington et al., 2010; Rocha Filho et al., 2014; Studnicki, Craver, Blanchette, Fisher, & Shahbazi, 2014; Zeitlin, Papiernik, & Breart, 2004).

The initial proposal for levels of obstetric and perinatal service was intended to be a solution to the problem of limited life-saving resources including both technological and workforce-related resources (Callaghan, 2012; Holloway, 2001; Little & Merenstein, 1993; Ryan, 1975). Designation of levels of obstetric service assumes the services that are vital to the safety of women at high obstetric risk are both clearly identified and also limited to facilities with the highest level of obstetric service. Korst et al. (2015) reported that, in California, at least 90% of hospitals had 24-hour maternal-fetal medicine coverage, 24-hour neonatologist coverage, a 24-hour adult critical care unit, and a 24-hour blood bank. Differences did exist; few hospitals had a labor and delivery unit emergency response team, cardiac monitoring on the labor unit, and 24-hour in-house anesthesia service. Associations between these services and delivery outcomes are unknown. Two interventions that significantly reduce maternal mortality, universal implementation of post-cesarean compression devices and anti-hypertensive treatment protocols, can be implemented in hospitals with even the lowest level of obstetric service (Clark, Christmas, Frye, Meyers, & Perlin, 2014). Thus, if there is little variation between hospitals in the resources known to prevent maternal morbidity and mortality, it is unlikely outcomes for women at high risk are associated with hospital obstetric service level.

Implementing levels of obstetric service could allow matching the complexity of a woman's needs to the resources available at a delivery hospital to improve outcomes for women at high risk (American College of Obstetricians and Gynecologists et al., 2015; Lasswell et al., 2010). Studies of antecedents of maternal deaths suggest between one-third and one-half of maternal deaths are preventable with appropriate care (Geller et al., 2014; Lawton et al., 2014; Vangen et al., 2014). Problems in receiving appropriate care include both 1) identification of risk and 2) failure to transfer women at high obstetric risk to hospitals with higher levels of obstetric service. It is worth noting that these benefits require not only the implementation of graduated levels of obstetric service, but also 1) validated methods of predicting risk and 2) appropriate transfer of care. Models simulating maternal transport have suggested timely transport is associated with a shorter length of stay (Strobino et al., 1993). A persistent pattern in the United States is that factors other than physical condition or the services available at the delivery hospital drive decisions regarding antenatal transfer (Dukhovny et al., 2012; Strobino et al., 1993; Richardson et al., 1984). Unfortunately, studies from other medical specialties suggest patterns of transfer do not change after formal regionalization (Janssens et al., 2012).

Implementation of levels of obstetric service may result in further improvements in neonatal morbidity and mortality. Risk factors for maternal morbidity and mortality, such as a high body mass index and hypertensive disorders, have also been shown to impact neonatal outcomes including perinatal death, prematurity, and low birth weight (Freitas et al., 2012; Kilpatrick, Abreo, Gould, Greene, & Main, 2016; Liu et al., 2014; Sultan et al., 2012). Studies that control for maternal conditions, such as preeclampsia, strengthen the association between hospital level of neonatal service and neonatal mortality (Afrasiabi, Mohagheghi, Kalani, Mohades, & Farahani, 2014; Lasswell et al., 2010). Antenatal treatment of women's conditions is associated with lower rates of NICU admission, shorter NICU stays, reduced mortality for very low birth weight infants, and fetal death (Cetinkaya et al., 2014; Churchill, Duley, Thornton, & Jones, 2013; Freitas et al., 2012; Liu et al., 2014). Evidence suggests hospitals with higher levels of obstetric service may be more successful at delaying delivery for women at high obstetric risk (Lee et al., 2003; Lubchenco et al., 1989).

Importance of estimating effect of service levels

Though regionalization with formal implementation of consistently defined levels of obstetric service has potential to improve maternal outcomes, it is not without risks. Formalized regional systems have been associated with the closure of small, rural hospitals, which increases distance to care for rural women (Grytten, Monkerud, Skau, & Sorensen, 2014). Increased distance to care is correlated with inadequate prenatal care, increased use of interventions such as non-medically indicated induction of labor, and poor delivery outcomes (Grytten et al., 2014; Grzybowski, Stoll, & Kornelsen, 2011; Kozhimannil, Hung, Prasad, Casey, & Moscovice, 2014; Larson, Hart, & Rosenblatt, 1997; Simpson, 2011; Tu, Tu, & Tedders, 2012). Increased distance to a delivery hospital can also reduce the social support available during hospitalization, a factor that may be important to the transition from pregnancy to parenting (Reisz, Jacobvitz, & George, 2015).

In the original March of Dimes proposal for designated levels of obstetric service, transfer of care for women at high obstetric risk was balanced with a return to standard care once the woman was stabilized (Ryan, 1975). Evidence points instead to the increased use of interventions for low risk women, leading to concerns that requiring transfer to higher levels of obstetric service would exacerbate the existing overuse of interventions for women with low obstetric risk (Grzybowski et al., 2011; Morton, 2014). The dearth of evidence for improved outcomes with perinatal regionalization suggests the need to confirm benefits of delivery at the appropriate obstetric level hospital to justify the potential increased use of resources (Rashidian et al., 2014; Staebler, 2011).

Finally, changes in medical technology, health workforce, and hospital systems in the forty years since the original proposal for regionalization may have resulted in overlap of services between the highest and lowest level hospitals; a phenomenon that would reduce the benefit of diverting women to higher level hospitals for delivery (Holloway, 2001). Two urban phenomena, the growth of small volume specialty units and consolidation of delivery services within hospital systems, have left few differences between urban hospitals, while disparities persist in rural areas suggesting hospital level may be a proxy for location (Attar, Hanrahan, Lang, Gates, & Bratton, 2006; Howell, Richardson, Ginsburg, & Foot, 2002; Kozhimannil, Hung, Casey, & Lorch, 2016; McCormick & Richardson, 1995). Despite these changes, the American College of

Obstetricians and Gynecologists and the Society for Maternal Fetal Medicine have proposed new definitions of levels of obstetric service and are currently advocating for implementation of these definitions by delivery hospitals (American College of Obstetricians and Gynecologists et al., 2015). Understanding the benefits of designated levels of service, and the improvement in outcomes that could be achieved through adoption of the newly proposed definitions, would provide evidence to hospitals of the value of implementing the new definitions.

Purpose

The overriding purpose of this study was to test a method to examine the associations between graduated obstetric service levels and both maternal and neonatal outcomes for women at high obstetric risk as measured by objective indices. Step one was to identify a sample of women at high obstetric risk. This step required comparing and selecting a method for identify women at high obstetric risk as there is not currently a gold standard for identification of risk status in administrative data. Once the sample was identified using data-driven criteria, step two was the estimation of the difference in maternal morbidity and mortality when women at high obstetric risk delivered at hospitals with low levels of obstetric service compared to hospitals with the highest level of obstetric service. Included in this step was the comparison of odds of severe maternal morbidity, delivery hospitalization mortality, and extended length of stay. The final step was to explore the potential for obstetric regionalization to further improve neonatal outcomes by identifying associations between level of obstetric service and perinatal morbidity and mortality.

Project Description

This retrospective, data-based study employed a secondary analysis of linked vital records and hospital discharge data to examine the association between graduated hospital obstetric service levels and maternal and neonatal morbidity and mortality for women at high obstetric risk in Georgia.

Specific Aims

Specific aims and hypotheses of this project are as follows:

Aim One. The first aim is to identify associations between delivery hospital level of obstetric service and maternal outcomes for women at high obstetric risk.

H1: Women at high obstetric risk, identified via the maternal comorbidity index, delivering at hospitals without the highest obstetric service level as measured by the American Hospital Association Levels of Obstetric Care will have higher odds of direct obstetric death than will women at high risk delivering at hospitals with the highest obstetric service level.

H2: Women at high obstetric risk, identified via the maternal comorbidity index, delivering at hospitals without the highest obstetric service level as measured by the American Hospital Association Levels of Obstetric Care have higher odds of severe maternal morbidity than will women at high risk delivering at hospitals with the highest obstetric service level.

Aim two. The second aim is to identify associations between delivery hospital level of obstetric service and neonatal outcomes for women at high obstetric risk.

H1: Women at high obstetric risk, identified via the maternal comorbidity index, delivering at hospitals without the highest obstetric service level as measured by the American Hospital Association Levels of Obstetric Care will have higher odds of delivering an infant with low birth weight than will women at high risk delivering at hospitals with the highest obstetric service level.

H2: Women at high obstetric risk, identified via the maternal comorbidity index, delivering at hospitals without the highest obstetric service level, measured by the American Hospital Association Levels of Obstetric Care will have higher odds of delivering an infant prematurely than will women at high risk delivering at hospitals with the highest obstetric service level.

H3: Infants born to women at high obstetric risk, identified via the maternal comorbidity index at hospitals without the highest obstetric service level as measured by the American Hospital Association Levels of Obstetric Care have higher odds of perinatal death than infants born women at high risk who deliver at hospitals with the highest obstetric service level.

Aim Three. The third aim is to identify associations between delivery hospital level of obstetric service and length of stay for women at high risk of obstetrical complications.

H1: Women at high obstetric risk, identified via the maternal comorbidity index, delivering at hospitals without the highest obstetric service level as measured by the American Hospital Association Levels of Obstetric Care will have higher odds of extended length of stay than those delivering at hospitals with the highest obstetric service level.

Setting

The setting for this secondary data analysis was Georgia because it provided several opportunities to overcome the challenges of estimating the benefits of levels of obstetric service. First, the Georgia Department of Public Health has collaborated with

Emory University to link the vital statistics data and hospital discharge data necessary to test the hypothesis that directing women at high obstetric risk to deliver at hospitals with the highest level of obstetric service will reduce maternal and neonatal mortality and morbidity and result in shorter length of stay. Second, the state of Georgia has a high maternal mortality ratio thus improving the possibility of identifying any effect in such a rare outcome. Third, Georgia was an early adopter of perinatal regionalization and incorporates levels of obstetric service within its regionalization scheme. A map of Georgia Perinatal Regions is available in Appendix 1, and a listing of hospitals from each region included in this study is available in Appendix 2.

Significance

The primary significance of this study was its examination of both clinical outcomes and resource use to provide evidence that can inform policy makers at the state and local levels as they consider altering definitions of levels of obstetric service. In addition, this study was the first to attempt the complex analysis of levels of obstetric service using linked data, a methodology that can be applied to other administrative databases in other states. Use of the American Hospital Association levels of obstetric service also provided estimates based on a system currently in place in all states, improving generalizability. Finally, this study identified women at high obstetric risk using a validated maternal comorbidity index, thus introducing a standard measure of obstetric risk and providing evidence for clinicians on appropriate cut-offs for transfer of maternal care.

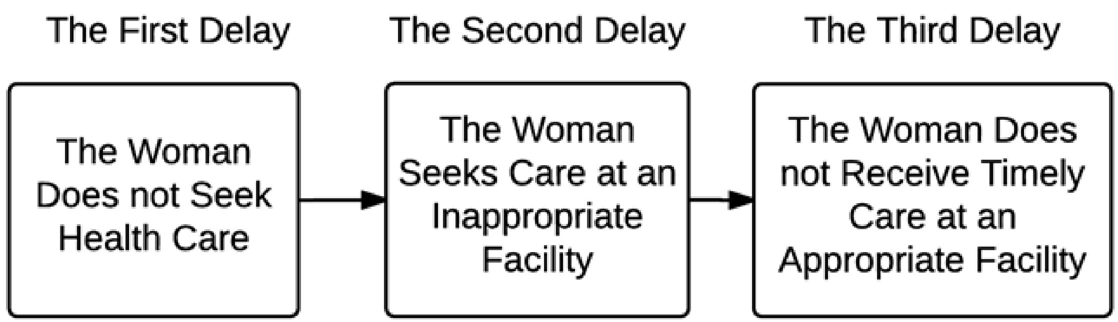
Theoretical Framework

The importance of a woman receiving care at a hospital with the appropriate obstetric service level is highlighted in the three delays framework introduced by

Thaddeus and Maine (Thaddeus & Maine, 1994). Per the framework, maternal death is the cumulative result of a lack of timely care. This framework identifies three points in care provision where delay threatens a woman's health to the extent that death may not be preventable, even when care is eventually provided. These points include the decision to seek care, reaching an appropriate health facility, and receiving adequate care at the facility. Originally created to highlight factors that lead to maternal mortality in both the developed and developing world, the framework has been used to describe maternal morbidity as well as neonatal and child mortality (Mbaruku, van Roosmalen, Kimondo, Bilango, & Bergstrom, 2009; Pacagnella, Cecatti, Osis, & Souza, 2012; Thaddeus & Maine, 1994; Upadhyay, Krishnan, Rai, Chinnakali, & Odukoya, 2014; Waiswa, Kallander, Peterson, Tomson, & Pariyo, 2010).

Identifying the hospital level of obstetric service is related to the second delay in the framework, reaching an appropriate health facility in a timely manner (See Figure 1). This second delay occurs when a woman has sought care, but does not receive care in an appropriate facility. In the United States, a delay in reaching an appropriate health facility may be due to failure to identify the patient's risk status or structural systems that discourage or limit transfers of care. Both a delay of identifying a patient as high risk as well as a failure to transfer to a higher level of care have been found to contribute to potentially preventable maternal morbidity and mortality in the United States and other developed countries (Geller et al., 2014; Lawton et al., 2014). A recent study identified delays of care in over half the cases of maternal mortality identified (Bauer, Lorenz, Bauer, Rao, & Anderson, 2015).

Figure 1: The Three Delays Framework



The three delays framework is unique in its ability to differentiate between health outcomes associated with graduated service levels and other currently used metrics. The focus of the three delays framework is the care seeking process immediately preceding death or morbidity rather than more distal antecedents such as the amount or quality of prenatal care received. The framework allows for the identification of delays from any cause instead of errors in individual caregiver decisions. The framework compares outcomes at groups of similar hospitals instead of individual hospitals to prevent confounding levels of obstetric service with hospital quality.

Assessing High Obstetric Risk

The lack of a gold standard for determining obstetric risk in administrative data has resulted in the use of inconsistent risk identification methods including comorbidity indices, lists of clinical conditions, or creating a unique variable based on the specific outcome of interest (Lindquist, Kurinczuk, Wallace, Oats, & Knight, 2015; Reddy et al., 2015; Wright et al., 2010). Other strategies rely on stratifying populations based on clinical guidelines or other lists of diagnoses associated with poor outcomes (Bolten et al., 2016; Kozhimannil, Casey, Hung, Prasad, & Moscovice, 2016). Some studies identify both physical and social factors to define high obstetric risk (Creanga, Bateman, Kuklina,

& Callaghan, 2014; Tolcher et al., 2016). What all these studies have in common is that identification of obstetric risk is measured as the presence of any condition or factor from the chosen list.

A comorbidity index designed to help standardize the control of obstetric risk in epidemiology studies may provide a standardized measure of obstetric risk (Bateman et al., 2013). The Obstetric Comorbidity Index (OCI) calculates a score for each woman by summing the weights of any conditions included in her hospital discharge record, a feature that allows the OCI to account for the complexity of each case. The index includes both pre-existing conditions and pregnancy complications and it significantly improves the classification of obstetric risk when compared to the Charlson Comorbidity Index and the Combined Comorbidity Score (Bateman et al., 2013). It was devised and validated using Medicaid Analytic eXtract data for 2000-2007 and has been validated for use with hospital administrative data (Metcalfe et al., 2015).

McGinn (2000) pointed out that models built to control for confounding are created in a fashion similar to clinical decision rules, which may indicate the OCI could act as a metric that assesses the complexity of comorbid conditions when identifying obstetric risk. However, before the OCI can identify a sample of women at high obstetric risk, a cut-off must be determined to allow dichotomous indication of risk status. The first part of this project evaluated potential cut-off points and assessed the usefulness of the OCI for identification of high-risk pregnancies in administrative data.

For the OCI to be useful, it must provide a better stratification of high obstetric risk than the existing dichotomous methods of including any woman with a comorbidity. This comparison must take into consideration that the prediction of obstetric risk status with a preventive model is intended to ensure appropriate care to minimize the likelihood of a poor outcome. Because of this, some women at high obstetric risk will not have a poor obstetric outcome even though the calculation of specificity and sensitivity would categorize them as false-positives. As the number of potential false-positives increases, the risk for misclassification bias also increases. An analytic method that provides comparison of risk identification methods while allowing for the uncertainty of the false-positives with a preventive model is net benefit analysis. This study compared the ability of the OCI to create a high-risk group against the ability of creating a group by including all women with any comorbidity. Because the OCI does not represent clinical decision making, the index was also compared to a current clinical practice guideline for identifying risk.

Assessing Hospital Obstetric Service Level

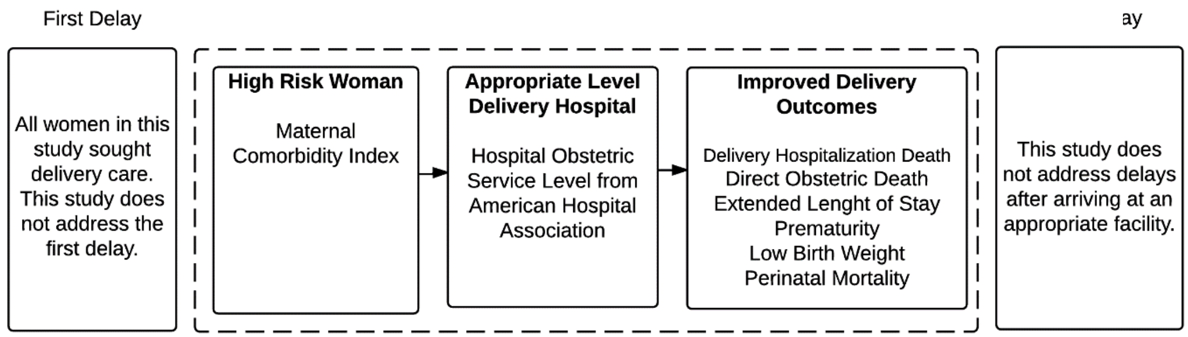
Though the original call for perinatal regionalization recommended both neonatal and obstetric levels of service, only the neonatal levels of service underwent development and testing (Hankins et al., 2012). In the absence of consistent and meaningful levels of obstetric service, researchers have relied on imprecise proxies such as teaching status or mean complication rates to stratify hospitals (Glance et al., 2014; Panchal, Arria, & Labhsetwar, 2001). Several studies have used ordinal distinctions based on number of hospital beds or annual deliveries, though the cut-offs have not been applied consistently (Moster et al., 1999; Tracy et al., 2006; Wright et al., 2010). As previously explained, linking these proxy measures to meaningful levels of obstetric service may not be possible (Korst et al., 2015).

Though the March of Dimes proposed a national standard for obstetric service levels, state-specific systems of service levels hinder the generalizability of evaluations based on this system (Rashidian et al., 2014). Georgia hospitals do participate in the American Hospital Association (AHA) annual survey which includes a self-identified obstetric level of service. AHA uses a three-tier system based on the types of patients served with level I representing the most basic obstetric care for low risk women and level III indicating the highest level of obstetric service for critically ill women (American Hospital Association, 2012). Because this is included in a national survey, this system is generalizable to all states. In addition to the AHA obstetric levels, Georgia hospitals also report an obstetric service level to the Georgia Department of Public Health (DPH). The DPH enhances the AHA categories by 1) defining the minimum capabilities of a basic obstetric hospital and the types of health care providers who would work at each level and 2) identifying some level III facilities as regional perinatal centers with administrative duties within the regionalization system (Barfield et al., 2012; Maternal & Child Health Section Office of Family and Community Health, 2013). The full description of DPH obstetric levels is included in Appendix 3. Like the AHA levels of obstetric service, the DPH levels of service are self-identified by hospitals, however these levels of service were recently reviewed for measurement accuracy (Barrera, 2015).

Evaluating Effect of Delivery Hospital Obstetric Level

Outcomes selected for this project meet two criteria: 1) the needed variables are in administrative data, and 2) measurement uses a standard definition or algorithm. Use of standardized outcomes allows reproduction of this study. In addition, the use of standardized measures improves the ability to synthesize the results of this study with the results of other studies. See figure 2 for a list of measures within the context of the three delays framework.

Figure 2 Situation of Measures within the Three Delays Framework



In the three delays model, a delay in reaching a facility that provides the appropriate level of obstetric service is an antecedent to maternal mortality. Both delays of care and failure to identify the need for higher level service contribute to maternal mortality in the United States, though there is disagreement on the proportion of these deaths that are preventable (Bauer et al., 2015; Berg et al., 2005; Clark et al., 2008). Despite recent increases in maternal mortality, overall maternal mortality remains rare with 21.5 deaths per 100,000 live births in 2014, making the identification of effects of hospital level of obstetric service on maternal mortality difficult (Creanga, Berg, et al., 2014; MacDorman, Declercq, Cabral, & Morton, 2016; Moaddab et al., 2016). Because of this, the focus of research on maternal mortality has shifted to near-miss mortality.

Near-miss maternal mortality represents cases in which the woman presented with a pregnancy-related life-threatening condition but survived (Say, Souza, & Pattinson, 2009). Cases of near-miss mortality are considered valuable for understanding problems in the delivery of health care and the health conditions that put women at risk for mortality, as well as identifying opportunities for improvement in health systems and women's health (Avenant, 2009; Creanga, Berg, et al., 2014; Say et al., 2009). In the United States, near-miss maternal mortality is termed severe maternal morbidity, as cases of near-miss mortality are at the extreme end of a continuum of maternal morbidity (Geller et al., 2004). Though the American College of Obstetricians and Gynecologists does not endorse any specific definition of severe maternal morbidity, one algorithm allows identification by ICD-9-CM condition and procedure codes in administrative data (Kilpatrick & Ecker, 2016; Creanga, Berg, et al., 2014). In the United States, incidence of severe maternal morbidity as measured by this algorithm has increased along with the increase in maternal mortality; racial disparities exist for both (Callaghan, Creanga, & Kuklina, 2012; A. A. Creanga et al., 2012; Howell, Egorova, Balbierz, Zeitlin, & Hebert, 2016; M. F. P. MacDorman et al., 2016; Moaddab et al., 2016). This study evaluated the effect of delivery hospital level of obstetric service on the odds of death during delivery hospitalization and severe maternal morbidity.

Extended maternal length of stay is associated with maternal comorbidities and provides information beyond patient condition (Krell, Girotti, & Dimick, 2014; Metcalfe et al., 2015). In the context of obstetric care, an extended length of stay may indicate appropriate antenatal care because delaying delivery to reduce prematurity is associated with longer antenatal length of stay (Helenius, Helle, & Lehtonen, 2016). This study estimated the effects of delivery hospital obstetric level on the odds of extended length of stay. Because of the complexity of interpreting an analysis for extended length of stay, it is important to consider neonatal outcomes.

Given the dependence of the fetus on maternal health conditions and outcomes, it is worth considering whether the delivery hospital level of obstetric service results in improved neonatal outcomes for women at high obstetric risk. Indeed, the evidence points to increased risk for preterm delivery and an increased length of NICU stay for infants born to women with certain obstetric conditions (Afrasiabi et al., 2014; A. M. Allen et al., 2015; Farr et al., 2017; Habli, Levine, Qian, & Sibai, 2007; Watson, Rowan, Neale, & Battin, 2003). Preterm delivery is more common among women with confirmed severe maternal morbidity (Kilpatrick, Anisha Abreo, Jeffrey Gould, Naomi Greene, & Elliot K. Main, 2016). Though studies are beginning to show that providing care for maternal conditions is associated with improved neonatal outcomes, the extent of association with levels of obstetric service and improved neonatal outcomes is unknown (Cetinkaya et al., 2014; Lee et al., 2003). This project evaluated the association between hospital level of obstetric service and neonatal outcomes by examining differences in odds of preterm delivery, low birth weight status, and perinatal mortality. Because hospitals differ in the resources available to care for newborns, this analysis included control for hospital level of neonatal service, also known as NICU level (Aliaga, Boggess, Ivester, & Price, 2014).

Limitations

As this was a secondary data analysis, the analyses undertaken for this project were limited to the inclusion of variables in the data sets that have been linked, as well as the accuracy of the data represented by those variables. Both vital statistics and hospital discharge data have variables with moderate or poor sensitivity or specificity, and this limitation is widely acknowledged and considered acceptable because the calculations for risk and morbidity used in this study have been validated for use with administrative data and are considered adequate for research (Allen et al., 2012; Dietz et al., 2015; Yasmeen, Romano, Schembri, Keyzer, & Gilbert, 2006). This project was also limited to the distribution of deliveries within Georgia and any disparities in identification of high risk status or access to both higher service level hospitals or ability to transfer that existed.

These data did not provide measurement of maternal readmission, a variable that would improve estimates of resource use. Similarly, these data did not provide variables necessary to include all sociodemographic factors associated with maternal and perinatal morbidity and mortality. These limitations were acceptable for this project because the use of data that do include readmission and sociodemographic variables would limit the size of the sample and could prevent linking out of hospital deaths to the main data. This study was intentionally weighted to report on clinical outcomes with the understanding that further research of resource use and sociodemographic factors will follow if hospital levels of obstetric service are found to be associated with maternal and neonatal outcomes.

This study was limited to analyzing the effects of the second delay in the three delays framework using ICD-9-CM coding to identify women at high risk. These limitations prevented this study from providing information about 1) outcomes of women who did not seek hospital care at delivery, 2) women whose risks were not identified, and 3) women whose identified risks were not coded in the hospital discharge record. When these data were collected, there was one birth center in Georgia, however, birth center delivery was only available to women with low obstetric risk and thus unlikely to affect the findings of this study.

Data for this project did not differentiate between women whose obstetric risk status was not identified until after hospital admission and women who were identified as having high obstetric risk but safe transfer to a higher service level hospital was not completed. This was acceptable because 1) the three delays framework measures the existence of a delay but not the reason for the delay and 2) this study does not attempt to assess the obstetric transfer system, but only to determine if delivery hospital level of service is associated with maternal and perinatal outcomes for women at high risk.

CHAPTER TWO: NET BENEFIT ANALYSIS OF OBSTETRIC HIGH RISK SAMPLE SELECTION METHODS

Abstract

Research Objective: The objective of this study was to compare the value of the Obstetric Comorbidity Index (OCI) in identifying a sample of women at high obstetric risk to the conventional practice of sample selection by identifying all comorbidities equally. Conventional sample selection uses dichotomous identification of various comorbid conditions or social factors resulting in an inconsistent standard and oversimplification of clinical complexity. The recently proposed OCI may provide a more consistent and precise epidemiologic definition of high obstetric risk because it provides a specific list of ICD-9-CM codes and applies weights to comorbidities to account for clinical complexity.

Study Design: The high-risk sample created by the OCI was compared to two other samples using net benefit analysis because it allowed comparison of the trade-off between misclassification of high risk and identification of poor outcomes. The two control samples included: 1) one created through dichotomous identification of any comorbidities from the OCI and 2) one created by dichotomous identification of any comorbidities from a clinical practice guideline. Comorbidities were identified by ICD-9-CM diagnosis codes from hospital discharge data. The weighed score from the OCI was transformed to a dichotomous indicator by assigning a cut-off value identified using net benefit analysis.

Population Studied: Women with singleton deliveries of live and stillborn infants in hospitals in Georgia for years 2008-2012.

Principal Findings: The sample created with the OCI had a small but positive net benefit (0.6), while control samples both had negative net benefits.

Conclusions: The obstetric comorbidity index was the only method created a sample with a positive net benefit, though all models had relatively poor sensitivity. The low specificity of the conventionally selected samples may result in misclassification bias that skews estimates to the null if used in research.

Implications for Policy or Practice: Researchers can use the obstetric comorbidity index for the sample selection of women at high obstetric risk in administrative data to help reduce misclassification as high obstetric risk while also improving the generalizability of findings.

Background

Epidemiological studies examining maternal morbidity and mortality have relied on inconsistent methods to define samples of women at high obstetric risk. Researchers have defined obstetric risk by inconsistent lists of social or medical conditions such as hypertension, diabetes, and insufficient prenatal care (Howell, Egorova, Balbierz, Zeitlin, & Hebert, 2015; Lindquist et al., 2015; Suidan, Apuzzio, & Williams, 2012; Tolcher et al., 2016). Other researchers have defined obstetric risk with clinical guidelines that may not be appropriate for epidemiological research because they 1) do not differentiate between maternal and fetal risk, 2) focus on identifying low-risk pregnancies to determine who is eligible for midwifery care or out-of-hospital birth, and 3) rely on clinical information not available in administrative data (Australian College of Midwives, 2013; Bolten et al., 2016; Kozhimannil, Casey, et al., 2016; Ministry of Health, 2012; National Institute for Health and Care Excellence, 2008). A standard definition of obstetric risk that can identify women in need of specialist care in administrative data would help improve comparability for observational studies.

In 2013, Bateman and colleagues proposed a comorbidity summary measure weighted specifically for conditions that affect women during pregnancy, childbirth, and the immediate postpartum period. This summary measure was created using regression models that identified the strength of association between comorbidities and end organ damage or mortality during delivery hospitalization (Bateman et al., 2013). The obstetric comorbidity index (OCI) improves the precision of risk identification by assigning weight to each condition to account for the complexity of multiple conditions (Tolcher et al., 2016).

Comorbidity summary scores, such as the OCI, have been suggested as indicators of clinical prognosis because of their predictive ability; summary scores performed better at discrimination and prediction of poor outcomes than identifying each comorbidity individually (Colinet et al., 2005; Thompson et al., 2015). Because of this, use of the OCI to identify obstetric risk may allow for both a standard definition and precise identification of a sample of women at high risk.

Purpose

The purpose of this study was to compare the net benefits of a sample of women at high obstetric risk selected in administrative data using the OCI, a clinical guideline, and the conventional method. All methods of sample selection were compared to the theoretical condition of assigning no women as high-risk.

Methods

This study was conducted as a retrospective cohort study using a net benefit approach.

Setting & Participants

This study was conducted using data from the Georgia Maternal Child Health Repository. This repository was created by linking hospital discharge data for all singleton delivery hospitalizations to birth, fetal death, and maternal death certificates. The repository includes 1,562,238 unique records for Georgia residents between 1999 and 2012. The hospital discharge data was used with permission of the Georgia Hospital Association and contained up to ten ICD-9-CM diagnostic and five ICD-9-CM procedure codes for each hospitalization. Maternal death certificates were identified by either an ICD-10 indicating maternal death or the checked box on death certificate and were linked to hospital discharge using a longitudinal ID. Linkage was successful for over 86% of live births.

The sample for this study included all deliveries in the Repository that occurred between 2008 and 2012. As these data did not include personal identifying information, this project was determined by the author's institutional review board as not meeting the federal definition of human subject research and did not require institutional review board approval.

Variables & Data Sources

High-Risk Identification Models. Three unique samples of women at high obstetric risk were identified using the three models.

The experimental sample was created using the comorbid conditions included in the Obstetric Comorbidity Index (OCI). The OCI was created by a logistic regression model testing 24 comorbidities identified in the literature. Of these, 20 were found to have a strong enough association to warrant inclusion in the final model (Bateman et al., 2013). The index provides a score by summing individual weights for each condition, the weights having been derived from the beta coefficient in the model. The overall score, but not the individual weights, has been validated to improve the prediction of maternal end organ damage compared to the Charlson, and the OCI has been validated with hospital discharge data in a separate sample (Bateman et al., 2013; Metcalfe et al., 2015). Scores for the OCI in the Georgia Maternal Child Health Repository ranged from 0-12 with a mean score of 0.55 (SD 0.90) compared to a score range from 0-19 with a mean score of 0.91 (SD 1.42) in the validation cohort when the maternal comorbidity index was created (Bateman et al., 2013). A cut-off value to indicate high obstetric risk status was selected using a net benefit analysis comparing the range of OCI scores in the data. The cut-off was selected to be a score of 4.

The first control group was created through the application of the conventional practice of creating a dichotomous value in which presence of any comorbid condition included in the OCI resulted in designation as obstetric high risk. This is the method currently used in the literature, though the specific list of conditions varies between studies (Howell et al., 2015; Suidan et al., 2012; Tolcher et al., 2016). By applying the standard practice with the same conditions used for the OCI, this study compared the value of the index summary score rather than the appropriateness of the specific comorbidities included in the OCI.

A second control group was created through the application of the conventional practice of creating a dichotomous value in which the presence of any comorbid condition listed in the New Zealand Guidelines for Obstetric Transfer resulted in designation as obstetric high risk. These guidelines were selected because they represent a risk identification method currently used in clinical practice and include a category for immediate transfer of care as an indication of high-risk status (Ministry of Health, 2012). Though transfer guidelines are included in Georgia's Perinatal Care Guidelines, the Georgia transfer guidelines are a list of conditions that warrant consideration of transfer rather than a standard list of conditions requiring transfer, and they are therefore less precise than guidelines which indicate a definite need for transfer (Maternal & Child Health Section Office of Family and Community Health, 2013). The New Zealand Guidelines for Obstetric transfer differ from the obstetric comorbidity index because they include both maternal and fetal conditions requiring transfer. Though the guidelines were created based on evidence of risk, no validation of the guidelines could be found.

Models to identify high obstetric risk are only useful if the model used performs better than treating no women as high obstetric risk (Vickers & Cronin, 2010; Vickers & Elkin, 2006). A model in which no woman is recognized as high obstetric risk is represented by a net benefit of zero; a negative net benefit indicates a model that performs worse than identifying no woman as high-risk.

Comorbid conditions for all models were identified using ICD-9-CM diagnostic codes in the medical record, which is consistent with prior literature addressing high-risk pregnancy (Kozhimannil, Casey, et al., 2016; Tolcher et al., 2016). The authors of the OCI provided the full list of included ICD-9-CM codes in their publication and are included as Appendix 4 (Bateman et al., 2013). These codes were used without alteration for the experimental group and the first control group. The New Zealand Guidelines for Obstetric Transfer do not include specific ICD codes to identify the conditions. As such, codes reflecting the conditions were selected to create the second control group using the codes identified in the OCI whenever appropriate. Codes used for the New Zealand Transfer Guidelines are listed in Appendix 5.

Predicted Outcome. The predicted outcome for this study was poor maternal outcome defined as either severe maternal morbidity or maternal mortality.

Maternal mortality was limited to direct obstetric deaths as defined by the World Health Organization and identified by ICD-10-CM codes on the maternal death certificate (World Health Organization, 2012a). The use of direct obstetric death allows a reproducible measure of maternal mortality beyond delivery hospitalization and is limited to deaths related to pregnancy. However, this definition is limited to 42 days postpartum and does not include deaths due to previously existing disease, even if the disease was aggravated by the physiologic effects of pregnancy, which differs from definition of pregnancy related mortality (Callaghan, 2012).

Severe Maternal Morbidity was calculated using a standard algorithm that identifies maternal end organ damage from ICD-9-CM diagnosis and procedure codes (Callaghan et al., 2012). This algorithm updated previous lists of codes that identified specific complications and used length of stay less than the 90^{th} percentile to eliminate diagnosis codes that may have been used to “rule out” conditions. When compared to the gold standard of medical record review, this method had a sensitivity of 77% for identifying severe maternal morbidity (Main et al., 2016). The most common problem with this algorithm is the ICD code for transfusion has a high rate of false positive because it is unable to discriminate between any transfusion and transfusion of four units that indicates severe maternal morbidity (Main et al., 2016). To prevent overestimation of severe maternal morbidity, this study did not include the ICD code for transfusion in the severe maternal morbidity algorithm. A sensitivity analysis was performed that included the ICD-9-CM code for transfusion to identify the potential extent of underestimation due to this change in calculation (Callaghan et al., 2012; Creanga et al., 2014).

Analysis

The samples created by each method were described by the sample size, sensitivity, specificity, positive predictive value, and the odds ratio for poor maternal outcome.

The samples were compared with net benefit. Net benefit analysis provided a comparison that allowed for a difference in value of benefit and harm, known as the exchange rate (Vickers, Van Calster, & Steyerberg, 2016). Classically, net benefit analysis is dependent on patients' valuation of the exchange rate (Vickers & Elkin, 2006). This is not possible for an epidemiological study; instead the models were compared using an exchange rate that matched the statistical threshold for a model, that is the probability of being identified as high obstetric risk by that model (Steyerberg et al., 2010; Vickers, Cronin, Elkin, & Gonen, 2008; Vickers et al., 2016).

The net benefit was calculated using the formula

$$Net\ Benefit = \frac{True\ Positives}{n} - \frac{False\ Positives}{n}\left(\frac{pt}{1-pt}\right)$$

where n is the total number of patients and pt is the probability of being identified as high risk (Steyerberg et al., 2010). In net benefit analysis, the method with the highest net benefit is considered superior.

Results

Participants

The sample derived from the repository for years 2008-2012 included 550,237 unique delivery hospitalizations. The mean maternal age was 27.04 years (SD 6.1) and the mean gestational age at delivery was 38.7 weeks (SD 2.2). Of these hospitalizations, 2,654 (0.5%) were identified as having a poor maternal outcome. The most common comorbidities identified in the OCI were previous cesarean delivery (17%), age 35-39 years (9.4%), and gestational hypertension (4.5%). The proportion of women with each comorbidity experiencing the outcome varied from 25.8% of women with chronic congestive heart failure to 0.6% with gestational hypertension. Full distributions are available in Table 1. Distributions of the conditions included in the New Zealand Transfer Guidelines are available in Table 2.

Table 1 Distribution of conditions included in the Obstetric Comorbidity Index among

	Total n=550,237	Rate per 1,000 deliveries	Women with Morbidity or Mortality n = 2654
Maternal age (years)			
Older than 44	673	1.22	12 (1.8%)
40-44	12499	22.72	136 (1.1%)
35-39	57879	105.19	429 (0.7%)
Gestational hypertension	24632	44.77	150 (0.6%)
Mild or unspecified preeclampsia	16350	29.71	332 (2.0%)
Asthma	12159	22.10	87 (0.7%)
Previous cesarean delivery	93634	17.02	648 (0.7%)
Severe Preeclampsia or Eclampsia	7062	12.8	550 (7.8%)
Pre-existing diabetes mellitus	4638	8.43	87 (1.9%)
Drug abuse	3947	7.17	39 (1.0%)
Pre-existing hypertension	2471	4.49	100 (4.0%)
Placenta previa	2439	4.43	117 (4.8%)
Cardiac valvular disease	2073	3.77	32 (1.5%)
Chronic renal disease	1258	2.29	81 (6.4%)
HIV	974	1.77	7 (0.7%)
Sickle cell disease	875	1.59	114 (13%)
Systemic lupus erythematosus	601	1.09	14 (2.4%)
Multiple gestation*	588	1.07	7 (1.2%)
Congenital heart disease	374	0.68	12 (3.2%)
Alcohol Abuse	272	0.49	4 (1.5%)
Pulmonary hypertension	88	0.16	13 (14.8%)
Chronic ischemic heart disease	71	0.13	2 (2.8 %)
Chronic congestive heart failure	31	0.05	7 (22.6%)

*Data was limited to singleton gestation by birth certificate
Note: ICD codes included for each set of conditions can be found in Appendix 4.
women delivering in Georgia, 2008-2012

Table 2 Distribution of conditions included in the New Zealand Transfer Guidelines among women delivering in Georgia, 2008-2012

	Total n=550,237	Rate per 1,000 deliveries	Women with Morbidity or Mortality n = 2654
Conditions in Pregnancy	87274	158.61	1369 (51.6%)
Endocrine Disorders	30663	55.73	232 (8.7%)
Cardiovascular Disorders	16949	30.80	310 (11.7%)
Neurological	1946	3.54	38 (1.4%)
Hematologic Disorders	1776	3.23	136 (5.1%)
Autoimmune Disorders	748	1.56	80 (3%)
Gastroenterological Disorders	192	0.35	1 0.04%
Infectious Diseases	73	0.13	3 (0.1%)
Renal Disease	57	0.10	11 (0.4%)
Organ Transplant	55	0.10	3 (0.1%)
Acute Unstable Psychosis	39	0.07	2 (0.08%)
Cystic Fibrosis	34	0.06	1 (0.04%)
Marfan’s	26	0.05	1 (0.04%)

Note: ICD codes included in each set of conditions can be found in Appendix 5.

Model Characteristics

Using the cut-off value of 4 for the score of the OCI identified 7,260 (1.3%) women as high obstetric risk. The conventional method of counting the presence of any comorbidity from the OCI identified 193,247 (35.1%) women as high obstetric risk. Using the presence of any comorbidity from the New Zealand Transfer Guidelines, identified 118,441 (21.5%) women as high obstetric risk. The samples varied greatly in their sensitivity and specificity (see Table 3). The experimental sample had the lowest sensitivity (16.4%), but the highest specificity (98.7%), positive predictive value (6%), and odds ratio for poor maternal outcome (OR 15.6 95% CI 14.0-17.3). The sample built from the New Zealand Transfer Guidelines was superior to the sample created using the conventional method with comorbidities from the OCI.

Main Results

The experimental sample created using a cut-off value with the OCI was superior to both control samples built using the conventional sample selection. The other models resulted in negative net benefit, which indicated they perform worse than identifying no woman as high risk (See Table 3). The OCI with a cut-off value of 4 remained the superior risk identification method in the sensitivity analysis.

Table 3 Description of accuracy of high-risk pregnancy models to predict severe maternal morbidity or direct obstetric death

	Obstetric Comorbidity Index	Unweighted Obstetric Comorbidity Index	New Zealand Transfer Guidelines
Total High Risk	7260 (1.3%)	193,247 (35.1%)	119,824 (21.8%)
True Positives	436	1588	1646
Sensitivity	16.4%	59.8%	62%
Specificity	98.7%	65%	78.4%
Positive Predictive Value	6%	0.8%	1.4%
OR (95% CI)	15.6 (14.0, 17.3)	2.8 (2.6, 3.0)	5.9 (5.5, 6.4)
Net Benefit	0.7	-185.7	-56.8

Discussion

This study compared methods of identifying a sample of women at high obstetric risk in administrative data using net benefit analysis. In this analysis, only the experimental sample created using a cut-off value with the OCI had a positive net benefit. Though both the conventional method of using any comorbidity from the OCI and using any comorbidity from the New Zealand Transfer Guidelines had better sensitivity, they had low specificity which likely results in misclassification of high obstetric risk. Both control samples had negative net benefits meaning it is likely that the harm due to potential misclassification as high-risk outweighed the benefit of correctly identifying women as high-risk. The high rate of misclassification in the control groups would skew the result of any study toward the null.

One unexpected result was that the conventional model using the New Zealand Transfer Guidelines was superior to the conventional model that identified risk as the presence of any comorbidity included in the OCI. This finding is interesting because unlike the OCI, the New Zealand Transfer Guidelines include conditions considered fetal, but not obstetric, risk factors. Additional research is needed to understand why this occurred.

The low sensitivity of all models raises questions about the ability to identify obstetric risk in administrative data. A recent call for hospital level screening and review of cases of severe maternal morbidity will likely result in more precise clinical definitions of risk, which can help improve epidemiologic risk prediction models (Kilpatrick & Ecker, 2016). Net benefit analysis may be useful not only to compare sample selection methods, but also to select the best comorbidities and social factors to include in a sample selection model.

Limitations

Identification of a sample of women at high obstetric risk in administrative data requires access to variables that code for comorbidities. The methods tested in this paper rely on ICD-9-CM codes, which may not reflect the true comorbidity in the community (Chantry et al., 2011; Lash, Abrams, & Bodnar, 2014). ICD-9-CM codes are not a precise representation of the clinical condition of a patient, making it difficult to code some criteria from the New Zealand Transfer Guidelines (Ministry of Health, 2012). For example, administrative data records only include that gestational diabetes was present, not if it was well controlled. Because of the lack of precision, clinical guidelines, such as the New Zealand Transfer Guidelines, are likely to perform better at identifying high obstetric risk in clinical practice than in epidemiological research.

This study was limited to risk identification methods that relied on comorbid conditions. However, sociodemographic characteristics such as poverty and race are also associated with maternal morbidity and mortality (Dukhovny et al., 2012; Janssens et al., 2012; Richardson et al., 1984; Sparks, 2009; Viisainen et al., 1994). High obstetric risk sample selection methods that include sociodemographic characteristics may improve sensitivity and specificity.

To use the OCI as a sample selection tool rather than to control for confounding, a cut-off value was selected by net benefit analysis. Though the cut off was superior for these data it is unlikely to be generalizable. These data were limited to singleton deliveries due to the linking protocol and appeared to include underreporting of some outcomes such as alcohol abuse. Such underreporting of alcohol abuse has been reported previously, which suggests this variable may be an inherent limitation to use of the OCI as proposed (Metcalfe et al., 2015).

Implications

The present findings highlight the usefulness of the OCI as a tool to select a sample of women at high obstetric risk for epidemiologic studies. The OCI was superior to the standard practice of identifying women at high obstetric risk with the presence of any comorbidity. Researchers who use the OCI should be aware of the potential for underreported comorbidities and therefore select the cut-off based on the data.

This analysis has shown that sensitivity for epidemiological definitions of high obstetric risk is low. This is an important finding as it may indicate the current understanding of obstetric risk is not precise enough to create a standard epidemiological definition that will prevent misclassification bias during sample selection. It is possible another obstetric risk identification model not tested in this study is superior to the OCI as a sample selection tool. Future research should continue to compare the usefulness of high obstetric risk sample selection methods for epidemiologic data.

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CHAPTER THREE: ASSOCIATIONS BETWEEN DELIVERY HOSPITAL LEVEL OF OBSTETRIC SERVICE AND MATERNAL DELIVERY OUTCOMES

Abstract

Research Objective: This study explored the associations between maternal outcomes for women with high obstetric risk and delivery hospital level of obstetric service as defined by the American Hospital Association.

Study Design: This study estimated the odds of poor maternal outcome and extended length of stay for women identified as high obstetric risk. High obstetric risk was defined using a sample-specific cut-off of the risk score calculated from the Obstetric Comorbidity Index. Poor maternal outcome was defined as either severe maternal morbidity or death during delivery hospitalization. Analysis was completed using hierarchical logistic regression with a 1 level model at hospital level controlling for maternal race and transfer status.

Population Studied: Women with singleton deliveries of live and stillborn infants in hospitals in Georgia for years 2008-2012.

Principal Findings: There were no differences in mean obstetric risk score by hospital level. There was no difference in odds of poor maternal outcome, however women at hospitals with obstetric level I and II had lower odds of extended length of stay.

Conclusions: The American Hospital Association’s levels of obstetric service do not appear to stratify hospitals according to the resources necessary to provide care for women at high obstetric risk.

Implications for Policy or Practice: Future research should identify the resources associated with improved outcomes for women at high obstetric risk to define evidence-

based categories of hospital level of service. Systems to categorize hospitals according to level of obstetric service should be validated prior to implementation.

Background

Recent increases in maternal morbidity and mortality have renewed interest in a formalized system of levels of obstetrical service, referred to as regionalization (Hankins et al., 2012; American College of Obstetricians and Gynecologists et al., 2015; Staebler, 2011). Under a regional system, hospitals would be “leveled” based on the availability of designated obstetrical capabilities. In such a system, women at high obstetric risk would be identified early and directed to a delivery hospital with the appropriate level of obstetric service where the care provided will be commensurate with the complexity of the case (Joint Commission on Accreditation of Healthcare Organizations, 2010; Little & Merenstein, 1993; Pacagnella et al., 2014). Studies of antecedents of maternal deaths suggest between one-third and one-half of maternal deaths could be prevented with appropriate care (Geller et al., 2014; Lawton et al., 2014; Vangen et al., 2014). At this point, evidence to support improvement of maternal outcomes with delivery at hospitals with higher levels of obstetric service is lacking, and challenges in measuring the association between obstetric service levels and maternal outcomes persist.

Objectives

The purpose of this study was to test the ability to explore associations between the delivery hospital level of obstetric service and maternal outcomes for women at high obstetric risk. The specific objectives were to identify differences by hospital level of obstetric service in 1) the odds of maternal mortality or severe maternal morbidity, and 2) the odds of extended length of stay.

Methods

This was a retrospective cohort study of linked administrative and vital statistics data from Georgia.

Setting

Between 2008-2012, Georgia averaged around 140,000 live births per annum. The pregnancy-related maternal mortality rate in 2009 was 24.8 deaths per 100,000 live births, with the rate four times higher for Black, non-Hispanic women than White, non-Hispanic women (Maternal Mortality Review Committee, 2015). Georgia was an early adopter and evaluator of perinatal regionalization and currently divides the state into six regions each with a defined regional perinatal center as can be seen in Appendix 1 (Maternal & Child Health Section Office of Family and Community Health, 2013; Sachs et al., 1983). Regional perinatal centers represent hospitals that meet the highest level for both obstetric and neonatal service and also undertake an administrative role to coordinate the region (Barfield et al., 2012). Other hospitals self-identify service levels in a three-tier system, where level III is the highest level. No differences in the rate of pregnancy-related mortality ratio have been found between rural and urban areas (Platner, Loucks, Lindsay, & Ellis, 2016).

Participants

This study used a sample from the Georgia Maternal Child Health Repository. This repository linked birth certificates, fetal and neonatal death certificates, and maternal death certificates to hospital discharge data for singleton pregnancies from 1999-2012. The sample for this study was created by selecting women at high obstetric risk who delivered during years 2008-2012, the most recent 5-year time span available, to ensure a large enough sample to identify differences in rare outcomes.

There is no standard epidemiologic definition of obstetric high risk, though current practice is to measure high risk as the presence of any comorbidity from various lists of conditions. Such inconsistent practice limits synthesis of evidence and may result in misclassification bias due to overestimation of clinical risk. Misclassification bias would reduce the likelihood of identifying differences between levels of obstetric service because outcomes of normal risk women do not vary by hospital level characteristics (Snowden, Cheng, Emeis, & Caughey, 2015). To avoid misclassification, a sample of women at high obstetric risk was identified by applying a cut-off value to the Obstetric Comorbidity Index (OCI), a tool that calculates a risk score by assigning weights to both chronic and pregnancy specific conditions that can be identified prior to hospital delivery admission (Bateman et al., 2013; Metcalfe et al., 2015). In a previous study, identifying a sample of women at high obstetric risk by using a sample-specific cut-off value for the OCI was found to have a higher net benefit when compared to selecting women with any comorbidity, which may reduce the risk of misclassification bias. Comorbidities in the hospital discharge record were identified using specific ICD-9-CM codes, provided by the OCI authors, and a population specific cut-off value for obstetric high risk was identified by identifying the cut-off with the superior net benefit (Vickers et al., 2016). The analytic sample size was determined by the number of records identified as high obstetric risk.

Variables and Data Sources

The predictor for this study was hospital obstetric service level measured as the self-identified American Hospital Association (AHA) obstetric service level from the 2012 survey (American Hospital Association, 2012). The AHA levels are self-reported in an annual hospital survey and therefore consistently applied throughout the United States, though not verified for accuracy of categorization. This self-identified level of service is based on the types of patients the hospital serves; level I hospitals provide care for uncomplicated cases, level II for both uncomplicated and complicated cases, and level III provide services for women with serious illness and abnormalities (American Hospital Association, 2012). Though the level is self-identified, a 2015 assessment of the self-identified hospital levels of obstetric service reported to the State of Georgia found all hospitals that self-identify as the highest level met the criteria for level III, with an overall kappa score of 0.81, suggesting self-assessment of obstetric service by Georgia hospitals is accurate (Barrera, 2015).

The primary outcome for this study, poor maternal outcome, was measured as either severe maternal morbidity or death during delivery hospitalization. Severe maternal morbidity refers to the significant unintended consequences of labor and delivery that may be considered as a woman nearly missing death (Geller et al., 2004; Kilpatrick & Ecker, 2016). While there is no measure of severe maternal morbidity endorsed by the American College of Obstetricians and Gynecologists or the Society for Maternal Fetal Medicine, an algorithm for identifying cases in administrative data using ICD-9-CM diagnosis and procedure codes exists and has been compared favorably with the gold standard of medical record review with a sensitivity of 0.77 (Callaghan et al., 2012; Main et al., 2016). One significant limitation of the severe maternal morbidity algorithm, however, is that it overestimates severe maternal morbidity in relation to transfusion (Main et al., 2016). Per the definition of severe maternal morbidity, a transfusion of four or more units constitutes severe morbidity, but the ICD-9-CM for transfusion does not specify the number of units received. For this reason, in this study, the measure of severe maternal morbidity has been calculated without including transfusion. A sensitivity analysis for poor maternal outcome was performed by including transfusion in the calculation for severe maternal morbidity to identify potential bias from underestimation.

Delivery hospitalization death was identified by discharge status in the medical record. The Georgia Maternal Mortality Review Committee (MMRC) began reviewing maternal deaths in 2012 allowing comparison of delivery hospitalization deaths included in the repository for 2012 to committee decisions. Of the five delivery hospitalization deaths in 2012, four were confirmed to be pregnancy-related and the fifth did not contain variables that allowed identification in the MMRC file.

The secondary outcome for this study was extended length of stay. Length of stay was taken from the delivery hospitalization discharge records and indicated the full length of delivery hospitalization without differentiating between antepartum and postpartum stays. Extended length of stay was measured as a length of stay of six or more days for a cesarean delivery, or four or more days for a vaginal delivery. These durations were chosen to allow adequate time for normal induction procedures prior to delivery and to meet the standard that women must be allowed to remain in the hospital 48 hours after a vaginal delivery and 96 hours after a cesarean delivery (Sabik & Laugesen, 2012).

Control of Bias

Two control variables were used. The first was maternal race and ethnicity, an individual characteristic associated with both delivery hospital and preventable poor maternal outcome so may cause confounding (Berg et al., 2005; Creanga et al., 2012; Dukhovny et al., 2012; Moroz, Wright, Ananth, & Friedman, 2016). Maternal race and ethnicity were identified on the birth certificate and transformed into a dichotomous variable indicating White non-Hispanic or other. The second control variable was transfer in from another hospital, which was identified by admission source on the delivery hospitalization discharge record. Transfer status was controlled because transfer was 1) unevenly distributed to hospitals with level II or III obstetric service, and 2) the data did not provide adequate information to determine what care had been provided prior to the transfer or the reasons for transfer. Because of this, lack of control for transfers may have biased the study against higher level facilities by shifting poor outcomes from lower to higher level facilities.

Statistical Methods

The cut-off value for high obstetric risk was selected as the value with the highest net benefit. After restricting the sample to those identified at obstetric high risk, deliveries that occurred at hospitals without an identified AHA obstetric service level were excluded from the analysis. Characteristics of women who delivered at level I or level II hospitals were compared to women who delivered at level III hospitals using the Kruskal-Wallis H Test due to the non-parametric nature of the variables.

Statistical analysis was conducted through univariate and multivariate hierarchical logistic regression using one level clustering at the delivery hospital. Deliveries at the highest obstetric service level hospitals served as the reference.

Results

Participants

The Georgia Maternal Child Health Repository contained 550,237 deliveries between 2008-2012. Of those, 7,260 (1.3%) were identified as high obstetric risk.

Of those identified at high obstetric risk, 833 (11.5%) were removed from analysis because they did not deliver at a hospital with a reported AHA level of obstetric service. These deliveries were unequally distributed among 27 hospitals within all six perinatal regions. Ten of these hospitals were no longer providing delivery services by

2017. The hospitals varied in size with seven reporting fewer than 50 beds, 10 with 50-100 beds, and 10 with more than 100 beds.

The final sample included data for 6,427 delivery hospitalizations. This sample size is adequate for hierarchical logistic regression modeling (Moineddin, Matheson, & Glazier, 2007).

Descriptive Data

Full descriptive data is presented in Table 4. The delivery hospitalizations were unequally divided among the service levels, with most women (73.8%) delivering at an obstetric level III hospital. No differences were identified in the OCI score across levels of obstetric service (p=.11). Statistically significant differences were identified across levels in proportion of deliveries to women identified as White non-Hispanic (p<.001) and the proportion of transfers (p<.001).

Table 4 Description of women at high obstetric risk with singleton deliveries in Georgia, 2008-2012 by Level of Obstetric Service

	n	OCI Score[1] m (sd)	White non-Hispanic[2] n (%)	Transfer[3] n (%)
Level I	362	4.4 (0.72)	182 (50.2%)	0
Level II	1325	4.5 (0.87)	605 (45.6%)	73 (5.5%)
Level III	4740	4.5 (0.88)	1788 (37.7%)	138 (2.9%)

1. X2=4.4 p=.111
2. X2=43.8 p<.001
3. X2=35 p<.001

Outcome Data

There were four cases of death during delivery hospitalization, one at a level II facility and three at level III facilities. There were 356 cases of severe maternal morbidity: 309 at level III hospitals, 57 at level II, and 18 at level I. There were 1,803 cases of extended length of stay: 1,463 at level III hospitals, 285 at level II, and 55 at level I.

Main Results

Table 5 summarizes the results of the hierarchical logistic regressions. As can be seen in the table, women at high risk delivering at level II hospitals had lower odds of poor maternal outcome than those delivering at a level III hospital. This difference was not observed between level I and level III hospitals. In the adjusted analysis, there was no difference in poor maternal outcome at any level.

The unadjusted hierarchical logistic regression for extended length of stay identified a significantly lower odds of extended length of stay at both level I and level II hospitals. The results remained statistically significant when maternal race and transfer were controlled. See Table 5 for full results.

Table 5 Associations between AHA Level of Obstetric Service and Maternal Outcomes for women at high obstetric risk, Georgia 2008-2012

	Level I OR (95%CI)	Level II OR (95%CI)	Level III OR (95%CI)	model p-value
Poor Maternal Outcome				
Unadjusted	0.71 (0.43, 1.19)	0.62 (0.45, 0.85)	Reference	.009
Adjusted	0.82 (0.34, 1.96)	0.64 (0.38, 1.07)		.042
Extended Length of Stay				
Unadjusted	0.33 (0.18, 0.62)	0.48 (0.31, 0.72)	Reference	<.001
Adjusted	0.36 (0.19, 0.69)	0.48 (0.32, 0.72)		<.001

Other Analyses

Sensitivity analysis was conducted for poor maternal outcome by including the ICD-9-CM code for hemorrhage in the calculation for severe maternal morbidity. In the sensitivity analysis, there was no statistically significant difference in odds of poor maternal outcome for either level I (AOR 0.79 95% CI 0.59-1.06) or level II (AOR 0.85 95% CI 0.63-1.13) when compared to level III. Both maternal race and transfer were included in the model for the sensitivity analysis.

Discussion

This study introduced a method to test associations between maternal outcomes and hospital obstetric level, specifically using standardized measures to identify women at high risk and outcomes of interest. The primary finding of this study was that delivery at the highest obstetric level hospital as defined by the American Hospital Association did not result in lower odds of poor maternal outcome or extended length of stay. Rather, this study had the unexpected finding of lower odds of extended length of stay at hospitals with lower levels of obstetric service.

One likely reason for the unexpected results is that the American Hospital Association obstetric level definitions do not specify what services hospitals are required to provide for women at high obstetric risk (American Hospital Association, 2012; Maternal & Child Health Section Office of Family and Community Health, 2013). Though the obstetric levels are self-reported, the assessment of self-reported levels in Georgia found hospitals accurately report obstetric level, suggesting it is not misidentification of levels that led to these unexpected findings, but rather an inability of the levels to differentiate between appropriate care for women at high obstetric risk (Barrera, 2015).

Another possible explanation for these results is that the measure of high obstetric risk may have misclassified women. It is reasonable to suggest clinical decisions to transfer to higher level care cannot be measured based on ICD-9-CM codes because they lack the precision to differentiate between cases of a controlled comorbidity and uncontrolled conditions (Sak et al., 2012). If high obstetric risk only existed in uncontrolled cases of comorbidities, this study will have overestimated the cases of high obstetric risk. Few differences in outcomes have been associated with hospital characteristics for low risk women, suggesting that any misclassification of high obstetric risk status would result in no significant difference in odds (Snowden et al., 2015). However, there was no difference in mean OCI score across levels of obstetric service, and analysis revealed lower odds of extended length of stay, but not poor maternal outcome, at lower level hospitals. This suggests something unrelated to the scoring of risk is, at a minimum, partially responsible for these results.

The results for the extended length of stay analysis, though opposite of what was expected, may indicate appropriate provision of care. The measure used for extended length of stay does not differentiate between antenatal, intrapartum, and postpartum length of stay. Antenatal length of stay is dependent on the level of prematurity (Helenius et al., 2016). If women who are hospitalized to be stabilized and delay delivery are diverted to the highest service level hospitals, or if higher level facilities are more successful at delaying delivery, this could increase the odds of extended length of stay at the highest service level hospitals without an expected increase in odds of poor maternal outcome. Future research should identify ways to distinguish between antenatal and postpartum length of stay in de-identified administrative data.

A final possible explanation for these results is that care for women at high obstetric risk has become routine, with all but the most extreme cases able to be cared for at any facility. The value of assigning levels of obstetric service in a regionalized system is to ensure all women have access to the limited resources needed to treat women at high obstetric risk. However, the lack of a difference in odds of poor outcome by service level suggest current technology and practice has resulted in negligible differences between hospitals' abilities to prevent morbidity or mortality for women at high obstetric risk. For example, interventions such as maternal early warning tools and universal use of pneumatic compression devices post cesarean have both been shown to reduce morbidity, though neither is limited to hospitals with high obstetric service level (Clark et al., 2014) (Shields, Wiesner, Klein, Pelletreau, & Hedriana, 2016).

Limitations and Generalizability

Use of the Georgia Maternal Child Health Repository limited this study to singleton hospital deliveries that could be matched to a birth or fetal death certificate; thus this data does not include maternal deaths prior to 24 weeks gestation. This study was also limited by the ability to identify obstetric risk and severe maternal morbidity in administrative data, and this presents several challenges. Identification of both measures in epidemiological studies is limited to ICD codes, which are limited by administrative errors and underreporting (Main et al., 2016). Though maternal age is included in the OCI, other sociodemographic variables were not included in the measure of risk (Bateman et al., 2013). This study included control for race but was not able to control for other risk factors such as poverty (Nagahawatte, 2008). The distribution of obstetric risk scores, and therefore the cut-off value for high obstetric risk, may have been different if multiple pregnancies were included. Further improvements in identification of high obstetric risk in epidemiological data will be helpful in future studies of associations with obstetric service levels.

This study was delimited by the measurement of maternal mortality as death during delivery hospitalization. This prevents this study from identifying associations with delivery hospital and out of hospital maternal deaths. While prior research found only 47% of in-hospital maternal deaths could be classified as direct obstetric deaths, all the deaths during delivery hospitalization in this sample were identified by the direct obstetric death algorithm (Clark et al., 2008). Similarly, a review of the delivery hospitalization deaths for 2012, the only year available, confirmed that four were pregnancy related and the fifth lacked the variables necessary to compare the death to the Maternal Mortality Review Committee decisions.

Implications

This study demonstrated a reproducible method for studying associations between delivery hospital obstetric level and outcomes for women at high risk. This study identified a potential problem that measures of extended length of stay may confound appropriate treatment with preventable prolonged hospitalizations. Development of a length of stay measure that isolates preventable extended length of stay could improve identification of benefits of obstetric service levels.

This study failed to find evidence that directing women at high obstetric risk to hospitals with the highest level of obstetric service as defined by the American Hospital Association is associated with lower odds of poor maternal outcome or extended length of stay. This is not surprising given the difficulty of matching existing hospital services to specific levels of service (Korst et al., 2015). The methodology used in this study could be used to test definitions of obstetric service level, including recent recommendations from the American College of Obstetricians and Gynecologists (ACOG), to identity systems of classification that correctly identify high level hospitals that reduce odds of poor outcome.

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CHAPTER FOUR: ASSOCIATIONS BETWEEN DELIVERY HOSPITAL LEVEL OF OBSTETRIC SERVICE AND NEONATAL DELIVERY OUTCOMES

Abstract

Research Objective: The objective of this study was to explore the associations between perinatal outcomes for women at high obstetric risk and delivery hospital level of obstetric service as defined by the American Hospital Association.

Study Design: This study estimated the odds of perinatal morbidity and mortality at each hospital obstetric service level for women at high obstetric risk. Perinatal morbidity was defined as premature delivery and low birth weight. Perinatal death included both fetal and neonatal death. Analysis was completed using hierarchical logistic regression with a one level model at hospital level controlling for race and transfer status. Hierarchical multinomial regression was used to examine associations with specific categories of prematurity and low birth weight with hospital obstetric service.

Population Studied: Women with singleton deliveries of live and stillborn infants in hospitals in Georgia for years 2008-2012.

Principal Findings: Hospital level of obstetric service was not associated with perinatal morbidity or mortality.

Conclusions: The level of obstetric service, defined by the American Hospital Association, is not associated with neonatal outcomes for women at high obstetric risk.

Implications for Policy or Practice: Future research should identify the resources associated with improved perinatal outcomes for women at high obstetric risk to define evidence-based categories of hospital level of service. Systems to categorize hospitals according to level of obstetric service should be validated prior to implementation.

Background

Only 49% of neonatal intensive care units (NICUs) are in a hospital with the highest level obstetric service, but studies of neonatal outcomes with high levels of NICU service do not adjust for the level of obstetric service at the delivery hospital (Brantley et al., 2017). As complexity of the obstetric risk increases, rates of both preterm delivery and NICU admission increase (Farr et al., 2017; Potti, Jain, Mastrogiannis, & Dandolu, 2012). Obstetric risk factors are associated with neonatal outcomes such as NICU admission and small for gestational age; controlling for these risk factors strengthens the association between NICU level and neonatal mortality (Afrasiabi et al., 2014; A. M. Allen et al., 2015; Capula et al., 2013; Habli et al., 2007; Watson et al., 2003). However, controlling for obstetric risk does not provide estimates of the association between delivery at a hospital with the highest level obstetric service and neonatal outcomes (Lasswell et al., 2010).

Objectives

The purpose of this study was to explore associations between delivery hospital level of obstetric service and neonatal outcomes for women at high obstetric risk.

Methods

This was a retrospective cohort study of linked administrative and vital statistics data from Georgia.

Setting

This study was conducted with data from Georgia. Georgia is divided into six perinatal regions, each with a designated regional perinatal center that is expected to maintain the highest level of both obstetric and neonatal service (Maternal & Child Health Section Office of Family and Community Health, 2013). In 2013, Georgia's perinatal mortality rate—deaths between gestational age of 24 weeks and 28 days after birth—was 13.65; only three states had higher perinatal mortality rates (MacDorman & Gregory, 2015). Though the infant mortality rate in Georgia is improving, it is still above the Healthy People 2020 goal (Infant Mortality Task Force, 2013).

Participants

The data for this study came from the Georgia Maternal Child Health Repository, a data file that links delivery hospitalization discharge data with vital statistics data including both fetal and neonatal death certificates. The repository is limited to singleton hospital deliveries between 1999 and 2012, contains 1,562,238 linked records, and has an 83% linkage rate.

The sample for this study was limited to women identified at high obstetric risk who delivered between 2008 and 2012. High obstetric risk was measured using a cut-off value with a weighted obstetric comorbidity score from a previously described Obstetric Comorbidity Index (OCI) (Bateman et al., 2013). The cut-off value was selected by identifying the cut-off that had the superior net benefit. This method of identifying a sample of women at high obstetric risk was previously found to be superior to creating a sample by identifying presence of any comorbidities from a selected list. Women were excluded from the sample if the delivery hospital did not report an obstetric level, and if the infant was reported to have congenital defects. The analysis of perinatal mortality was limited to years 2008-2010 due to availability of data. Study size was determined by the number of cases that met the inclusion criteria.

Variables & Data Sources

Three neonatal outcomes were identified for this study: gestational age at birth, birth weight, and perinatal mortality.

Gestational age at birth was limited to live births and was taken from the birth certificate with gestational age recorded in weeks. Infants reported as having less than 37 completed weeks' gestation were considered premature. Because differences may exist between very preterm and later preterm deliveries, a second analysis was conducted with gestational age at birth categorized as very preterm (less than 32 completed weeks' gestation), moderately preterm (32- 34 weeks), late preterm (34-36 weeks) and term (37 weeks and beyond).

Birth weight was also limited to live births and taken from the birth certificate where it is recorded in grams. Infants with a birth weight less than 2500 grams were considered to have low birth weight. Because outcomes may differ for infants with the lowest birth weights, a second analysis was conducted with birth weight categorized as very low birth weight (less than 1,500 grams), low birth weight (less than 2,500 grams) and normal birth weight (2,500 grams and above).

Perinatal mortality was limited to deliveries occurring between 2008-2010 due to limitations with linking the data. Perinatal mortality included both fetal and infant deaths, without congenital anomaly, as recorded on the death certificates. Including both fetal and infant deaths prevents biasing the results against higher service level hospitals with the most resources to prevent fetal death (Phibbs et al., 2007). Fetal death was counted as any death between 24 weeks gestation and delivery. Though neonatal death is defined as any death between delivery and 42 days after birth, these data provided only the number of months from delivery. As such, neonatal death was defined for this study as any death within 2 months after birth.

Predictor

The independent variable was hospital level of obstetric service as measured by the self-identified level reported as part of the 2012 version of the American Hospital Association (AHA) annual survey. The AHA uses a three-tier system with service levels based on the condition of the woman; level I provides care for uncomplicated cases, level II for uncomplicated and complicated cases, and level III for serious illnesses and abnormalities (American Hospital Association, 2012). These levels are voluntarily reported and do not require verification for accurate categorization. A 2015 assessment of the self-identified hospital levels of obstetric service reported to Georgia found all hospitals that self-identify as obstetric level III or regional perinatal center met the criteria defined by Georgia for obstetric level III and overall kappa score of 0.801 (Barrera, 2015). The results of the assessment suggest hospitals in Georgia accurately report their obstetric level.

Control Variables

Three variables were included in the adjusted models for control; maternal race, transfer from another hospital, and neonatal intensive care unit service level. A fourth control variable, gestational age, was included in the adjusted models for low birth weight and perinatal mortality. These variables were chosen a priori due to peer-reviewed evidence of associations.

Maternal race has been shown to be associated with poor neonatal outcomes in the United States and in Georgia specifically (Dunlop, Salihu, Freymann, Smith, & Brann, 2011; Zhang et al., 2013). Controlling for this variable helped reduce the risk of bias against higher service level hospitals that may serve higher proportions of minorities (CreangaBateman, et al.; Howell et al., 2016).

The second control, transfer from another hospital, was included because these data did not provide a way to determine 1) the reason for transfer, 2) the amount of care provided prior to transfer, or 3) the condition of the woman on transfer. Control for this variable helped prevent bias against higher service level hospitals who are more likely to receive a transfer, but did not necessarily have an opportunity to provide care to prevent poor outcomes.

Level of neonatal intensive care unit (NICU) service may not match the level of obstetric service but is a driving factor for delivery location and is associated with improved neonatal survival for infants with very low birthweight (Brantley et al., 2017; Hankins et al., 2012; Kozhimannil, Casey, et al., 2016; Lasswell et al., 2010). Including presence of a level III B or C NICU, the level of NICU able to care for the smallest infants, helped isolate the effect of the level of obstetric service (Blackmon et al., 2004). NICU levels were taken from the 2012 version of the American Hospital Association Annual Survey (American Hospital Association, 2012).

Because both birth weight and perinatal mortality are associated with prematurity, control for gestational age was included for analyses of these outcomes to provide control for any unequal distribution which may occur in the data.

Statistical Methods

Characteristics of women at high risk who delivered at level I or level II hospitals were compared to women who delivered at level III hospitals using the Kruskal-Wallis H Test.

Statistical analysis for prematurity and low birth weight were conducted through univariate and multivariate hierarchical logistic regression using one level clustering at the delivery hospital with deliveries at the highest obstetric service level hospitals serving as the reference. Analysis for perinatal mortality was completed using logistic regression because there was no variance between hospitals for this rare outcome.

The analysis for categories of prematurity and low birth weight was performed using a hierarchal multinomial regression using one level clustering at the delivery hospital to determine if differences existed between the categories. The multinomial models included the control variables and deliveries at the highest obstetric service level hospitals served as the reference.

Results

The sample derived from the repository for years 2008-2012 included 550,237 unique delivery hospitalizations. Within these data, a cut-off value of 4 for the OCI was found to have the superior net benefit. Applying the cut off resulted in 7,260 women identified at high obstetric risk.

A total of 833 (11.5%) women were excluded from the sample because they did not deliver at a hospital with a reported obstetric service level. These deliveries were unequally distributed among 27 hospitals within all six perinatal regions. Ten of these hospitals were no longer providing delivery services by 2017, 3 had stopped by 2012. The hospitals varied in size with seven reporting fewer than 50 beds, 10 with 50-100 beds, and 10 with more than 100 beds.

An additional two women were excluded due to congenital malformations of the fetus. The final sample for analysis included data for 6,425 delivery hospitalizations, an adequate sample for hierarchical analysis (Moineddin et al., 2007). A total of 3,778 records were available for the analysis of perinatal death.

Descriptive Data

The delivery hospitalizations were unequally divided among the service levels, with most the women (73.8%) delivering at an obstetric level III hospital (See Table 6). No differences were identified in the OCI score across levels of obstetric service (p=.112). Statistically significant differences were identified across levels in proportion of deliveries to women identified as White non-Hispanic (p<.001) and the proportion of transfers (p<.001) and delivery at a hospital with a level III B or C NICU (p<.001).

Table 6 Description of deliveries for women at high risk, Georgia 2008-2012

	n	OCI Score[1] m (sd)	White non-Hispanic[2] n (%)	Transfer[3] n (%)	Level III B or C NICU[4]
Level I	362	4.4 (0.72)	182 (50.2%)	0	70 (19%)
Level II	1325	4.5 (0.87)	605 (45.6%)	73 (5.5%)	351 (26.7%)
Level III	4738	4.5 (0.88)	1,787 (37.7%)	138 (2.9%)	3,543 (74.7%)

1. X^2=4.4 p=.112
2. X^2=43.9 p<.001
3. X^2=35.3 p<.001
4. X^2=1031 p<.001

Outcome Data

There were 2,526 (39.6%) cases of preterm delivery. Of those who delivered at obstetric level III facilities, 40% were preterm. This differed from the 33.2% at level I facilities (p=.010), but not the 39.4% at level II (p=.641).

There were 1,783 (27.9%) cases of low birth weight. Of those who delivered at obstetric level III facilities, 37.9% had low birth weight. This differed significantly from both the 24.6% at level I facilities (p<.001) and 33% at level II facilities (p=.001).

There were 35 cases of fetal death and 41 cases of neonatal death. Of those who delivered at obstetric level III facilities, 1.7% experienced perinatal death. This did not differ significantly from the 1.8% at level I (p=.961) nor the 1.2% at level II facilities (p=.275).

Main Results

Full results of the analysis can be found in Table 7. As can be seen in the table, the unadjusted hierarchal analysis for premature birth resulted in a significantly lower odds of prematurity at level I hospitals but no difference at level II hospitals. When maternal race, maternal transfer from another hospital, and presence of a level III NICU were controlled, the differences between obstetric levels was no longer significant.

In the unadjusted analysis for low birth weight, there were lower odds of low birth weight at both level I and level II hospitals compared to level III. This association was no longer significant after controlling for maternal race, maternal transfer, level III NICU, and gestational age.

Table 7 Associations between AHA Levels of Obstetric Service and Perinatal Outcomes for women at high risk in Georgia, 2008-2012

	Level I OR (95%CI)	Level II OR (95%CI)	Level III OR (95%CI)	Model p value
Prematurity				
Unadjusted	0.69 (0.51, 0.93)	0.89 (0.71 ,1.10)	Reference	.046
Adjusted	0.86 (0.51, 1.44)	1.02 (0.75, 1.39)		.014
Low Birth Weight				
Unadjusted	0.47 (0.34, 0.65)	0.67 (0.52, 0.89)	Reference	<.001
Adjusted	0.77 (0.38, 1.58)	0.93 (0.61, 1.41)		<.001
Perinatal Death				
Unadjusted	0.80 (0.29, 2.12)	0.64 (0.34, 1.23)	Reference	--
Adjusted	1.15 (0.37, 3.59)	0.83 (0.41, 1.69)		--

In the unadjusted analysis for overall perinatal death, obstetric service level was not associated with perinatal death. The lack of association persisted when race, transfer status, NICU level, and gestational age were controlled.

The analysis for preterm delivery by category found no significant difference in odds of preterm delivery at level I or level II facilities. The full results of the multinomial analysis can be seen in Table 8. The analysis for low birth weight revealed no statistically significant difference in odds of any category of low birth weight at any level hospital. The full results of the multinomial analysis for low birth weight can be seen in table 9. To allow analysis using hierarchal models, these models exclude all intrapartum transfers from the sample.

Table 8 Associations between category of prematurity and hospital obstetric service level for women at high obstetric risk, Georgia 2008-2012

	Level I n=362 OR (95% CI)	Level II n=1325 OR (95% CI)	Level III n=4740
Very Preterm	0.46 (0.15, 1.40)	0.93 (0.56, 1.53)	Reference
Moderately Preterm	0.38 (0.11, 1.35)	0.75 (0.42, 1.34)	Reference
Late Preterm	1.15 (0.70, 1.89)	1.24 (0.90, 1.69)	Reference

$F_{12,6146} = 2.104$ $p=.014$

Table 9 Associations between category of low birth weight and hospital obstetric service level for women at high obstetric risk, Georgia 2008-2012

	Level I n=362 OR (95% CI)	Level II n=1325 OR (95% CI)	Level III n=4740
Extremely Low Birth Weight	0.45 (0.12, 1.78)	0.66 (0.34, 1.28)	Reference
Very Low Birth Weight	0.37 (0.11, 1.23)	0.70 (0.41, 1.22)	Reference
Low Birth Weight	0.74 (0.44, 1.26)	0.94 (0.69, 1.27)	Reference

$F_{15,6143} = 34.135$ $p<.001$

Discussion

This study tested a method to identify associations between improved perinatal outcomes associated with hospital level of obstetric service. The primary finding of this study was the lack of association between odds of perinatal morbidity or mortality and delivery hospital obstetric service level for women at high obstetric risk. These data do not provide evidence that further improvements in neonatal morbidity and mortality could be achieved by diverting women at high obstetric risk to hospitals with higher level obstetric service as measured by AHA levels of service.

One possible explanation for these results is that, although obstetric risk is associated with poor neonatal outcomes, diversion to a hospital with the appropriate level NICU is sufficient to address the risk and the access to high level obstetric service does not offer additional prevention of poor neonatal outcomes (Cetinkaya et al., 2014). Though evidence suggests some maternal risks are associated with poor neonatal outcomes, it does not mean all risks to a woman's health equally affect the odds of poor neonatal outcomes (Potti et al., 2012). This supports the position that the NICU level of a hospital does not need to match the obstetric level because a fetus can have risks independent of the risks of the woman (Hankins et al., 2012).

Another possible explanation for these results is that the levels of obstetric service, as defined by the American Hospital Association (AHA), do not differentiate between the resources that account for differences in outcomes for women at high obstetric risk. This is possible, as the AHA levels define service levels by the types of patients served rather than the resources available to provide care (American Hospital Association, 2012). New categories of obstetric levels of service proposed by the

American College of Obstetricians and Gynecologists and the Society for Maternal Fetal Medicine define obstetric service levels based on facility capabilities and workforce (American College of Obstetricians and Gynecologistis, 2015). Such a system is likely to better differentiate hospitals by their ability to provide care for the highest risk patients and should be investigated in future research.

Limitations and Generalizability

This study was limited to the self-assessed hospital obstetric and NICU levels reported to the American Hospital Association (AHA). It is possible that, although the NICU level was controlled, assessment of NICU level does not account for differences which may exist between hospitals with the same level NICU, such as the size of the NICU (Heller et al., 2002). While objective assessment revealed hospitals accurately assess obstetric service level, the self-identified neonatal levels had less agreement with objective assessment (Barrera, 2015). This may mean lower level NICUs were misclassified as level III B or C and included in the control.

This study was limited by the ability to identify obstetric risk by ICD-9-CM codes which are limited by administrative errors and underreporting (Main et al., 2016). The distribution of obstetric risk scores, and therefore the cut-off value for high obstetric risk, may be different if multiple gestation pregnancies were included. In this study, perinatal mortality was counted regardless of cause. Due to the low number of deaths involved, inclusion of non-medically precipitated deaths may skew the result to the null for neonatal mortality.

Delimiting this study to singleton pregnancies allowed linking of data, but may have reduced associations between obstetric risk and neonatal outcomes. Multiple gestation is a risk factor for poor neonatal outcomes and is also associated with obstetric risk (Afrasiabi et al., 2014; Artymuk, Trishkin, Bikmetova, & Noskova, 2012; Bateman et al., 2013). This study was also delimited to examine deliveries by hospital service level without regard to urban or rural location. Associations between rural residence and perinatal outcomes are complex and beyond the scope of this study (Kozhimannil, Casey, et al., 2016; Tu et al., 2012).

Georgia uses a certificate of need process for expansion of neonatal intensive care services which is associated with distribution of NICUs (Lorch, Maheshwari, & Even-Shoshan, 2012). States without certificate of need processes may have a higher number of NICUs with fewer beds per NICU, a type of regionalization that has been associated with poorer perinatal outcomes (Howell et al., 2002; Kastenberg, Lee, Profit, Gould, & Sylvester, 2015).

Implications

This study demonstrated a reproducible method for studying associations between delivery hospital obstetric level and neonatal morbidity and mortality for women at high risk. While there is evidence that some obstetric risks are associated with poor perinatal outcomes, this study did not find evidence that delivery at hospitals with level III obstetric services was associated with lower odds of poor perinatal outcomes. This is consistent with the evidence on perinatal regionalization; associations for levels of neonatal service are limited to cases with the most extreme prematurity (Lasswell et al., 2010). In the 40 years since perinatal service levels were first recommended in United States, there has been limited high-quality evidence that graduated levels of neonatal service have decreased perinatal morbidity and mortality (Lee et al., 2003; Rashidian et al., 2014). This study found no evidence of potential improvements in perinatal outcomes by diverting women at high obstetric risk to hospitals with level III obstetric service as defined by the American Hospital Association (AHA).

Levels of obstetric and perinatal service were one part of a system that was proposed to ensure all women have access to limited resources (Little & Merenstein, 1993; Ryan, 1975). Levels of obstetric service are only a reasonable strategy to address poor delivery outcomes if 1) maternal risks associated with poor perinatal outcomes can be clearly identified before delivery hospitalization and 2) the resources needed to stabilize and treat obstetric conditions are only available at the highest level of obstetric service. Future research should examine associations between obstetric risks and hospital resources to better define what services mediate the relationship between obstetric risk and poor perinatal outcomes. In this way, differentiation of levels of both obstetric and neonatal service could be constructed to provide evidence-based guidance for hospitals that provide care for women at high obstetric risk.

Conclusion

This study introduced a method to test associations between systems of defining obstetric service level and perinatal outcomes. This study failed to identify associations between the AHA levels of obstetric service and perinatal mortality and morbidity for women at high obstetric risk. Further research should be conducted to determine if associations exist for other systems of defining hospital levels of obstetric service and to identify the most appropriate definitions of levels of obstetric service.

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CHAPTER FIVE: CONCLUSION

Review of Objective and Aims

The overriding purpose of this study was to test a method to examine the associations between graduated obstetric service levels and poor maternal and neonatal outcomes for women at high obstetric risk as measured by objective indices. Following the three delays framework, this paper examined the odds of severe maternal morbidity, maternal mortality, and length of stay for women with the hypothesis that women at high obstetric risk who deliver at hospitals with lower levels of obstetric service would have higher odds of poor maternal outcomes (Thaddeus & Maine, 1994). In addition, this study examined associations between levels of obstetric service and the neonatal outcomes of prematurity, low birth weight, and perinatal mortality.

Aim One

The first aim was to identify associations between delivery hospital level of obstetric service and two maternal outcomes for women at high obstetric risk: death during delivery hospitalization and severe maternal morbidity. Because of the low number of maternal deaths, severe maternal morbidity and direct obstetric death were combined to create a variable for poor maternal outcome.

Hypothesis: Women at high obstetric risk, identified via the maternal comorbidity index, delivering at hospitals without the highest obstetric service level, measured by the American Hospital Association Levels of Obstetric Care, will have higher odds of poor maternal outcome than those delivering at hospitals with the highest obstetric service level.

Result: This study did not produce evidence that women at high obstetric risk have higher odds of poor maternal outcome if they deliver at hospitals with AHA level I or II obstetric service.

Aim Two

The second aim was to identify associations between delivery hospital level of obstetric service and three neonatal outcomes for women at high obstetric risk: prematurity, low birth weight, and perinatal mortality.

H1: Women at high obstetric risk, identified via the maternal comorbidity index, delivering at hospitals without the highest obstetric service level as measured by the American Hospital Association Levels of Obstetric Care, will have higher odds of delivering an infant with low birth weight than will women at high risk delivering at hospitals with the highest obstetric service level.

Result: This study did not produce evidence that women at high obstetric risk have higher odds of delivering an infant with low birth weight if they deliver at hospitals with AHA obstetric level I or II.

H2: Women at high obstetric risk, identified via the maternal comorbidity index, delivering at hospitals without the highest obstetric service level as measured by the American Hospital Association Levels of Obstetric Care, will have higher odds of delivering an infant prematurely than will women at high risk delivering at hospitals with the highest obstetric service level.

Result: This study did not produce evidence that women at high obstetric risk have higher odds of delivering an infant prematurely if they deliver at hospitals with AHA obstetric level I or II.

H3: Infants born to women at high obstetric risk, identified via the maternal comorbidity index, delivering at hospitals without the highest obstetric service level as measured by the American Hospital Association Levels of Obstetric Care, have higher odds of perinatal death than infants born women at high risk who deliver at hospitals with the highest obstetric service level.

Result: This study did not produce evidence that infants born to women at high obstetric risk have higher odds of perinatal mortality if they deliver at hospitals with AHA obstetric level I or II.

Aim Three

The third aim was to identify associations between delivery hospital level of obstetric service and length of stay for women at high risk of obstetrical complications.

H1: Women at high obstetric risk, identified via the maternal comorbidity index, delivering at hospitals without the highest obstetric service level as measured by the American Hospital Association Levels of Obstetric Care, will have higher odds of extended length of stay than those delivering at hospitals with the highest obstetric service level.

Result: Though this study found evidence of associations between American Hospital Association levels of obstetric service and extended maternal length of stay, the association was in the opposite direction than the hypothesis predicted. This study did not produce evidence that women at high obstetric risk have higher odds of extended length of stay if they deliver at hospitals with AHA obstetric level I or II.

Advances in Study

To accomplish the purposes of this project, it was necessary to first assess the validity of the measure of high obstetric risk in epidemiologic data. Using net benefit analysis, the first paper compared the value of the recently proposed Obstetric Comorbidity Index (OCI) against the conventional method of using the presence of any comorbidity for identifying a sample of women at high obstetric risk in administrative data (Bateman et al., 2013). Under a standard comparison, the net benefit indicated the OCI was the superior method due to improved specificity despite reduced sensitivity. However, the low sensitivity identified in all models highlights problems with identification of women at high obstetric risk in administrative data.

The main advantage of the OCI was its improved specificity. The standard method of risk identification categorized approximately one-third of the sample as high obstetric risk. This estimation seems unreasonably high given that 1) the sample only included singleton deliveries and 2) previous studies estimate between 78-90.8% of the general population have no risk factors for maternal morbidity (Lindquist et al., 2015; Mhyre, Bateman, & Leffert, 2011). Given that only 0.5% of the women in these data experienced a poor obstetric outcome, identification of 33% of the women as having high obstetric risk is likely the result of misclassification. Misclassification of women at high obstetric risk is likely to move the estimate of any analysis toward the null, increasing the difficulty of finding true differences caused by interventions (Cheng, Branscum, & Stamey, 2010).

The imprecision of identifying risk with ICD-9-CM codes is an accepted risk in research (Chantry et al., 2011). Using the OCI corrects for some of the imprecision by weighting conditions and summing the weights to account for the complexity of different conditions, however this study demonstrated that additional improvements in risk identification may be possible. The net benefit analysis found that an unweighted dichotomous indicator using the New Zealand Transfer Guidelines was superior to an unweighted dichotomous indicator using the OCI. This was unexpected because the New Zealand Transfer Guidelines include conditions associated with risks to the fetus which could result in misclassification of high obstetric risk (Ministry of Health, 2012). Future iterations of the OCI can be tested using net benefit analysis to determine which combination of ICD-9-CM codes and weighting provide the least risk of misclassification bias.

After establishing a method to identify a sample of women at high obstetric risk, the next task was to examine associations between hospital level of obstetric service and poor maternal outcome, defined as severe maternal morbidity or direct obstetric death, and maternal length of stay for delivery hospitalization. The results, in direct conflict with the three delays framework, suggested women have either similar or better outcomes at hospitals with level I or II obstetric service when compared to level III obstetric service. While it initially appears that, based on length of stay data, the women at level III hospitals were “sicker” than the women at lower level hospitals, this was not supported by the results of this project; there was no difference in mean OCI score, odds of poor maternal outcome, or odds of perinatal morbidity or mortality. Based on this, the results of this analysis appear to indicate that there is no association between the American Hospital Association levels of obstetric service and outcomes for women at high obstetric risk.

The analysis of extended length of stay identified a potential problem using this measure with high obstetric risk deliveries; obstetric level III hospitals likely had the longest length of stay due to appropriate care. Women at high risk of preterm delivery were likely diverted to a regional perinatal center for antepartum stabilization. The data for this study were not able to limit length of stay to postpartum stay, which meant any antepartum stabilization to delay delivery was included in the measure of extended length of stay. Because of this, the results of the length of stay analysis cannot be considered to represent a preventable outcome at obstetric level III hospitals. Future research should define extended length of stay as postpartum length of stay to identify differences in length of stay due to inappropriate hospital level rather than appropriate care.

The analysis for maternal outcomes was robust, overcoming several challenges to be the first estimation of the effect of hospital levels of obstetric service. First, this study used linked hospital discharge and vital statistics data and was therefore not limited to maternal deaths that occurred during delivery hospitalization. Second, this study used existing levels of obstetric service rather than a proxy, and Georgia hospitals were assessed to report self-identified obstetric levels correctly (Barrera, 2015). Third, the measure of high obstetric risk was shown to reduce misclassification bias when compared to the conventional method. Finally, this study adjusted for hospital transfer of care to prevent biasing the study against hospitals with high obstetric service levels.

Once associations between hospital level of obstetric service and maternal outcomes were explored, this project examined associations between hospital level of obstetric service and poor neonatal outcome, described as prematurity, low birth weight, and perinatal mortality. The analysis found no association between obstetric service level and perinatal morbidity and mortality measures examined in this study. This study controlled for the effect of neonatal service levels by adjusting the odds for presence of a level III B or C NICU which represents hospitals that can care for the smallest newborns (Blackmon et al., 2004). However, Georgia hospitals have been assessed to have less accuracy when self-reporting neonatal levels of care than obstetric levels (Barrera, 2015).

Interpretation

The three delays framework assumes that maternal mortality and morbidity are preventable if appropriate care is accessed in a timely manner. The findings of this project failed to identify opportunities to prevent maternal morbidity and mortality by diverting women at high obstetric risk to the hospitals with the highest level of obstetric service defined by the AHA. This is consistent with estimates of preventability of maternal death in the United States which suggest that although the overall proportion may be as high as 50%, as few as 18% are preventable after a woman presents to the hospital for delivery (Berg et al., 2005; Clark et al., 2014; Geller et al., 2014). This is also consistent with the literature that shows limited improvements in perinatal outcomes by diverting women with high risk fetuses to the hospitals with the highest level of neonatal service (Lee, Fung, & Fu, 2003; Rashidian et al., 2014; Strobino et al., 1993; Wright et al., 2010). In contrast to the three delays framework, the results of this study identified reduced odds of extended maternal length of stay at hospitals with lower levels of obstetric service.

One explanation for the results of this study is that the sample was limited to women whose comorbidities were identified and included in their medical record, which may mean they were likely to receive additional surveillance during the delivery hospitalization regardless of delivery hospital level of obstetric service. Under this explanation, we would assume the increased surveillance would result in the transfer of women whose risks exceeded any hospitals' ability to provide care regardless of the level of obstetric service. These differences, though clinically obvious, would not be visible in administrative data, which is limited to general ICD-9-CM codes for conditions. With this explanation, we assume that the women most likely to experience a problem (i.e., those with the highest risk) were diverted to the hospitals with the highest level obstetric service and are therefore not comparable to the women who remained at the hospitals with lower levels of obstetric service. This explanation is supported by the increased odds of maternal extended length of stay at level III hospitals. However, this explanation is inconsistent with the findings of no difference in odds of poor maternal outcome or perinatal morbidity and mortality. Instead, these results suggests that despite shorter length of stay, risks remained equivalent for women who did not deliver at hospitals with the highest level of obstetric service.

Another explanation is that the cut-off value for the OCI failed to correctly identify women at high obstetric risk resulting in misclassification of normal risk women as high risk. The use of the OCI to identify women at high obstetric risk was validated as superior to the conventional method to identify a sample of women at high obstetric risk and identification of high risk with the OCI was associated with an increased odds of poor maternal outcome. This suggests that while improvements in precision may be possible, the measure does reflect obstetric risk. Additionally, there is no evidence that misclassification would result in higher proportions of women with normal obstetric risk delivering at the lower level hospitals, as would be necessary for misclassification to result in lower odds of any poor outcome. This study found lower odds of extended length of stay at lower level hospitals, an unlikely finding if the measure of risk resulted in misclassification bias. It is more likely that the measure of extended length of stay is capturing appropriate diversion of women at risk for prematurity to higher level hospitals where the delivery can be delayed.

The final explanation to consider is that the measure of hospital level of obstetric service—that is the American Hospital Association levels of obstetric service—do not accurately identify differences in obstetric service capability. Though Georgia hospitals were assessed as accurately reporting the self-identified obstetric level, the levels themselves have not been validated as an appropriate measure of obstetric service (Barrera, 2015). Predicting the effect of misclassification of hospital service levels is difficult because 1) the AHA levels do not define the resources necessary for each level of obstetric service and 2) hospitals invest in different resources (Korst et al., 2015). In fact, in a study that attempted to match hospitals to levels of obstetric service based on the resources available, 48% of hospitals did not have all the resources required to meet any level of service criteria, including the most basic (Korst et al., 2015). In that study, some hospitals met the criteria for the highest level of obstetric service without meeting the criteria for the most basic level. This means that even though the hospitals met criteria for the AHA levels of obstetric service, it is possible the AHA levels do not account for the differences in hospital capability that may play a role in maternal and neonatal morbidity and mortality.

Limitations

This study is limited to describing the morbidity and mortality at or after delivery hospitalization. As such, this project was only able to identify women at high obstetric risk who 1) received delivery care at a hospital, 2) had the comorbidities and obstetric conditions coded into the hospital discharge data, and 3) met the OCI cut-off for high obstetric risk. Similarly, this project was only able to identify severe maternal morbidity if the conditions were properly coded in the hospital discharge file. This means this study does not include 1) maternal mortality prior to 24 weeks gestation, such as with ectopic pregnancy or self-induced abortion; 2) maternal or fetal deaths that did not occur with a corresponding delivery hospitalization; and 3) women whose high obstetric risk was not identified. An inherent challenge of administrative data is both false positive and false negatives for complications (Chantry et al., 2011). This can result in both overestimation and underestimation of associations when performing conventional analysis (Lash et al., 2014).

This study was limited to the data available in the Georgia Maternal Child Health Repository. The linked data included only singleton deliveries that occurred in the hospital. Though hospital discharge records were available, prenatal records were not linked, preventing verification of antenatal identification of the comorbidities and obstetric complications used to identify obstetric risk. The data included limited variables to control for sociodemographic variables known to be associated with morbidity and mortality.

In this project, 60% the women at high obstetric risk delivered in the Atlanta Perinatal Region, which has a higher proportion of urban areas that other perinatal regions. Rural areas have a reduced access to high level care, including a reduced access to high-volume, high level care which is associated with perinatal outcomes, though not all studies have identified differences in care in rural facilities (Attar et al., 2006; Glance et al., 2014; Grzybowski et al., 2011; Korst et al., 2015; Snowden et al., 2015). Associations between rural residence and specific maternal or fetal outcomes are complex and unable to be examined in this project. However, in Georgia the concentration of maternal fetal medicine specialists in urban areas has been identified as a barrier to delivery at a higher-level hospital for women in rural areas, despite mechanisms to allow physician collaboration with specialists (Pinto, Rochat, Hennink, Zertuche, & Spelke, 2016). Though this barrier has not resulted in a difference in the pregnancy-related mortality ratio between rural and urban areas, it has resulted in different causes for maternal mortality, which may result in different ratios for death during delivery hospitalization, direct obstetric death, or severe maternal morbidity (Platner et al., 2016).

Generalizability

This project examined associations between obstetric and neonatal level of service and maternal and perinatal outcomes. This should not be confused with measures of hospital quality, which would require examination of associations with specific hospitals. By stratifying women by the obstetric level of the hospital, this study estimated the difference in odds of poor outcome for women at high obstetric risk based on the level of the hospital only. This provides information about the ability of the AHA levels of obstetric service to differentiate hospital capabilities but does not provide information about the quality of care provided.

States differ in their implementation of obstetric and perinatal regionalization (Blackmon et al., 2009; Lorch, Maheshwari, et al., 2012; Rashidian et al., 2014). Georgia uses a perinatal regionalization scheme that divides the state into six perinatal regions, each with a regional perinatal center (See Appendix 1). Georgia requires hospitals to submit a certificate of need to establish a neonatal intensive care or obstetric service. During the time frame of this study, 2008-2012, Georgia reported a surplus of obstetric beds (Division of Health Planning, 2008; Division of Health Planning, 2013), though the supply of neonatal intensive care beds varied within regions (Division of Health Planning, 2008).

Though the repository includes data on all singleton deliveries, the analysis of associations with obstetric service level were limited to women identified as obstetric high risk and should not be considered generalizable to normal and low risk women. The sample of women at high obstetric risk differed significantly from the women considered low or normal risk in several ways. Women identified as high obstetric risk were less likely to be White non-Hispanic (39.2% vs. 45.7%) and had a higher mean maternal age (33.5 vs. 27). Women in the high obstetric risk sample had a lower mean gestational age at delivery (36.4 weeks vs. 38.7 weeks) and were more likely to deliver at a hospital identified as obstetric level III (73.8% vs. 59.8%).

Implications

This project introduced a method to study associations between obstetric levels of service and maternal and perinatal outcomes. The study provides evidence that the American Hospital Association levels of obstetric service may not adequately differentiate between hospitals with and without the capabilities to prevent poor maternal and perinatal outcomes for women identified as having high obstetric risk. This introduces two important questions about use of obstetric service levels. First, what, if any, are the hospital capabilities that reduce the odds of poor maternal outcome for women at high risk? Second, are these capabilities only available at hospitals with the highest service level?

Future research must not only investigate the overall effect of different systems to identify obstetric service levels, but must also identify the capabilities within each level that are responsible for improved outcomes. This is important because as technology improves, access to technology increases. Perinatal regionalization was initially proposed because the medical technology and the neonatologist workforce were in limited supply (Holloway, 2001). Regionalization ensured every woman in need had access to limited life-saving resources (Little & Merenstein, 1993; Ryan, 1975). Over time, improvements in technology and expansion of the subspecialty allowed even level II NICUs to employ neonatologists (Holloway, 2001). As the presence of an NICU became a selling point for hospital delivery services, hospital investment in small volume NICUs resulted in proliferation of small volume NICUs in urban areas, a phenomenon termed deregionalization of the perinatal system (Howell et al., 2002). Similar changes in medical technology and subspecialty workforce may also have occurred in obstetrics reducing differences between the highest and lowest obstetric level hospitals.

Recent interest in the potential for graduated levels of obstetric service to prevent maternal morbidity and mortality has resulted in the proposal of a new level of obstetric service scheme that highlights not only the types of appropriate patients, but also the minimum capabilities and health care providers for each level of service (American

College of Obstetricians and Gynecologists, 2015). It is not yet known whether the specific capabilities identified by the newly proposed scheme will result in significant differences in outcomes for women at high obstetric risk. An analysis using the method presented in this project should be performed to test for associations between the proposed levels of obstetric service and maternal outcomes. In addition to testing the overall categories of level of service, future research should also determine which specific capabilities and resources are related to improved maternal outcomes. This allows criteria for specific levels of service to be based on capabilities and resources with evidence to improve care, reducing unnecessary burden on hospitals.

In this study, hospital level III obstetric service was not associated with improved maternal or perinatal outcomes for women whose risk status could be identified from ICD-9-CM coding of comorbidities. If testing of other methods for stratifying obstetric care are also unable to demonstrate better outcomes for women with identified risks at the highest level hospital, it would suggest a better method for reducing poor obstetric outcomes would be to have all hospitals equipped to handle the most common unpredictable emergent situations, the third delay in the three delays framework. This concept is supported by evidence that delay of escalation of care during hospitalization, as opposed to lack of services, was found to occur in as many as 53% of emergent obstetric cases, and only 13% of obstetric sepsis cases receive appropriate antibiotics (Bauer et al., 2015). Early warning trigger tools, designed to prevent delay of escalation, have been shown to reduce severe maternal morbidity (Shields et al., 2016). Similarly, universal implementation of compression devices and antihypertensive treatment protocols have been shown to reduce maternal deaths, two interventions that rely on identification of risk rather than transfer of care (Clark et al., 2014).

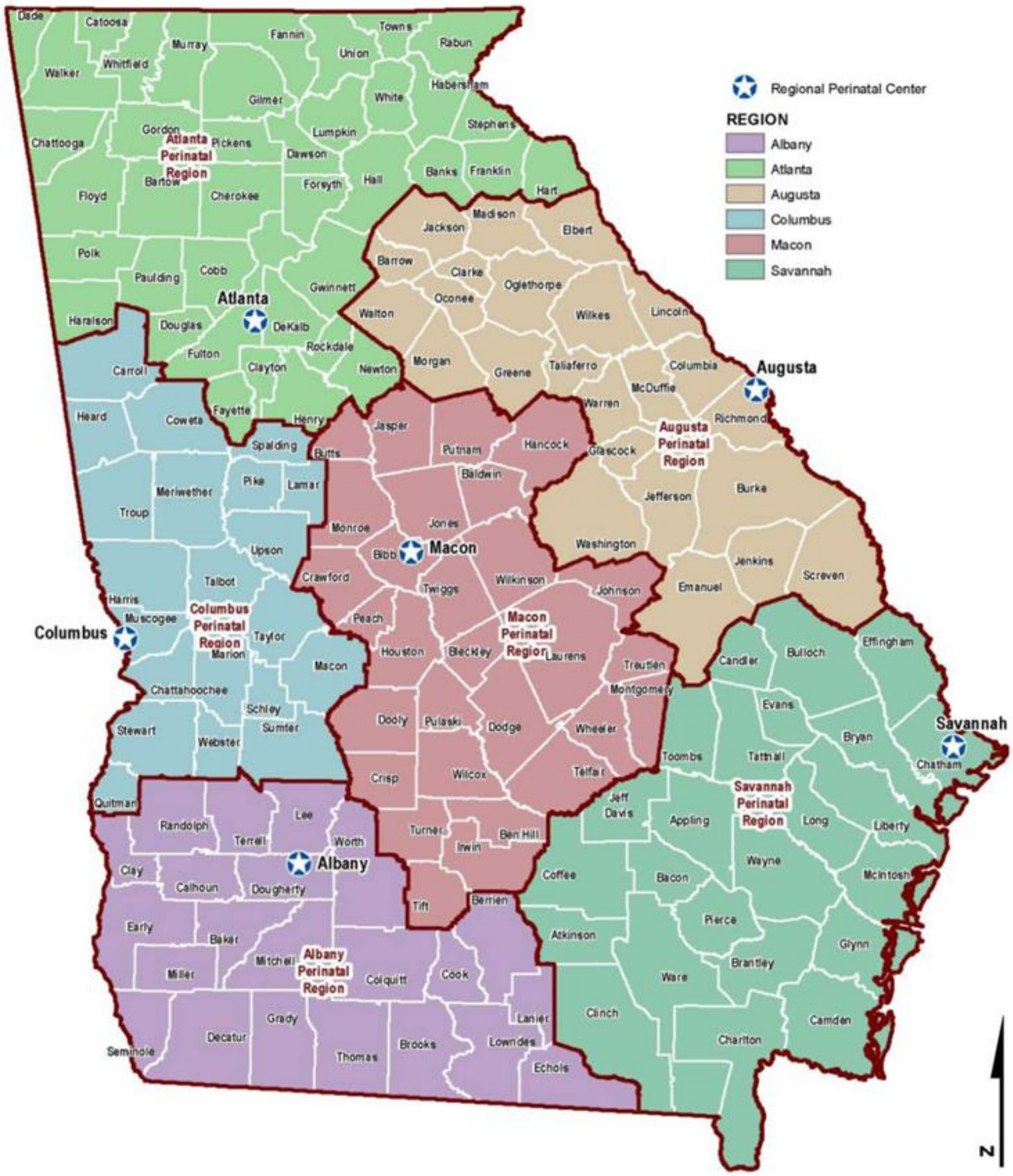
A related concern from this study is the difficulty of identifying women at high obstetric risk in epidemiologic studies. Although the OCI increased specificity, it did so at the cost of sensitivity. For research to identify the capabilities that contribute to reduced morbidity and mortality, robust methods to identify obstetric risk in administrative data must be developed. Without robust identification methods, research and evaluation of outcomes for women at high obstetric risk will be hindered by misclassification bias (Lash et al., 2014). Future research can use the net benefit technique employed in this study to compare risk identification models, selecting the best model and the best comorbidities to include in the model.

Conclusion

This study failed to find evidence to support its hypotheses that women at high obstetric risk have higher odds of poor outcomes when they deliver at hospitals with level I or II obstetric services as defined by the American Hospital Association. Future research is needed to determine if more precise stratification of resources can provide level III obstetric definitions associated with improved outcomes. For this research to move forward, a validated and standardized definition of high obstetric risk must be created for use with administrative data.

APPENDICIES

Appendix 1: Georgia Regional Perinatal Centers and Perinatal Regions



Reproduced from Core Requirements and Recommended Guidelines for Designated Regional Perinatal Centers, Georgia Department of Public Health, 2012

Appendix 2: Bed size and AHA Obstetrical Service Level of Delivery Hospitals in Georgia Maternal Child Health Repository, 2008-2012

Atlanta Perinatal Center (35 facilities)

Hospital	**AHA OB Level**	**Total Beds**
Atlanta Medical Center	3	460
Cartersville Medical Center		119
Chestatee Regional Hsopital		48
Cobb Memorial Hospital	1	56
Dekalb Medical Center at Hillandale		80
Dekalb Medical Center at North Decatur	2	628
Eastside Medical Center	3	310
Emory John’s Creek Hospital	3	113
Emory University Hospital Midtown	3	511
Fannin Regional Hospital		50
Floyd Medical Center	2	304
Gordon Hospital	2	69
Grady Memorial Hospital	3	971
Gwinnett Medical Center	3	582
Habersham County Medical Center	1	53
Hamilton Medical Center	2	282
Henry Medical Center	3	227
Hutcheson Medical Center		179
Newton Medical Center	3	87
North Fulton Regional Hospital		202
Northeast Georgia Medical Center	3	614
Northside Hospital - Atlanta	3	601
Northside Hospital - Cherokee	2	105
Northside Hospital - Forsyth	2	231
Piedmont Fayette Hospital	2	189
Piedmont Atlanta Hospital	3	643
Piedmont Mountainside Hospital	1	52
Rockdale Medical Center	2	138
South Fulton Medical Center		302
Southern Regional Medical Center		331
Stephens County Hospital	2	96
Union General Hospital		45
Wellstar Cobb Hospital	3	382
Wellstar Douglas Hospital	1	102

Wellstar Kennestone Hospital	3	382

Albany Perinatal Center (9 hospitals)

Hospital	**AHA OB Level**	**Total Beds**
Archbold Memorial Hospital	2	264
Colquitt Regional Medical Center	1	100
Cook Medical Center	1	140
Donalsonville Hospital	1	140
Grady General Hospital	1	46
Memorial Hospital and Manor		80
Phoebe Putney Memorial Hospital	3	691
Smith Northview Hospital		45
South Georgia Medical Center	2	418

Augusta Perinatal Region (11 hospitals)

Hospital	**AHA OB Level**	**Total Beds**
Athens Regional Medical Center	2	360
Barrow Regional Medical Center	1	56
Burke Medical Center		40
Elbert Memorial Hospital		52
Augusta University Medical Center	3	478
Clearview Regional Medical Center		77
Doctor’s Hospital of Augusta	2	350
Saint Mary’s Healthcare System	1	196
Trinity Hospital of Augusta		231
Georgia Regents Medical Center	3	430
Washington County Regional Medical Center		77

Columbus Perinatal Region (9 hospitals)

Hospital	**AHA OB Level**	**Total Beds**
Doctor’s Hospital – Columbus		219
Phoebe Sumter Medical Center		76
Piedmont Newnan Hospital	1	136
Spalding Regional Hospital	2	160
Tanner Medical Center – Carrollton		185
Tanner Medical Center – Villa Rica		40
Upson Regional Medical Center	1	101
The Medical Center		583
West Georgia Health	2	276

Macon Perinatal Center (11 hospitals)

Hospital	**AHA OB Level**	**Total Beds**
Coliseum Medical Center		310
Crisp Regional Hospital	1	73
Dodge County Hospital	1	55
Dorminy Medical Center		75
Fairview Park Hospital		163
Houston Medical Center	2	237
Irwin County Hospital	1	64
Medical Center of Central Georgia	3	637
Oconee Regional Medical Center	1	118
Taylor Regional Hospital	1	157
Tift Regional Medical Center	2	181

Savannah Perinatal Center (13 facilities)

Hospital	**AHA OB Level**	**Total Beds**
Appling Healthcare System		34
Bacon County Hospital		25
Coffee Regional Medical Center	3	88
East Georgia Regional Medical Center	2	149
Evans Memorial Hospital		49
Liberty Regional Medical Center		50
Mayo Clinic Health System in Waycross	2	199
Meadows Regional Medical Center	1	65
Memorial University Medical Center	3	604
Southeast Georgia Health System – Brunswick Campus	1	300
Southeast Georgia Health system – Camden Campus	1	40
St. Joseph's/Candler Hospital	2	
Wayne Memorial Hospital		84

Appendix 3: Capabilities of Health Care Providers in Hospitals Delivering Basic, Specialty and Subspecialty Care

Reproduced from Core Requirements and Recommended Guidelines for Designated Regional Perinatal Centers, Georgia Department of Public Health, 2012

Level of Care	Capabilities	Health Care Provider Types
Basic	• Surveillance and care of all patients admitted to the obstetric service. • An established triage system for identifying patients of high risk who should be transferred to a specialty or subspecialty hospital. • Proper detection and initial care of unanticipated maternal-fetal problems that occur during labor and delivery • Capability to begin an emergency cesarean delivery within an interval based on the timing that best incorporates maternal and fetal risks and benefits • Availability of appropriate anesthesia, radiology, ultrasonography, laboratory and blood bank services on a 24 hour basis • Care of postpartum conditions	Family physicians, obstetricians, laborists, hospitalists, certified nurse midwives, nurse practitioners, advanced practice registered nurses, physician assistants, surgical assistants, anesthesiologists, and radiologists

	• Ability to make transfer arrangements in consultation with physicians at higher level receiving hospitals • Provision of accommodations and policies that allow families, including their children, to be together in the hospital following the birth of an infant • Data collection, storage and retrieval • Initiation of quality improvement programs, including efforts to maximize patient safety	
Specialty	Provision of basic care services plus care of appropriate women at high risk and fetuses, both admitted and transferred from other facilities	All basic health care providers, plus sometimes maternal medicine specialists
Subspecialty	Provision of all basic and specialty care services, plus evaluation of new technologies and therapies	All specialty health care providers, plus maternal fetal medicine specialist
Regional Subspecialty Perinatal Care Center	• Provision of comprehensive perinatal healthcare services at and above those of subspecialty care facilities • Responsibility for regional perinatal health care service organization and	All subspecialty health care providers, plus other subspecialists, including obstetric and surgical subspecialist

	coordination, including the following areas: • Maternal and neonatal transport • Regional outreach support and education programs • Development and initial evaluation of new technologies and therapies • Training of health care providers with specialty and subspecialty qualifications and capabilities • Analysis and evaluation of regional data, including perinatal complications and outcomes	
All institutions providing perinatal care should be capable of providing neonatal resuscitation and stabilization		

Appendix 4: ICD Codes used for conditions included in the Obstetric Comorbidity Index

Appendix 1. Diagnostic Codes Used to Define Maternal End-Organ Injury

Complication	ICD-9 CM Codes
Acute heart failure	415.0x, 427.5x, 428.0x, 428.1, 428.21, 428.31, 428.41, 997.1x, 669.4x, 428.23, 428.33, 428.43, 428.9x
Acute renal failure	584.x, 669.3x
Acute liver disease	570, 646.7x
Acute myocardial infarction	410.x
Acute respiratory distress syndrome/respiratory failure	518.81, 518.82, 518.84, 518.5x, 799.1x, 518.7x
Disseminated intravascular coagulation/coagulopathy	666.3x, 286.6x, 286.7x, 286.9x, 287.4
Coma	780.01, 780.03, 572.2x, 250.2x, 250.3x, 251.0x
Delirium	293.x
Puerperal cerebrovascular disorders	671.5x, 674.0x, 430.xx-432.xx, 436, 997.01, 997.02, 433.01, 433.11, 433.21, 433.31, 433.81, 433.91, 434.01, 434.11, 434.91, 325, 348.1, 348.3x, 348.5x, 437.1x, 437.2x, 437.6x, 346.6x
Pulmonary edema	514.xx, 518.4x 428.1x
Pulmonary embolism	673.x, 415.1x
Sepsis	038.x, 995.91, 995.92, 112.5x, 659.3x, 785.52
Shock	669.1x, 785.5x, 998.0x, 995.4x, 995.0x, 995.94, 999.4x
Status asthmaticus	493.01, 493.11, 493.21, 493.91
Status epilepticus	345.3x

ICD-9-CM, International Classification of Diseases, 9th Revision, Clinical Modification.

Bateman BT, Mhyre JM, Hernandez-Diaz S, Huybrechts KF, Fischer MA, Creanga AA et al. Development of a comorbidity index for use in obstetric patients. Obstet Gynecol 2013;122.

The authors provided this information as a supplement to their article.

 Page 1 of 1

Appendix 5: ICD Codes for conditions included in the New Zealand Transfer Guidelines

Autoimmune Conditions

Connective tissue disorders (SLE) 710.0x

Thrombophilia 286.9

Cardiovascular Conditions

Valve Disease or Replacement 394.x-397.x, 424.x, v43.3

Cardiomyopathy 425.x

Hypertension >150/100 401.x-405.x, 585.x, 587.x, 646.2x

Ischemic Heart Disease 412.x-414.x

Pulmonary Hypertension 46.0x, 416.8x, 416.9x

Pregnancy Related Conditions

Intrauterine Growth Restriction / Small for Gestational Age 764.x, 649.6x

Malignancy 140-208

Pre-Eclampsia (mild and severe) 642.4x -642.7x

Morbid Obesity 278.0x, 649.1x, V85.3 -V85.39 is 35-39, V85.4

Multiple Pregnancy V27.2 - V27.8, 641.x

Placenta Previa 641.0x, 641.1x

Polyhydramnios 657.x

Premature Labor 644.0x-644.1x ,644.2x

Vasa Previa 663.5x

Endocrine Conditions

Gestational Diabetes 648.8x

Pre-existing Diabetes 250.x, 648.0x

Gastroenterological Conditions

Cholestasis of pregnancy 646.73

Hepatitis 070.20, 070.21, 070.30, 070.31

Esophageal Varices 456.0-456.2x

Marfan's Syndrome 759.82

Hematological Conditions

Hemolytic Anemia 283

Sickle Cell Disease 282.4x, 282.6x

Thromboembolism V12.51, 453.4x-453.9

Infectious Diseases

CMV 78.5

HIV 042.x, V08.x

Listeriosis 27

Toxoplasmosis 130.x

Tuberculosis 647.3x

Varicella 052.x

Acute Unstable Psychosis 298.x

Neurologic Conditions

Epilepsy 649.4x

Muscular dystrophy 359.0, 359.1

Myasthenia gravis 358.0x

Spinal cord lesion 952.x

<u>Renal Disease</u>

Glomerulonephritis 580.x, 582.x

Renal Failure 586, 585.5, 585.6

<u>Cystic Fibrosis</u> 277.0x

<u>Organ Transplant</u> V42.x

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