System-level risk factors and postpartum morbidity: the role of health insurance and health care financial burden

By

Menolly Kaufman, MPH

A DISSERTATION

Presented to the Oregon Health & Science University-Portland State University School of Public Health in partial fulfillment of the requirements for the degree of

Doctor of Philosophy in Epidemiology

May 2022

School of Public Health

Oregon Health & Science University-Portland State University

CERTIFICATE OF APPROVAL

This is to certify that the PhD dissertation of

Menolly Kaufman, MPH

has been approved

Jonathan M. Snowden, PhD

Maria I. Rodriguez, MD MPH

K. John McConnell, PhD

Dawn M. Richardson, DrPH MPH

Dedication

To Bryce, I love you like XO.

ACKNOWLEDGEMENTS

Before I could even dream of completing a PhD, so many professors, educators, and mentors got me to this point. First, thank you to **Dr. Karen Hoppes-Fischer**, my AP U.S. History professor. I will never forget the first paper I submitted to you that was not even worthy of an F. You taught me crucial lessons in doing hard things, writing really fast, and pushing myself farther than I could ever have imagined. Next, thank you to **Dr. Kristy Maher**, professor of sociology at Furman University. Without you, I would never have discovered public health and epidemiology. You were critical to my epidemiology origin story. You helped me discover not just a career but also a calling. Keep taking chances on college kids with rough edges. Finally, **Dr. Dante Verme**, there are no words to express my gratitude for your kindness, mentorship, and dedication to not just me but every student that passes through the epidemiology and biostatistics programs at GW. You see the best in everyone and the potential in every student.

I dedicate my progress and sanity to all of my classmates. I started this doctoral journey with two of the kindest, most loyal people on the planet, **Kim Yee** and **Lauralee Fernandez**. I am honored to end this journey with both of you still in my life. Thank you to the brilliant trainees who came before me and paved the way for my successes, especially Dr. **Sarah Andrea** and Dr. **Kelly Reavis**. **Jonah Geddes**, **Dr. Angela Senders**, **Sarah-Truclinh Tran**, **Abigail Newby-Ku**, and **Christina Jaderholm**, the journey would have been a slog without all of you. The hours of studying, coding, and over-analyzing nuances of bias were infinitely more successful and fun with you all. Finally, Dr. **Jennifer Ku**, I am your biggest fan. You are not only a brilliant and talented epidemiologist but a kind and caring friend. Thank you for being my dissertation buddy.

In addition to my inspiring classmates, I am deeply grateful to many faculty members, staff, and administrators within and outside of OHSU-PSU School of public health. Thank you to Dr. **Marhsall** for wearing many hats to support and promote epi doctoral students. And I'm sorry for all the times you had to track me down to turn in forms! Thank you to Dean **David Bangsberg** for being a kind and supportive mentor from my very first term in the program. You will be very missed next year. Thank you to many other faculty members who impacted me during my training - Drs. **Boone-Heinonen, Messer, Dinno, Carmichael, Jukic, Lambert, and Becker.**

I am deeply grateful to my dissertation committee members for their expertise, time, and patience. Thank you, Drs. **McConnell** and **Rodriguez**, for the high expectations and your approachable mentorship style. You have pushed me to be a better researcher, thinker, writer, and communicator. Oh, and thanks for the awesome day job. Dr. **Richardson**, thank you for always keeping me and my dissertation grounded in my purpose – to inspire health system change to benefit birthing and postpartum people. And to Dr. **Snowden**, what a ride! We've laughed, I've cried, and without a doubt, I am a better person because of your mentorship. Since day one, you have pushed me to be a better scientist than I thought possible. I'm so grateful for your mentorship and proud of our work together. I hope this is the start of a research collaboration journey, not the end.

Last and certainly not least, my family is my rock. **Mom** and **dad**, you "never gave me any idea that I couldn't do whatever I wanted to do or be whomever I wanted to be" (Rory Gilmore). Thank you for teaching me resilience and how to live a full life on my own terms. **Bryce**, you brought me back to Oregon and helped me build this beautiful, messy life. Thank you for your never-ending patience and always finding a way to make me laugh. I love you like

XO. **Amelia,** thank you for giving me my best job yet - your mom. Your silly smile and big hugs have kept me grounded through the dark times. I love you to the moon and back.

ABSTRACT OF THE DISSERTATION

System-level risk factors and postpartum morbidity: the role of health insurance and health care financial

By

Menolly Kaufman, MPH

Doctor of Philosophy in Epidemiology

Oregon Health & Science University, Portland 2022

Associate Professor Jonathan Snowden, Chair

Inequities in maternal health in the United States are a national crisis. Despite half of the maternal deaths occurring up to one year postpartum, we lack foundational knowledge on the drivers of postpartum morbidity beyond the first six weeks, often referred to as the 'traditional' postpartum period. Utilizing the Oregon All Payer All Claims database, we followed birthing people up to twelve months postpartum to examine how clinical factors, health insurance, and health care financial burden impact postpartum morbidity and care-seeking.

My first research aim was to estimate associations of demographics, clinical factors, and health insurance with postpartum readmissions. We characterized readmissions as with and without evidence of severe maternal morbidity (SMM) and the timing of readmissions (≤6 weeks and 7-52 weeks). We found that SMM at birth was the strongest risk factor for readmissions with evidence of SMM. Comparatively, we found that pre-pregnancy diabetes was the strongest risk

factor for readmissions without SMM. Factors such as mental health diagnoses and substance use disorder have similar magnitudes of risk for readmissions without SMM as hypertension and diabetes.

The second aim took an in-depth look at the role of insurance on postpartum care-seeking and morbidity. We used a time-to-event approach to examine the role of insurance type at birth (Medicaid, High Deductible Health Plans (HDHPs), and other commercial plans) with emergency department visits, readmissions, and comprehensive postpartum visit attendance. We accounted for population differences in insurance type using multinomial propensity score weights. We found that Medicaid-funded births were more likely to readmit to the hospital, more likely to seek care at the ED, and less likely to attend the universally recommended postpartum care visit. We found no statistically significant differences in postpartum care-seeking among birthing people with HDHPs and other commercial insurances.

My final aim focused on the role of health care financial burden among the commercially insured population. We described health care financial burden incurred before birth through the childbirth hospitalization, assessed if the highest levels of financial burden (>$5,000) were primarily among those with HDHPs, and examined if an association existed between financial burden and postpartum care-seeking. We found that most birthing people with over $5,000 in financial burden were not enrolled in an HDHP. Finally, we found that as financial burden increased, the likelihood of attending the comprehensive postpartum visit or seeking care in the ED decreased.

Taken together, this body of work highlights that the mechanisms by which system-level factors impact postpartum health are nuanced and warrant more research and thoughtfully tailored interventions. We described how the US healthcare system in its current form, notably

our approach to cost-sharing, may contribute to the well-documented inequities in postpartum health outcomes. Policies and interventions must grapple with the complex ways birthing people interact with the healthcare system in order to mitigate these inequities.

TABLE OF CONTENTS

LIST OF TABLES

Appendices

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACA	Patient Protection and Affordable Care Act
ACOG	American College of Obstetricians and Gynecologists
APAC	All Payer All Claims
ED	Emergency Department
HCUP	Health Care Utilization Project
HDHP	High Deductible Health Plan
MH	Mental Health
NAM	National Academy of Medicine
NIS	National Inpatient Sample
PPR	Postpartum Readmissions
SMM	Severe Maternal Morbidity
SUD	Substance Use Disorder
TWANG	Toolkit for Weighting and Analysis of Nonequivalent Groups

CHAPTER 1. INTRODUCTION & RESEARCH AIMS

1.1. Introduction

The United States (US) has the highest rates of maternal death and complications of childbirth among high resource countries.[1] Within the US, structural inequities such as economic inequalities are critical drivers of disparities in maternal mortality and severe maternal morbidity (SMM).[2,3] These inequities are exacerbated by health systems-level factors, which are both understudied and critical determinants of maternal morbidity. To date, little research exists about how systems-level factors, such as health insurance and health care financial burden, may drive inequities in maternal morbidity.

Half of the maternal deaths occur during the postpartum period[4], but limited knowledge exists on the quality of care and health outcomes postpartum. Even less is known about care and outcomes *after* the traditional 6-week postpartum period. The data we do have reflect a stark reality: within the traditional postpartum period, unplanned health care use (emergency department (ED) visits and inpatient admissions) has increased by 20% in the last decade,[5–7] and 35% of all women do not attend a postpartum preventive care visit.[8] Taken together, this indicates potential under-use of preventive care resulting in overuse of unplanned care, suggesting a missed opportunity to prevent maternal morbidity during the postpartum period.

It is important to recognize that not only do health systems factors affect utilization, *they are a driver of maternal morbidity itself*. In the US, where healthcare costs continue to rise, many individuals bear a high financial burden for their care.[9] Across commercial plans, the financial burden, often measured as direct patient costs, varies widely and can be as high as $8,150[10] or 13% of median household income.[11] No research to date has examined if maternal morbidity varies amongst those with the highest levels of financial burden.

This work creates foundational knowledge about postpartum morbidity up to one year postpartum and represents one of the first studies to establish an association between health care financial burden and postpartum care-seeking.

1.2. Dissertation Overview & Research Aims

In Chapter 2, I begin with a review of the literature on maternal morbidity and the current standard of care for postpartum people. I review the literature on the role of health insurance and health care financial burden related to postpartum morbidity. Finally, I assess the gaps and limitations in the current body of research on postpartum health.

In Chapter 3 (**Aim 1**), I estimate associations between demographics, clinical factors, health insurance, and postpartum readmissions. Readmissions are classified by the presence or absence of severe maternal morbidity and timing ($\leq$ 6 weeks, 7-52 weeks). I accounted for confounding using a causal modeling approach and utilized log-binomial and log multinomial regression to estimate cumulative incidence ratios.

In Chapter 4 (**Aim 2**), I estimated associations between health insurance at birth (Medicaid, High Deductible Health Plans (HDHP), and other commercial plans) and postpartum care utilization using a time-to-event approach. The primary outcomes included readmissions and emergency department visits within one-year postpartum and comprehensive postpartum visit attendance within 12 weeks. I accounted for confounding in my Cox Proportional Hazard models by estimating propensity score weights using the Toolkit for Weighting and Analysis of Nonequivalent Groups (TWANG).

In Chapter 5 (**Aim 3**), I describe health care financial burden among birthing people with commercial insurance and establish an association between financial burden and postpartum care utilization using robust Poisson regression. I compared the direction and magnitude of the

association between HDHPs and postpartum care utilization with the association between the highest levels of financial burden (>$5,000) and postpartum care utilization.

In Chapter 6, I conclude with a summary of the dissertations rationale, key study findings, future research directions, and public health implications. Finally, the appendices provide supplemental materials for all three aims.

CHAPTER 2. REVIEW OF THE LITERATURE

The United States (US) has the highest maternal death rates and complications of childbirth among high resource countries, nearly twice the rate of Canada or the United Kingdom.[12] Of maternal deaths, half occur during the postpartum period.[13,14] Within the US, structural inequities such as economic inequality and racism are critical drivers of maternal mortality and severe maternal morbidity. For example, Black and American Indian/Alaskan Native rates of maternal mortality are 2-3 times higher than rates in white women.[15]

In addition to maternal mortality, severe maternal morbidity is a compelling maternal health concern. Severe maternal morbidity (SMM) are acutely severe health events that indicate a serious health condition that could have led to death (a "near miss"), such as acute respiratory distress syndrome or acute renal failure.[16,17] SMM exhibits similar trends in racial disparities as maternal death - non-white women experience higher rates of SMM.[18] The alarming disparities in maternal mortality and morbidity shed light on unmet postpartum health care needs and missed opportunities to address structural barriers to reduce maternal inequities

2.1 A New Postpartum Paradigm

In response to the trends in maternal mortality and severe maternal morbidity, the American College of Obstetricians and Gynecologists (ACOG) put forth a new postpartum paradigm to incorporate "well-woman" care past the traditional postpartum period.[19] Prior guidelines recommended a single comprehensive visit within six weeks of delivery. In the updated guidelines, ACOG suggests at least one visit within three weeks postpartum and a follow-up visit within 12 weeks postpartum. For women with chronic conditions such as hypertension, the guidelines suggest blood pressure screenings very early postpartum to prevent

future SMM. For all women, care provided within the remainder of the extended postpartum period should be individually tailored and patient-centered.

The ACOG postpartum recommendations call for postpartum care to be a continuous, patient-centered process extending past the traditional postpartum period. This call was echoed by the National Academy of Medicine (NAM), which proposed extending the postpartum period to 12 months after delivery.[20] The postpartum visit is a key point of care to address the holistic short- and long-term physical, social, emotional, and mental health needs of many birthing people. However, up to 40% do not currently attend their comprehensive postpartum visit, with higher rates of non-attendance observed among Medicaid-funded births (50%) compared to those with commercial insurance (25-30%).[8,21]

Despite the call for an extended postpartum period by two prominent professional societies (ACOG & NAM), little research to date follows birthing people past the first 6 to 12 weeks. One potential reason for the lack of evidence is that most claims-based research is limited to Medicaid-funded births. Many pregnant women with no insurance or low-income women with private insurance may become eligible for Medicaid; in 2016, Medicaid funded 43% of all US births.[22] However, Medicaid eligibility for pregnant women varies widely from state to state. At a federal level, all states must provide pregnant women with pregnancy-related care if their income is up to 138% of the federal poverty line.[23] While some states increased the income threshold to 185% or more of the federal poverty line, many did not.[24]

Unfortunately, Medicaid coverage in most states ends 60 days after delivery.[25] Given that Medicaid is the largest payer of deliveries in the US and many women may become uninsured or privately insured after Medicaid coverage ends, it is difficult to follow up on long-term maternal health outcomes for Medicaid-funded births beyond the traditional 6-week postpartum window.

2.2 Postpartum Unplanned Health Care Use

Within the extended postpartum period, a continuum of morbidity can affect long-term maternal health but does not necessarily rise to the level of SMM. Notably, a focus on this continuum of maternal morbidity (up to, but not exclusively, SMM and maternal death) will be necessary to prevent progression to SMM and death. Postpartum morbidity is often identified during hospital readmissions or emergency department visits. Evidence suggests these unplanned visits disproportionately affect lower-income and women of color and highlights the need for a new postpartum paradigm.

Postpartum Readmission

Postpartum readmission (PPR) is a critical, albeit imperfect, marker of maternal morbidity, given that the most serious maternal complications are diagnosed during hospitalizations.[26] To date, evidence on PPR is restricted to large inpatient datasets such as the National Inpatient Sample (NIS)[27] or State Inpatient Databases (SID).[6] Research shows that 60-day PPR has steadily increased from 1.72% in 2004 to 2.16% in 2011.[6] Additionally, data from the NIS from 2014 show that Black women and deliveries paid by Medicaid were more likely to be readmitted and experience SMM during readmission.[18,28]

PPR encompasses inpatient stays with various levels of medical and social complexity. At the highest level of acuity is PPR, with evidence of SMM. This category of PPR is typically viewed as "near misses" of maternal mortality.[29] Significant clinical and policy attention has been given to address high acuity PPR in an effort to prevent maternal mortality. For example, the Biden administration included in the American Rescue Plan, the COVID-19 relief legislation,

which allowed states to extend Medicaid insurance coverage for low-income birthing people up to one year postpartum. Postpartum Medicaid expansion aims to increase access to preventive care and ultimately reduce maternal morbidity and SMM.[30–32] However, PPR without evidence of SMM could be just as medically and socially complex with lasting impacts on maternal morbidity. More research is needed to assess if the drivers for PPR with and without evidence of SMM differ and if they point to different intervention approaches.

As previously stated, most of the evidence on PPR with and without SMM is from the NIS. While the NIS provides information on maternal demographics and some hospital factors, it lacks many contextual clinical and system-level factors that are potential drivers of both categories of PPR. These factors may include, but are not limited to, rural residence, having an infant in the Neonatal Intensive Care Unit, clinical morbidities not documented at delivery, insurance type,[33] health care costs, and other social vulnerabilities. Both categories of PPR are likely the result of existing health inequities. However, each type of PPR requires unique interventions at the health system and policy levels.

Postpartum Emergency Department Use

Similar to PPR, very little research has explored postpartum ED visits. While not the same severity level as SMM, ED visits represent an understudied marker of maternal morbidity. One population-based study from California found that 1 in 12 women visited the ED in the first 12 weeks postpartum.[7] Across the three studies that assessed postpartum ED use, Medicaid insurance and delivery complications (classified as SMM at delivery) were associated with postpartum ED visits.[34,35] Notably, one study found that the majority of postpartum ED visits at one urban hospital resulted in a standard postpartum exam with no complications.[35]

Postpartum ED may serve as an indicator for structural barriers to receiving timely and appropriate preventive care. Further evidence is needed to differentiate what clinical and system-level factors drive postpartum ED use and if they are the same as drivers of PPR.

With maternal mortality and SMM rising, there is a renewed focus on maternal health and morbidity. The renewed focus has led to a call for a new postpartum paradigm, but little evidence exists that identifies optimal postpartum care in the extended postpartum period. Evidence suggests that PPR is rare but rising, and postpartum ED visits are more common but severely understudied. Both categories of unplanned health care have not been studied beyond the traditional 6-week postpartum period. The current body of evidence shows that Medicaid-funded births and Black women are at higher risk for unplanned health care. Still, we lack the evidence to support the causal role of structural inequities or missed opportunities for clinical management. One important and understudied structural inequity that affects maternal morbidity is how patients pay for their health care.

2.3 Health Care Coverage and Rising Costs

Health care financing in the US is complex. Approximately 90% of Americans have health insurance[36], with 55.1% of Americans having employer-sponsored insurance in 2018.[37] The total cost of health care for individuals and families includes monthly premiums paid to an insurance company and the direct out-of-pocket costs patients pay for their care.[10,38] The Affordable Care Act (ACA) requires employer-based insurance plans to cover maternity services, but plans are allowed to impose cost sharing[39], such as copayments[40] and deductibles[41] for these services. Many insurance plans have a set deductible, or dollar amount that a patient is responsible for paying for in full before the insurance company implements cost-sharing (a set

dollar amount per encounter or percentage of total charges paid for by the patient). After the deductible is met and cost-sharing is in place, plans have an out-of-pocket maximum amount[10] that caps the total dollar amount a patient pays before the insurance company pays for the remainder of care. The deductible and out-of-pocket maximums are reset to $0 at the start of each calendar year.

To offset the rise in premiums, a growing number of employers have offered high deductible health plans (HDHP), health plans where the deductible is over a specific dollar amount set by the Internal Revenue Service (IRS).[42] In 2020, the deductible minimum to classify as an HDHP is $1,400,[43] an increase from $1,250 in 2014.[44] In the last decade, HDHP enrollment has increased from 14.6% in 2007 to 43.4% in 2017,[45] and the proportion of people with deductibles over $2,000 per person has doubled from 9 to 18%.3 The rise in HDHPs has been accompanied by higher out-of-pocket maximums, which increased by 28% between 2014 and 2020 ($6,350 to $8,150).[39]

As noted above, insurance changes before and after delivery are common. Despite Medicaid being the largest single payer for deliveries, private insurers cover over 50% of deliveries. The cost and quality of commercial insurance coverage vary widely. In the last decade, patients, including delivering persons, continue to pay more for their health care, in line with national trends. In 2016, the US spent twice as much on health care per capita compared to similar high-income countries.[46] Despite the US having the most expensive health system in the world with the highest childbirth costs, the US still has the highest rates of maternal mortality among developed nations (19 per 100,000 live births in 2017 compared to 5 per 100,000 live births in Western Europe).[12,15,47]

2.4 The Cost of Maternity Care

Consumers can experience financial burdens from health care expenditures without necessarily being enrolled in a high-deductible plan. With childbirth as the number one reason for hospitalizations in the US,[48] birthing persons face increasing health care costs. Further, most birthing people with private insurance that delivery in a hospital will reach their out-of-pocket maximum during childbirth hospitalization. For women enrolled in an HDHP, that amount can be as high as $8,150, equivalent to 13% of median household income.[49] However, lower out-of-pocket amounts could also cause a financial burden on postpartum women and potentially impact morbidity.

Calculating and assessing the effects of the financial burden of health care costs around childbirth is particularly complicated. After the passage of the Affordable Care Act (ACA), certain preventive care services are covered with no cost-sharing. For example, prenatal visits are fully covered under the ACA, but an ultrasound is not; a comprehensive diabetes screening test may be covered, even if diabetes treatment is not.[50] The ACA requires health insurers to cover childbirth hospitalizations, but there are no limits on cost-sharing for these stays.[51] As a result, the out-of-pocket cost of maternity care has followed national health care trends and has increased by 50% from 2008 to 2015 ($3,069 to $4,569, respectively).[9]

As it relates to postpartum outpatient care, since most women meet their deductible and out-of-pocket maximums during childbirth (or even before) and thus have no cost-sharing for subsequent care, it is unclear why postpartum visit attendance is so low across insurance types. If health care costs were the primary driver of seeking (or not seeking) preventive care, we would expect attendance to be much higher. Additional research is needed to examine if forgone

preventive care is the driver of maternal morbidity (i.e., SMM, PPR, ED visits) or if the financial burden influences maternal morbidity directly.

2.5 Financial Burden and Health Outcomes

Like many areas of health research, postpartum health typically groups insurance status as public, private, and uninsured based on payer at delivery. Few studies account for insurance changes or different cost-sharing levels across commercial plans. One study assessed the impact of an employer-mandated switch to an HDHP plan from 2002-to 2007 and found that out-of-pocket costs increased by 250% but had no impact on the odds of postpartum visit attendance.[52] Additional research is needed to elucidate how financial burden impacts maternal morbidity rather than just postpartum visit attendance.

HDHPs have been shown to cause women of all socioeconomic backgrounds, races, and ethnicities to forego preventive care. HDHP enrollment led to delays in care-seeking for acute health care episodes among diabetic patients,[53] and deferred breast cancer diagnostic imaging for women across socio-economic groups.[54] HDHPs may also exacerbate existing racial inequities in health outcomes. One study found that cancer survivors with HDHP insurance delayed prescriptions to save money and that Black cancer survivors were more likely to delay prescriptions than white cancer survivors.[55]

Most studies have grouped all HDHP plans as one sub-type of private insurance. As noted previously, HDHP plans have a minimum deductible of over $1,350, but the total cost for maternity care can be much higher. Additionally, it remains unknown if the gradient of actual health costs paid by the patient is a more precise measure of health care financial burden and if a more precise measure will elucidate a more nuanced understanding of drivers of maternal

morbidity. Despite the lack of research on HDHP enrollment or direct financial burden on maternal health specifically, analogous evidence from other chronic conditions supports the hypothesis that high financial burden can lead to deferred preventive care postpartum. Yet, the literature has not demonstrated if deferred care leads to subsequent maternal morbidity. The postpartum period remains immensely understudied, and more research is needed to identify and ultimately address the drivers of maternal morbidity.

2.6 Postpartum Research Gaps

The disparities in maternal mortality and SMM in the US have led to a renewed focus on postpartum health. Clinicians, researchers, policymakers, and patients support a new postpartum paradigm that includes ongoing care for women up to one year postpartum. However, due to data limitations outlined in **Table 2.1**, little research exists to inform maternal morbidity prevention efforts past the traditional 6-week postpartum period. In addition, the majority of evidence for postpartum care and morbidity comes from a single care setting (inpatient as opposed to an outpatient or emergency department setting)[5], follow-up for a single calendar year,[6,28,56–59] single-payer (commercial insurance or Medicaid), or a single hospital setting.[35]

Table 2.1 Shortcomings of data sources to study postpartum health up to one year postpartum

Data Sources to Study Maternal Health	Shortcomings
National Inpatient Sample National Readmissions Sample State Inpatient Databases (HCUP)	(1) Limited to health care use in one calendar year (2) Inpatient claims only
Private Insurer Databases (Optum, Truven)	(3) Limited to one payer (4) Unable to follow people who disenroll from one insurance company
Medicaid Claims data	(5) Limited to one payer, and pregnancy eligibility ends 60 days after delivery.

Hospital Specific data	(6) Health care encounters with one hospital or hospital system

The existing research indicates that unplanned health care is steadily rising, and 25-40% of women do not attend at least one postpartum outpatient visit.[6,8] Taken together, this represents a missed opportunity to prevent maternal morbidity. Foundational research is needed to characterize unplanned postpartum care use and maternal morbidity in the extended postpartum period. Our research seeks to fill this gap by (1) studying drivers of postpartum readmissions with and without SMM; (2) estimating the impact of health insurance type (including HDHPs) and unplanned postpartum care (a critical marker of maternal morbidity) up to one year postpartum; and (3) quantifying the impact of health care financial burden on unplanned postpartum care use up to 12 months post-delivery among commercially insured women. Collectively, our research aims to address if health insurance and health care financial burdens are driving existing inequities in maternal morbidity.

CHAPTER 3. RESEARCH PAPER #1

Postpartum Readmissions with and without Severe Maternal Morbidity within One Year of Birth, Oregon 2012-2017

Menolly Kaufman[a,b], K. John McConnell[b], Suzan L. Carmichael[c], Maria I. Rodriguez[b,d], Dawn Richardson[a], Jonathan M. Snowden[ad]

[a] School of Public Health, Oregon Health & Science University and Portland State University

[b] Center for Health Systems Effectiveness, Oregon Health & Science University

[c] Departments of Pediatrics and Obstetrics and Gynecology, School of Medicine, Stanford University

[d] Department of Obstetrics and Gynecology, Oregon Health & Science University

Keywords: maternal morbidity, postpartum, readmissions.

3.1 Abstract

Postpartum readmissions (PPR) represent a critical marker of maternal morbidity. Most Severe Maternal Morbidity (SMM) events result in a hospital admission, but most PPRs do not have evidence of SMM. Little is known about PPR and SMM beyond the first six weeks postpartum. We examined the associations of maternal demographic and clinical factors with PPR within 12 months postpartum. We categorized PPR as with and without evidence of SMM to assess whether risk factors and timing differed. Using the Oregon All Payer All Claims database, we analyzed hospital births from 2012-2017. We used log-binomial regression to estimate associations between maternal factors and PPR. Our final analytic sample included 158,653 births. Overall, 2.7% (N = 4,141) of births had at least one readmission within 12 months postpartum (808 (19.5% of PPRs) with SMM). SMM at delivery was the strongest risk factor for PPR with SMM (Risk Ratio (RR): 5.55, 95% Confidence Interval (CI): 4.14, 7.44). PPR without SMM had numerous risk factors, including any mental health diagnosis (RR: 2.10, CI: 1.91, 2.30), chronic hypertension (RR: 2.17, CI: 1.85, 2.55), and pre-pregnancy diabetes (RR: 2.85, CI: 2.47, 3.30), all which were on par with SMM at delivery (RR: 1.89, CI: 1.49, 2.40).

3.2 Introduction

Maternal mortality is a critical marker of population health.[60] To address the maternal mortality crisis in the United States (US),[61,62] researchers and policymakers have refocused on a critical and understudied driver of maternal mortality - severe maternal morbidity (SMM). SMM is a sentinel event defined by a composite index of acutely severe health events that indicate a serious maternal health condition, such as acute respiratory distress syndrome and acute renal failure.[17] SMM can occur prenatally, but most SMM events occur during or after birth.[63] Approximately 50% of maternal deaths[13] and 15% of SMM[64] happens in the postpartum period, making postpartum health and care a national priority.[19,20]

Postpartum readmissions (PPR) represent an important but understudied marker of SMM and other forms of maternal morbidity. Nearly all SMM events postpartum result in hospital readmission.[65,66] However, PPR without SMM occur more frequently than PPR with SMM, indicate medical complexity, and may represent dimensions of maternal morbidity that have not yet been characterized.[6]

PPRs within the first six weeks postpartum have increased steadily in the US[6] and are disproportionately concentrated within low-income populations. Medicaid recipients are up to 24% more likely to be readmitted and experience SMM during readmission.[12-14] However, we lack detailed information on PPR and its drivers. Previous studies of PPR are limited by single care settings (inpatient data),[67] a single calendar year,[6,28,56–59,67] a single-payer (e.g., Medicaid),[5,68] or a single hospital system.[35] Evaluating PPR beyond the first six weeks postpartum is essential: 25% of maternal mortality occurs outside the traditiona6-weekek postpartum window.[13]

While it is well established that maternal morbidity and mortality occur throughout the first year postpartum, little is known about maternal morbidity that occurs after the first six weeks postpartum.[20,65] However, knowledge is sorely lacking regarding PPR during the entire first year postpartum, including timing and drivers of SMM and PPR that results from other maternal factors (whether physical health conditions, mental health conditions, or social factors). It is possible that PPR without evidence of SMM has overlapping risk factors than PPR with SMM, or the drivers might differ. We do know that PPR without SMM is more prevalent than PPR with SMM[69,70] and is associated with non-clinical risk factors, such as access to preventive care through expanded access to insurance.[4,71] An improved understanding of who is most likely to experience PPR, both with and without SMM, would help in identifying interventions to improve maternal health. A deeper understanding of when PPR occurs up to one year postpartum can also inform recommendations for clinical care, policy (e.g., insurance coverage policy), and other social supports that people may require after experiencing pregnancy.

We assessed and compared the associations of demographic, clinical, and health insurance-related factors with PPR, by SMM status and timing of PPR. We used Oregon's All Payer All Claims (APAC) database, which included continuous enrollment of all individuals in a state across calendar years (including prenatal, delivery, and postpartum health care), in all care settings, regardless of insurance type. We hypothesized that factors associated with PPR would differ depending on the presence or absence of SMM and would differ according to the timing of PPR in the year after childbirth.

3.3 Methods

Data Source

We used Oregon All Payer All Claims (APAC) data from 2011-2018.[72] APAC collects medical and pharmacy claims, insurance enrollment data, and demographic information from commercial insurance plans that cover at least 5,000 people and Medicaid across the state of Oregon. Each person has a unique, de-identified person key allowing linkage of medical claims, demographic information, and enrollment data. Overall, APAC covers 3.4-3.9 million people per year, approximately 87% to 98% of the Oregon population.[73] This study was approved by the OHSU institutional review board. To avoid loss of privacy or confidentiality, we suppressed cell sizes of less than 11.

Study Population

Our analytic population included persons between 15-44 years of age with evidence of a hospital live birth in medical claims data. Births were identified using a previously published algorithm[74] and codes identified by the American College of Obstetricians & Gynecologists (ACOG).[75,76] We included deliveries from January 1, 2012, to December 31, 2017. Our inclusion criteria allowed for 12 months of data prior to delivery in order to identify comorbidities in the prenatal and pre-conception periods. We did not require continuous enrollment in the prenatal period.

The follow-up period for our analyses was 12 months postpartum. In order to not equate lack of health insurance enrollment (resulting in no recorded health care claims) with the absence of PPR in the follow-up period, we further restricted our analytic population to individuals with at least 11 months of insurance enrollment postpartum. The insurance enrollment data were reported on the person-key, insurance type (Medicaid or commercial), and calendar month level. We required at least 11 of 12 calendar months of any type of insurance enrollment postpartum.

Our criteria allowed people to have either commercial, Medicaid insurance, or a mix of insurance plans in the postpartum period. This represents a distinct advantage of an all-payers database over single-payer databases, given that insurance discontinuities and changes are very common in the postpartum period in the US.[71,77] We conducted a sensitivity analysis to examine how the deliveries excluded due to lack of insurance enrollment differed from the final analytic population.

Study Variables: Outcomes

Our primary outcome was PPR, which we identified using a quality metric methodology from the Oregon Health Authority. The methodology includes a wide range of metrics, including readmissions.[78] We were primarily interested in *de novo* readmissions separate from admissions directly related to the index childbirth. Therefore, we did not classify inpatient stays in the follow-up period for a transfer of the index birth to another hospital or a subsequent birth as a readmission. To ensure that we did not capture transfers as a readmission, we required at least one full day between the index birth and the subsequent readmission. Our outcome measure included inpatient readmissions from one day up to one year after delivery discharge and was based on the hospital admission date. While it is possible for birthing people to readmit multiple times to the hospital, we only considered the first readmission in our outcome measure.

We were also interested in how PPR may differ according to the presence or absence of SMM diagnosed at readmission. Therefore, we classified each readmission as with or without evidence of SMM. We identified SMM at readmission as containing at least one of the International Classification of Diseases (ICD) 9 or 10 diagnosis or procedure code for SMM as defined by the CDC.[79] Knowledge is currently lacking about which SMM-defining conditions

are most important common at delivery hospitalization versus at readmission. Therefore, we assessed the frequency of all of the specific SMM indicators at childbirth hospital admissions compared to PPRs. The 21 comorbidity indicators included in the CDC definition are not mutually exclusive, meaning one hospital encounter could have more than one SMM indicator. In accordance with the CDC index, the measure most commonly used in SMM surveillance, we included blood transfusion in our definition of SMM. The transfusion of blood products is commonly considered a proxy measure for obstetric hemorrhage but can be indicated for non-SMM defining conditions.

To understand if drivers of PPR within the traditional postpartum period (i.e., six weeks after childbirth) differed from PPR after the traditional postpartum period, we further classified PPR by timing. Our timing categories included: (1) the traditional postpartum period (first six weeks after hospital delivery) and (2) the extended postpartum period (after the traditional postpartum period and up to 12 months postpartum, 7-52 weeks). For analyses, we categorized outcome measures by both presence of SMM and the timing of PPR. For example, for PPR with evidence of SMM, the outcome measure has three mutually exclusive categories: no readmissions (reference), PPR with evidence of SMM in the traditional postpartum period ($\leq$6 weeks), and PPR with evidence of SMM in the extended postpartum period (7-52 weeks). Among birthing people with multiple PPRs, we classified their PPR as occurring in the traditional postpartum period if the first PPR occurred in the first six weeks postpartum.

Study Variables: Predictors of PPR and SMM

Many factors are potentially associated with PPR, with and without SMM. To assess these associations, we included demographic factors, clinical factors, and health insurance as

covariates based on our conceptual model and data availability. Demographic factors include maternal age (15-19, 20-24, 25-29, 30-34, 40+ years) and maternal residential rurality. A rurality indicator was based on Rural-Urban Commuting Area Code categories assigned to residential ZIP codes.[80] If maternal residential rurality was missing, we classified them as missing and did not drop the observations from our analysis. In other words, residence was coded as one of three categories: Urban, Rural, or Missing. Zipcode was missing for three observations in our database. In our database, maternal race/ethnicity was missing for nearly 50% of births. Given the high rate of missing data, we did not include maternal race/ethnicity in our analyses. In addition, we included insurance type (Medicaid or commercial) at birth. To obtain insurance type at birth, we linked the enrollment calendar month to the calendar birth month. In rare cases, people did have both Medicaid and commercial insurance during the birth month. In those instances, we prioritized Medicaid insurance.

Delivery-related covariates included mode of delivery (cesarean versus vaginal birth), extended delivery length of stay (categorized as lengths of stay > 90th percentile by mode of delivery),[16] and SMM at delivery. We included SMM at delivery as a covariate given the limited and emerging research on repeat SMM rehospitalization.[69] We identified SMM at delivery using the same methodology noted above.

Finally, we examined the following morbidities: pre-pregnancy diabetes, gestational diabetes, hypertensive disorders of pregnancy (chronic hypertension, gestational hypertension, eclampsia/preeclampsia, and preeclampsia superimposed on chronic hypertension), substance use disorders, and mental health diagnoses. All comorbidities were identified as the presence of one or more ICD 9 or ICD-10 diagnosis codes from 12 months prior to delivery admission through the delivery discharge date. The diagnosis codes could appear on any health care encounter in our database, including outpatient and inpatient encounters. The relevant codes for

each comorbidity are listed in Supplemental Table A1.1. For mental health diagnoses, we created a binary indicator for any mental health comorbidities. In addition, we created binary indicators for mental health diagnosis categories (depressive (major depression disorder classified under serious mental illness), anxiety, serious mental illness (SMI), and other).

Statistical Analysis

We used multiple approaches to estimate associations between maternal factors and PPR, with and without SMM. First, we conducted bivariate analyses of each covariate by readmission status (any readmission within 12 months postpartum compared to no readmission) and SMM status (readmission with SMM; and readmission without SMM).

Next, we compared the frequency of SMM-defining conditions during birth hospitalizations and during readmissions. We used standardized differences to evaluate the comparability of each SMM comorbidity indicator prevalence during birth hospitalization and during readmissions.[81] Standardized differences are independent of sample size and represent a measure of the mean difference for a given covariate between two groups. We reported the standardized differences as absolute values. To maintain subjects' confidentiality, we did not report the count, percentage, or calculate the standardized difference for any SMM comorbidity indicator with a cell size of less than 11.

To estimate the unadjusted cumulative incidence ratio (relative risk, RR) between each factor and our primary outcome (PPR with and without SMM), we utilized log-binomial regression to estimate multivariable adjusted RR for each predictor. We identified potential confounders for each predictor of PPR and SMM through the process of creating causal diagrams (Directed Acyclic Graphs, DAGS).[82] This process of confounder identification is based on pre-

specified assumptions and *a priori* knowledge about how variables are connected and the temporal relationships between them.[83] Therefore, the multivariable model for each predictor is parsimonious and only contains confounders specific to the individual predictor being studied as identified by our DAGs.

Many of our predictors have complex causal associations with PPR and SMM that have yet to be fully explored in scientific literature. For instance, cesarean is most commonly considered a mediator (and thus should generally not be adjusted for), and recent work has studied the mediating role of cesarean as it relates to the outcome of SMM.[84] This framework applies when considering a prenatal exposure (e.g., BMI) and postpartum outcome. It underlies our decision to refrain from controlling for cesarean birth in most models, given that a majority of our predicators also precede birth (e.g., insurance, maternal residential location, hypertensive disorders of pregnancy, diabetes, substance use disorder, and mental health conditions). The exception is extended delivery LOS, which occurs after birth. For this variable, cesarean birth is plausibly a confounder, and thus we controlled for it.

In addition to PPR with and without SMM (dichotomous outcome measures), we assessed the timing of PPR by creating categorical outcome variables differentiating PPR within the traditional postpartum period (≤6 weeks postpartum) and PPR in the extended postpartum period (7-52 weeks postpartum). Given that our outcome variables to assess PPR timing are categorical rather than dichotomous, we conducted log multinomial regression.[41] This method is an adaption of the log-binomial regression model for categorical outcome measures. We adjusted each factor for the same confounders as the multivariate log-binomial regression models described above. We reported the adjusted relative risks and 95% confidence intervals for all models.

To understand the impact of our *a priori* health insurance enrollment inclusion criterion (at least 11 months of postpartum insurance enrollment), we conducted a bivariate analysis comparing the excluded population to the final analytic sample. We compared demographics, clinical factors, and health insurance across groups using Pearson's chi-square. Finally, we assessed the robustness of our results by conducting two sensitivity analyses. First, we assessed if relaxing our continuous enrollment criteria to 60 days and assessing readmissions within 60 days meaningfully changed any associations. Next, we removed transfusion of blood products from our SMM definition. Blood transfusion by itself has the lowest clinical validity as a marker for SMM.[16,85] The transfusion of blood products is often used as a proxy measure for obstetric hemorrhage, but blood transfusion could be indicated for a variety of non-SMM defining conditions such as chronic anemia or hemoglobinopathies without crisis. We assessed if the associations between covariates and PPR with and without evidence of SMM changed when we removed transfusion of blood products from the SMM definition both at birth and during PPR. All other modeling specifications remained the same as our primary modeling approach.

For statistical comparisons, we used two-sided tests with a 0.05 alpha level. All analyses were completed in R 4.01.

3.4 Results

We identified 202,273 unique Oregon hospital births from 2012-2017. We excluded 28 (0.01%) who did not meet our age criteria (15-44) and 43,592 (21.6%) who did not meet our continuous postpartum insurance enrollment criteria, leaving 158,653 hospital births for analysis (**Figure 3.1**). Overall, 2.6% (N = 4,141) of births had at least one PPR within 12 months (**Table 3.1**). Deliveries with any PPR were more likely to have Medicaid insurance at delivery (73.0% vs 59.2%, p<0.001), cesarean delivery (36.8% vs 28.2%, p<0.001), any hypertensive disorders of

pregnancy (17.3% vs 9.5%, p<0.001), any SUD diagnosis (13.0% vs 5.9%, p<0.001) and any mental health diagnosis (14.0% vs 7.3%, p<0.001).

Among readmissions, 19.5% had evidence of SMM (N=808). Among PPR with evidence of SMM (**Table 3.2**), the top indicators included sepsis (41.4%), acute renal failure (11.2%), adult respiratory distress syndrome (11.0%), and transfusions of blood products (10.3%). In contrast, the top SMM indicators during delivery were transfusions of blood products (42.1%), eclampsia (15.0%), and disseminated intravascular coagulation (14.8%). Of the top indicators, the standardized difference effect sizes indicate non-negligible differences in prevalences between SMM diagnosed at childbirth hospitalization versus PPR, with the exception of acute renal failure.

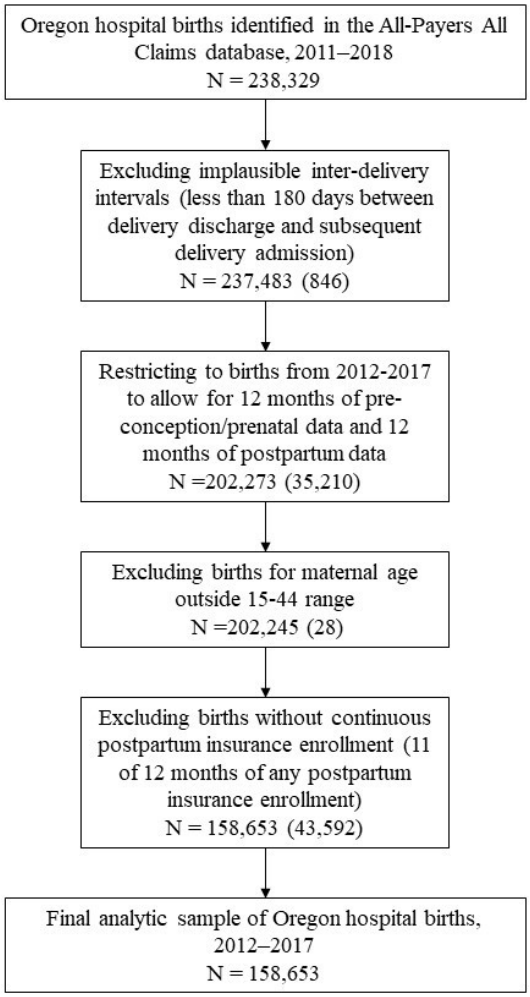
The strongest risk factor for PPR with SMM was SMM at delivery (RR: 5.55, 95% CI: 4.14 , 7.44; **Figure 3.2, Supplemental Table A1.3**). SMM at delivery was also associated with an increased risk for PPR without SMM (RR: 1.95, 95% CI: 1.55, 2.45), but was not the strongest risk factor. We found that PPR without SMM had numerous factors with measures of association on par with SMM at delivery, including any mental health diagnosis (RR: 2.10, CI: 1.91, 2.30), substance use disorder (excluding cannabis) (RR: 2.01, CI:1.80 , 2.24), chronic hypertension (RR: 2.17, CI: 1.85, 2.55), and pre-pregnancy diabetes (RR: 2.85, CI: 2.47, 3.30).

When considering the timing of PPR, a modestly higher proportion of PPR with SMM occurred in the traditional postpartum period (n=352, 43.6%) compared to PPR without SMM (n=1,259, 37.8%). SMM at delivery was the strongest risk factor for PPR with SMM in the traditional postpartum period (RR: 9.03, 95% CI: 6.40, 12.75; **Table 3.3**), followed by preclampsia/eclampsia (RR: 5.51, 95% CI: 3.94, 7.72). For PPR without SMM, chronic hypertension was the strongest risk factor in the traditional postpartum period (RR: 2.42, 95% CI: 2.12, 2.77) but not in the extended postpartum period (RR: 1.88, 95% CI: 1.51, 2.33). In

addition, any mental health diagnosis (RR: 2.46, 95% CI: 2.19, 2.75), pre-pregnancy diabetes (RR: 3.14, 95% CI: 2.63, 3.76) were among the strongest risk factors for PPR without SMM in the extended postpartum period.

Finally, our comparison of demographic and clinical characteristics of the excluded population (people with less than 11 months of postpartum insurance coverage) showed some key differences (**Supplemental Table A1.2**). We found that the excluded population was younger (32.3% 15-24 compared to 27.9% in the analytic sample, $p<0.001$) and more likely to have Medicaid insurance at birth (67.9% vs. 59.6%, $p<0.001$). When relaxing our continuous enrollment criteria to 60 days and assessing readmissions within 60 days, we found that Medicaid insurance at delivery (RR: 1.11, 95% CI: 0.99, 1.24) and gestational diabetes (RR: 1.14, 95% CI: 0.97, 1.34) were no longer statistically significantly associated with PPR without evidence of SMM (**Supplemental Table A1.5**). Further, we observed that the association between any mental health diagnosis and PPR with evidence of SMM (RR: 1.36, 95% CI: 1.00,1.86) was no longer statistically significant. When excluding transfusion of blood products in our SMM definition, we did not observe meaningful differences between covariates and PPR with and without SMM (**Supplemental Table A1.4**).

Figure 3.1 Selection of participants for a study of postpartum readmissions, Oregon Hospital Births, 2012-2017



Note: The numbers in parantheses indicate the number of births excluded from the final analytic sample.

Table 3.1 Maternal Demographics, Delivery and Clinical Characteristics for Any Postpartum Readmission and Severe Maternal Morbidity (SMM) Status of Births with a Readmission, Oregon Hospital Births, 2012-2017 (N=158,653)

	Overall (N=158,653)		**No Postpartum Readmission (N=154,512)**		**Any Postpartum Readmissions (N=4,141)**		**Any Postpartum Readmissions**			
							With Evidence of SMM **(N=808)**		*Without* Evidence of SMM **(N=3,333)**	
	N	%	N	%	N	%	N	%	N	%
Maternal Age										
15-19	9853	6.2%	9468	6.1%	385	9.3%	64	7.9%	321	9.6%
20-24	34417	21.7%	33437	21.6%	980	23.7%	165	20.4%	815	24.5%
25-29	45085	28.4%	43923	28.4%	1162	28.1%	233	28.8%	929	27.9%
30-34	43043	27.1%	42086	27.2%	957	23.1%	190	23.5%	767	23.0%
35-39	21460	13.5%	20935	13.5%	525	12.7%	123	15.2%	402	12.1%
40+	4795	3.0%	4663	3.0%	132	3.2%	33	4.1%	99	3.0%
Maternal Residential Location										
Urban	103353	65.1%	100742	65.2%	2611	63.1%	502	62.1%	2109	63.3%
Rural	55297	34.9%	53767	34.8%	1530	36.9%	306	37.9%	1224	36.7%
Missing	3	0.0%	3	0.0%	0	0.0%	0	0.0%	0	0.0%
Insurance Type at Delivery										
Commercial	64165	40.4%	63048	40.8%	1117	27.0%	198	24.5%	919	27.6%
Medicaid	94488	59.6%	91464	59.2%	3024	73.0%	610	75.5%	2414	72.4%
Mode of Delivery								0.0%		
Vaginal	113496	71.5%	110880	71.8%	2616	63.2%	490	60.6%	2126	63.8%
Cesarean	45157	28.5%	43632	28.2%	1525	36.8%	318	39.4%	1207	36.2%
Extended Delivery Length of Stay	26344	16.6%	25202	16.3%	1142	27.6%	253	31.3%	889	26.7%
SMM at Delivery	1365	0.9%	1251	0.8%	114	2.8%	48	5.9%	66	2.0%
Pre-pregnancy Diabetes	3380	2.1%	3145	2.0%	235	5.7%	47	5.8%	188	5.6%
Gestational Diabetes	16577	10.4%	16046	10.4%	531	12.8%	89	11.0%	442	13.3%
Any Hypertensive Disorders of Pregnancy	15459	9.7%	14744	9.5%	715	17.3%	159	19.7%	556	16.7%

Hypertensive Disorders of Pregnancy										
Chronic Hypertension	3676	2.3%	3478	2.3%	198	4.8%	46	5.7%	152	4.6%
Gestational Hypertension	6315	4.0%	6106	4.0%	209	5.0%	50	6.2%	159	4.8%
Eclampsia/Pre-eclampsia	3416	2.2%	3237	2.1%	179	4.3%	45	5.6%	134	4.0%
Superimposed*	2052	1.3%	1923	1.2%	129	3.1%	18	2.2%	111	3.3%
Substance Use Disorder				0.0%						
Any	9686	6.1%	9146	5.9%	540	13.0%	122	15.1%	418	12.5%
Any (excluding cannabis)	8200	5.2%	7716	5.0%	484	11.7%	111	13.7%	373	11.2%
Mental Health Diagnosis										
Any	11877	7.5%	11297	7.3%	580	14.0%	86	10.6%	494	14.8%
Depressive	2356	1.5%	2224	1.4%	132	3.2%	24	3.0%	108	3.2%
Anxiety	5347	3.4%	5085	3.3%	262	6.3%	39	4.8%	223	6.7%
Serious Mental Illness	4786	3.0%	4523	2.9%	263	6.4%	30	3.7%	233	7.0%
Other	2414	1.5%	2252	1.5%	162	3.9%	20	2.5%	142	4.3%

Note: * Superimposed indicates preeclampsia for people with existing chronic hypertension[49]

Table 3.2 Severe Maternal Morbidity Indicators (CDC Definition) During Delivery Hospitalization and Postpartum Readmission for Oregon Hospital Births, 2012-2017

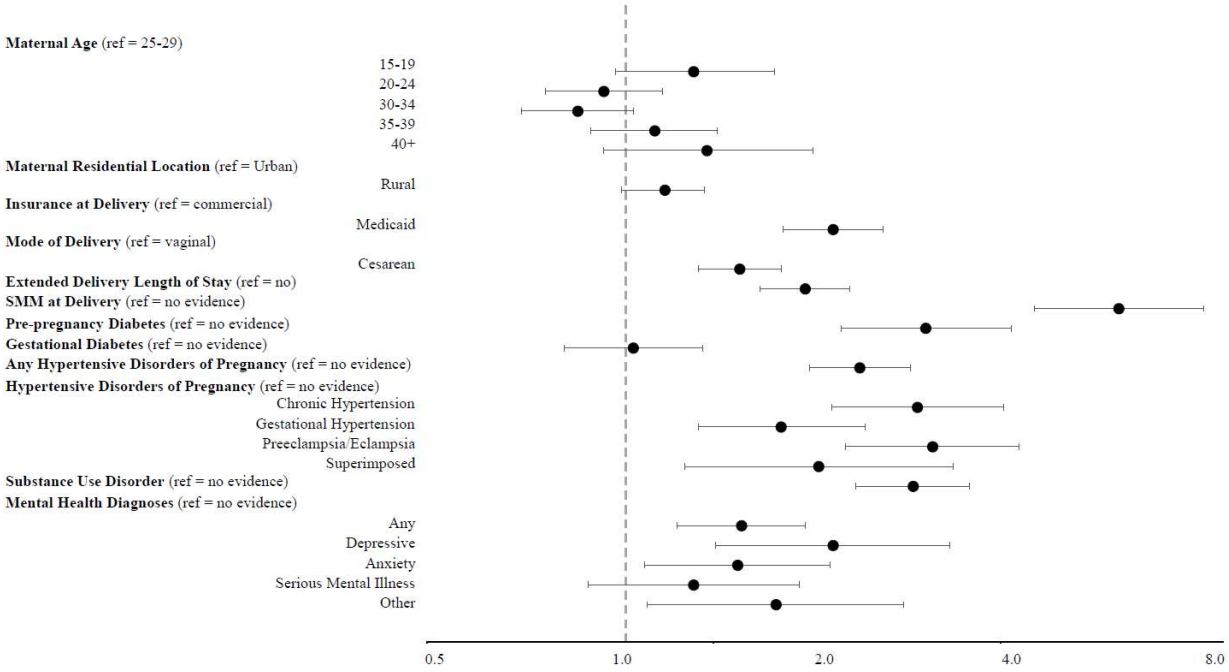
Severe Maternal Morbidity Indicator	Births with Evidence of SMM		Postpartum Readmission with Evidence of SMM		Standardized Difference*
	N=1,365	%	N=808	%	
1. Acute myocardial infarction	<11	-	22	2.7%	
2. Aneurysm	<11	-	<11	-	
3. Acute renal failure	119	8.7%	90	11.1%	8.1
4. Adult respiratory distress syndrome	93	6.8%	91	11.3%	15.6
5. Amniotic fluid embolism	<11	-	<11	-	
6. Cardiac arrest/ventricular fibrillation	<11	-	<11	-	
7. Conversion of cardiac rhythm	<11	-	<11	-	
8. Disseminated intravascular coagulation	202	14.8%	20	2.5%	45.0
9. Eclampsia	205	15.0%	49	6.1%	29.5
10. Heart failure/arrest during surgery or procedure	11	0.8%	<11	-	
11. Puerperal cerebrovascular disorders	33	2.4%	55	6.8%	21.0
12. Pulmonary edema / Acute heart failure	35	2.6%	70	8.7%	26.7
13. Severe anesthesia complications	14	1.0%	<11	-	
14. Sepsis	74	5.4%	338	41.8%	94.9
15. Shock	100	7.3%	63	7.8%	1.8
16. Sickle cell disease with crisis	<11	-	<11	-	
17. Air and thrombotic embolism	31	2.3%	71	8.8%	28.8
18. Blood products transfusion	575	42.1%	75	9.3%	81.1
19. Hysterectomy	80	5.9%	75	9.3%	13.0
20. Temporary tracheostomy	<11	-	<11	-	
21.Ventilation	28	2.1%	33	4.1%	11.8

Notes: SMM indicators are not mutually exclusive, meaning one person could have evidence of multiple comorbidity indicators; therefore, the percentages will not add to 100%. For any cell counts of <11, we suppressed percentages and did not calculate standardized differences.

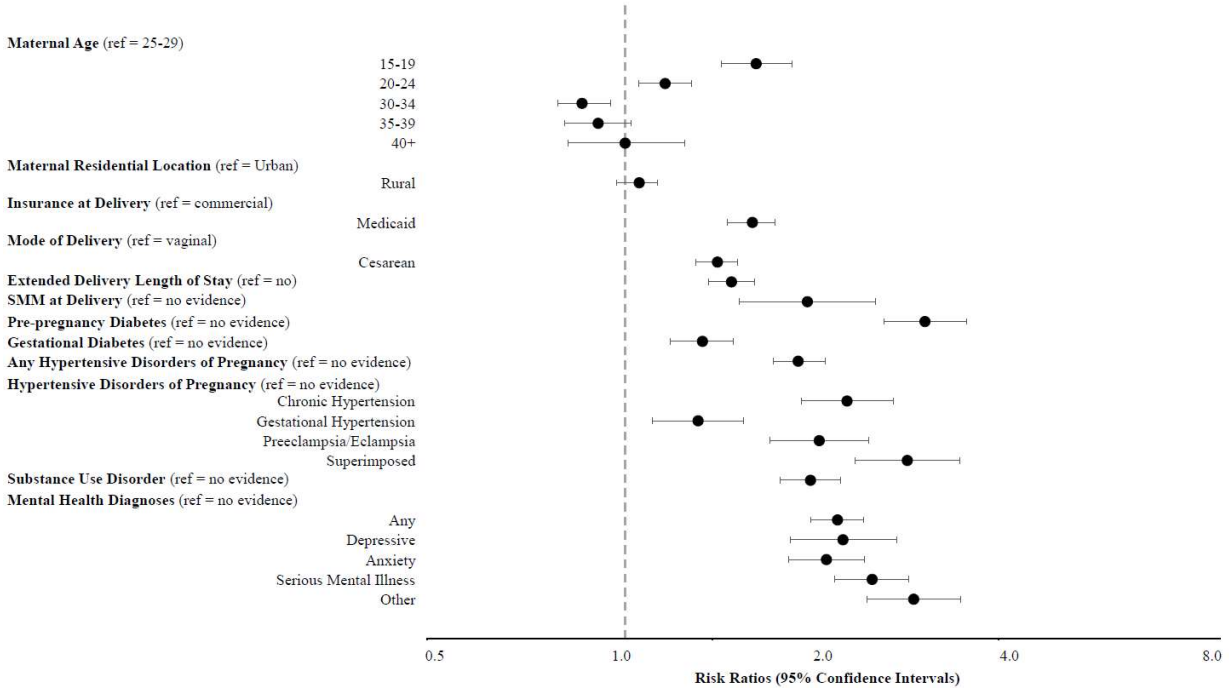
*An absolute standardized difference less than 10 may be indicative of a negligible difference in prevalence of the SMM indicator between births with evidence of SMM and readmissions with evidence of SMM.

Figure 3.2 Adjusted Cumulative Incidence Ratios for (A) Postpartum Readmissions with Evidence of Severe Maternal Morbidity (SMM) and (B) Postpartum Readmissions without Evidence of SMM, Oregon Hospital Births, 2012-2017 (N=158,653)

A.



B.



Notes:

1. Model adjusts for maternal age;
2. Model adjusts for maternal age, maternal residential location, any substance use disorder (SUD), and any mental health (MH) diagnosis;
3. Model adjusts for maternal age, maternal residential location, insurance type at delivery, any SUD, any MH, any diabetes, and any hypertensive disorders of pregnancy (HDP);
4. Model adjusts for maternal age, maternal residential location, insurance type at delivery, any SUD, any MH, any diabetes, HDP, and mode of delivery;
5. model adjusts for maternal age, maternal residential location, insurance type at delivery, any diabetes, and HDP;
6. Model adjusts for maternal age, maternal residential location, any SUD, and any MH;
7. Models adjust for maternal age, maternal residential location, any SUD, and any MH;
8. Model adjusts for maternal age, maternal residential location, and any MH;
9. Model adjusts for maternal age and maternal residential location.

Table 3.3 Adjusted Relative Risks for Postpartum Readmissions with and without Evidence of Severe Maternal Morbidity (SMM) by Readmission Timing for Oregon Hospital Births, 2012-2017 (N=158,653)

	Postpartum Readmission With Evidence of SMM				Postpartum Readmission Without Evidence of SMM			
	≤ 6 weeks (N=352)		7-52 weeks (N=456)		≤ 6 weeks (N=1,259)		7-52 weeks (N=2,074)	
	Adj. OR	95% CI	Adj. OR	95% CI	Adj. OR	95% CI	Adj. OR	95% CI
Maternal Age								
15-19	1.53	(1.01 , 2.31)	1.11	(0.76 , 1.61)	1.50	(1.21 , 1.85)	1.64	(1.40 , 1.91)
20-24	0.92	(0.67 , 1.27)	0.93	(0.72 , 1.21)	0.98	(0.84 , 1.15)	1.25	(1.11 , 1.40)
25-29	*ref*		*ref*		*ref*		*ref*	
30-34	0.96	(0.72 , 1.30)	0.78	(0.61 , 1.00)	0.85	(0.73 , 0.99)	0.87	(0.78 , 0.99)
35-39	1.66	(1.22 , 2.26)	0.75	(0.55 , 1.04)	1.15	(0.96 , 1.37)	0.77	(0.65 , 0.90)
40+	1.14	(0.61 , 2.12)	1.46	(0.93 , 2.28)	1.36	(1.02 , 1.83)	0.78	(0.58 , 1.05)
Maternal Residential Location[1]								
Urban	*ref*		*ref*		*ref*		*ref*	
Rural	1.24	(1.00 , 1.54)	1.08	(0.89 , 1.31)	1.00	(0.89 , 1.13)	1.07	(0.98 , 1.17)
Insurance Type at Delivery[2]								
Commercial	*ref*		*ref*		*ref*		*ref*	
Medicaid	1.81	(1.41 , 2.34)	2.29	(1.80 , 2.90)	1.10	(0.97 , 1.25)	2.00	(1.79 , 2.24)
Model of Delivery[3]								
Vaginal	*ref*		*ref*		*ref*		*ref*	
Cesarean	1.66	(1.33 , 2.06)	1.37	(1.13 , 1.67)	1.69	(1.50 , 1.89)	1.21	(1.10 , 1.33)
Extended Delivery Length of Stay[4]	1.99	(1.57 , 2.51)	1.78	(1.44 , 2.19)	1.53	(1.34 , 1.74)	1.41	(1.27 , 1.56)
SMM at Delivery[5]	8.03	(5.49 , 11.75)	3.72	(2.31 , 5.97)	2.40	(1.70 , 3.38)	1.57	(1.12 , 2.21)
Pre-pregnancy Diabetes[6]	1.60	(0.90 , 2.86)	3.88	(2.74 , 5.49)	2.42	(1.88 , 3.12)	3.14	(2.63 , 3.76)
Gestational Diabetes[6]	1.15	(0.81 , 1.62)	0.93	(0.66 , 1.31)	1.14	(0.95 , 1.37)	1.41	(1.23 , 1.62)
Hypertensive Disorders of Pregnancy[7]								
Any	2.67	(2.08 , 3.43)	1.96	(1.54 , 2.5)	2.42	(2.12 , 2.77)	1.51	(1.34 , 1.71)

No evidence	*ref*		*ref*		*ref*		*ref*	
Hypertensive Disorders of Pregnancy[7]								
Chronic Hypertension	2.95	(1.89 , 4.59)	2.62	(1.75 , 3.93)	2.70	(2.12 , 3.44)	1.88	(1.51 , 2.33)
Gestational Hypertension	1.81	(1.17 , 2.79)	1.66	(1.13 , 2.44)	1.70	(1.35 , 2.15)	1.06	(0.85 , 1.32)
Preeclampsia/Eclampsia	4.49	(3.07 , 6.58)	1.78	(1.08 , 2.93)	2.64	(2.05 , 3.39)	1.60	(1.26 , 2.03)
Superimposed	1.82	(0.86 , 3.86)	2.06	(1.13 , 3.74)	3.76	(2.88 , 4.91)	2.09	(1.61 , 2.72)
No evidence	*ref*		*ref*		*ref*		*ref*	
Substance Use Disorder[8]								
Any	2.68	(1.97 , 3.65)	2.75	(2.12 , 3.56)	1.57	(1.30 , 1.90)	2.10	(1.86 , 2.38)
Any (excluding cannabis)	2.90	(2.11 , 3.99)	2.9	(2.21 , 3.79)	1.68	(1.37 , 2.04)	2.19	(1.92 , 2.50)
Mental Health Diagnosis[9]								
Any	1.22	(0.85 , 1.77)	1.71	(1.29 , 2.27)	1.53	(1.29 , 1.83)	2.46	(2.19 , 2.75)
Depressive	1.38	(0.66 , 2.92)	2.58	(1.59 , 4.18)	1.33	(0.90 , 1.98)	2.63	(2.12 , 3.26)
Anxiety	1.40	(0.85 , 2.31)	1.54	(1.01 , 2.34)	1.58	(1.24 , 2.02)	2.29	(1.95 , 2.68)
Serious Mental Illness	0.87	(0.45 , 1.69)	1.58	(1.02 , 2.45)	1.85	(1.45 , 2.35)	2.68	(2.29 , 3.14)
Other	1.37	(0.65 , 2.89)	1.93	(1.11 , 3.36)	1.96	(1.42 , 2.70)	3.22	(2.65 , 3.90)

Notes:

1. Model adjusts for maternal age;
2. Model adjusts for maternal age, maternal residential location, any substance use disorder (SUD), and any mental health (MH) diagnosis;
3. Model adjusts for maternal age, maternal residential location, insurance type at delivery, any SUD, any MH, any diabetes, and any hypertensive disorders of pregnancy (HDP);
4. Model adjusts for maternal age, maternal residential location, insurance type at delivery, any SUD, any MH, any diabetes, HDP, and mode of delivery;
5. model adjusts for maternal age, maternal residential location, insurance type at delivery, any diabetes, and HDP;
6. Model adjusts for maternal age, maternal residential location, any SUD, and any MH;
7. Models adjust for maternal age, maternal residential location, any SUD, and any MH;
8. Model adjusts for maternal age, maternal residential location, and any MH;
9. Model adjusts for maternal age and maternal residential location.

3.5 Discussion

Working with a database that covered all hospitals births in a state, spanning eight years, and across insurance types, we examined the frequency, timing, and drivers of postpartum readmissions, with and without SMM. Our findings add nuance to what is known about both PPR and SMM. We found that birthing people with evidence of any SMM indicator at delivery were five times more likely to be rehospitalized for any SMM within 12 months postpartum compared to birthing people without evidence of SMM at delivery. We also found that SMM at delivery was driven by transfusion of blood products whereas SMM during readmission was driven by sepsis.

The associations between maternal factors and postpartum health outcomes are complex, and our study sheds light on associations between PPR, SMM, and their overlap. We found further evidence of a strong association between SMM at childbirth and rehospitalization for SMM. Preventing birthing people from experiencing this life-threatening outcome more than once in the perinatal period should be a high priority. Our findings show that SMM rehospitalization is more likely to occur in the traditional postpartum period, with an eight-fold higher risk for those with SMM at delivery. Our association, while indicating a very high risk for SMM rehospitalization, is less pronounced than recent findings from a commercially insured population that found SMM at delivery lead to a 12-fold higher risk of rehospitalization.[66] Yet, SMM at delivery still poses a risk for PPR with SMM up to 12 months postpartum. The risk of rehospitalization past the first six weeks is more than three times higher for birthing people with SMM at delivery than without. Our sensitivity analysis that removed transfusions of blood products from the SMM definition only modestly attenuated the risk for SMM rehospitalization and did not change our conclusions. Future research should examine the role of postpartum

preventive care in reducing SMM rehospitalization, in particular the timing and frequency of outpatient care.

We also found that the prevalence of SMM-defining conditions differed if SMM was diagnosed at childbirth versus readmission. The most common SMM indicator diagnosed at childbirth was transfusion of blood products (42.1%), followed by disseminated intravascular coagulation and eclampsia. None of these were among the most common SMM-defining conditions diagnosed at readmissions; sepsis was the most common (41.8%). This demonstrates that the profile of maternal morbidity occurring at postpartum readmission cannot be assumed to reflect morbidity occurring during childbirth. SMM is a composite measure. Defining specific strategies to prevent the progression of maternal morbidity will require targeted interventions depending on when SMM is diagnosed.

Two important and understudied postpartum risk factors are substance use disorders and mental health diagnoses. We found that both factors were associated with PPR with and without SMMHowever, the strength of the associations between substance use disorder and any mental health diagnoses and PPR without SMM varied depending on the timing of the PPR. Strikingly, the magnitude of association for substance use and mental health diagnoses and PPR without SMM were on par with traditional clinical comorbidities such as chronic hypertension and pre-pregnancy diabetes. In addition to the critical importance of SMM, factors that require ongoing management are important to consider when devising strategies to prevent deterioration of maternal well-being to the point of requiring hospitalization.

Strengths of our study include the use of a multi-year, multi-payer, multi-care setting database and examining PPR in the extended postpartum period. Our All-Payer All Claims database overcomes the limitations of prior studies that are limited to one care setting[6,56,67] or one

payer.[5,68] Our study also had limitations. First, claims data is limited to people with insurance at the time of any health care encounter. Approximately 50% of pregnant people gain Medicaid insurance because of their pregnancy and lose coverage 60 days after delivery.[71,86] Our study excluded people who had insurance at delivery but did not have at least 11 months of continuous insurance coverage postpartum (22% of total births in our sample) – an important and vulnerable population that warrants further study. By excluding those with intermittent insurance coverage postpartum, we may be excluding those at higher risk for PPR, thus underestimating the total PPR prevalence. Notably, our sensitivity analysis that relaxed the continuous enrollment criteria to 60 days postpartum did not change our overall conclusions. In addition, we were unable to reliably capture out-of-hospital births (e.g., births taking place at a birth center or at home) because they are often paid for outside of insurance. Out-of-hospital births account for approximately 4% of births in Oregon.[87] The association between birth setting and PPR and SMM warrants further study.

Next, the current scientific literature demonstrates that interpersonal and structural racism are drivers of maternal health inequities.[2,88] However, the Oregon APAC database was missing race and ethnicity information for 50% of our population and could not be reliably used in our analyses. In addition, our analyses rely on documentation of comorbidities on health care encounter records using ICD 9/10 codes, which are often underestimated in administrative claims data. If comorbidities are underestimated, our results may be biased towards the null. Finally, our analysis is limited to Oregon, a state with less racial and ethnic diversity than other regions in the US,[48] which reduces the generalizability of our findings.

Our study shows that the associations between maternal factors and postpartum morbidity are complex. As maternal health research progresses, more work is needed to understand and

ultimately prevent the spectrum of maternal morbidity. In particular, more research is needed to understand the proximal health factors that drive PPR, such as continuous insurance coverage and access to preventive and mental health care. This work will enable clinicians and policymakers to improve maternal morbidity and mortality, helping promote healthy pregnancy, delivery, and well-being for all pregnant people.

CHAPTER 4. RESEARCH PAPER #2

Postpartum Care Utilization within One Year across Insurance Types, Oregon 2012-2017

Menolly Kaufman[a,b], K. John McConnell[b], Maria I. Rodriguez[b,c], Dawn Richardson[a], Jonathan M. Snowden[a,c]

a School of Public Health, OreSnowdenth & Science University and Portland State University

b Center for Health Systems Effectiveness, Oregon Health & Science University

c Department of Obstetrics and Gynecology, Oregon Health & Science University

Keywords: postpartum, maternal morbidity, Medicaid, high deductible health plans.

4.1 Abstract

Background: Little is known about the frequency and timing of postpartum health care utilization, including hospital encounters (i.e., emergency department (ED) visits and inpatient readmissions) and comprehensive postpartum visit attendance. Research on health insurance and its association with postpartum health care utilization is often limited to the first six weeks after birth.

Objective: To quantify the association between insurance type at birth (including Medicaid, high deductible health plans (HDHPs), and other commercial plans) and postpartum utilization (hospital encounters within one year and comprehensive postpartum visit attendance within 12 weeks of birth), accounting for the loss of insurance postpartum.

Methods: We conducted a time-to-event analysis of all Oregon hospital births from 2012 to 2017 using the Oregon All Payer All claims database. We utilized multinomial propensity score weights to account for differences in insurance type at birth and weighted Cox Proportional Hazard regressions to estimate hazard ratios.

Results: Among our sample of 202,167 hospital births in Oregon from 2012 to 2017, 24.9% of births had at least one hospital encounter within one postpartum. Births funded by Medicaid were associated with a higher risk of a postpartum ED visit (Hazard Ratio (HR): 2.05, 95% CI: 1.99,2.12) and associated with a lower likelihood of attending the comprehensive postpartum visit (HR: 0.71, 95% CI: 0.70, 0.72) compared to other commercial plans. We observed no difference in risk of hospital encounters (HR: 0.89, 95% CI: 0.76, 1.03) or comprehensive postpartum visit attendance (HR: 0.96, 95% CI: 0.91, 1.02) between HDHPs and other commercial plans.

Conclusions: Postpartum people with Medicaid insurance were more likely to receive care in the ED within one year postpartum. This highlights unmet care needs for those with Medicaid insurance at birth and up to 12 months postpartum.

4.2 Introduction

Postpartum hospital encounters, such as unscheduled urgent care in the emergency department (ED) or hospital readmissions, are a critical marker of maternal morbidity. Postpartum hospital encounters may reflect a near miss for maternal mortality or a missed opportunity to provide preventive care in the outpatient setting. Evidence shows postpartum hospital readmissions are rare, with severe events requiring hospitalization occurring in just 2.2% of births.[6] However, between 7-11% of postpartum people visit the ED in the first 12 weeks following birth.[7,89] Limited data exist on the determinants of postpartum hospital encounters, especially postpartum ED use within and beyond the traditional postpartum period.

An improved understanding of how the types of insurance are associated with postpartum hospital encounters may identify systems solutions to address the US maternal mortality crisis.[90] Visits to the ED or readmissions in the postpartum period may reflect an inability to access appropriate, timely, and affordable outpatient care. This may result in adverse health consequences during the postpartum period due to foregone or delayed preventive care.

Medicaid insurance is known to be associated with increased rates of postpartum hospital encounters within the traditional postpartum period[7,18,28]; however, it is not known if different types of commercial plans, specifically commercial plans with high patient cost-sharing, are linked with unscheduled, urgent postpartum care. For instance, the cost of health care has been well established as a barrier to receiving timely care.[91] Yet, current studies of insurance and postpartum health are limited by dichotomizing insurance as either public or private when substantial heterogeneity exists within private plans.[92] Commercial plans may vary by the provider network, covered services, monthly premium, and patient cost-sharing (including deductibles that must be met before insurance coverage begins).

The highest patient cost cost-sharing among commercial insurance plans occurs among high deductible health plans (HDHP). In the last decade, HDHP enrollment has increased from 14.6% to 43.4%[9] and yet there is minimal research on the role of HDHPs and care-seeking among pregnant and postpartum people. Only one study from 2002 to 2007 found that HDHP enrollment had no impact on postpartum visit attendance.[52] To our knowledge, no study has examined the role of HDHPs and postpartum hospital encounters.

The objective of this study was to estimate the association between insurance type at birth (Medicaid, commercial plans with high financial burden, or HDHPs, and other commercial plans) with postpartum care utilization up to one year postpartum. We leveraged eight years of Oregon's All Payer All Claims database to evaluate the association between insurance type at birth and postpartum hospital encounters and comprehensive postpartum visit attendance.

4.3 Methods

Data Source

We utilized Oregon All Payer All Claims (APAC) data from 2011-2018.[72] APAC collects medical and pharmacy claims, member enrollment, and demographic information from commercial insurers covering at least 5,000 people and Medicaid (both fee-for-service and managed care) across the state of Oregon. Each person within APAC has a de-identified person key that allows us to link medical claims, pharmacy claims, enrollment data, and demographic information. APAC captures 3.4-3.9 million people per year, approximately 87% to 98% of the Oregon population.[73] This study was approved by the Oregon Health and Science University institutional review board.

Study Population

Our analytic population included persons between 15 and 44 years of age with evidence of a hospital birth in medical claims data. Births were identified using Diagnostic Related Group (DRG) and Current Procedural Terminology (CPT) codes from a previously published algorithm[74] and codes identified by ACOG.[75,76] We identified unique births based on delivery discharge date from January 1, 2012, to December 31, 2017. Our sampling frame ensures that all births have at least 12 months of look-back in order to identify diagnoses in the prenatal and preconception period. We also required up to 12 months of follow-up for all deliveries to measure our primary outcome, hospital encounters.

Study Variables

Exposure

Our primary exposure was insurance type at birth, which we categorized as HDHPs, all other commercial plans, and Medicaid. We separated commercial plans as HDHP and all other commercial plans because we were interested in the role of insurance coverage and the magnitude of care cost-sharing in postpartum care-seeking. We classified HDHPs using an indicator variable from the enrollment database provided by the data stewards (Oregon Health Authority). The insurers self-report to the data stewards if a plan is HDHP (i.e., a health plan with a deductible at or above the federally set minimum for a calendar year[43]). We linked the enrollment files to the month of delivery to establish insurance type at birth. In rare cases, people did have evidence of both Medicaid and commercial insurance during the birth month. In those instances, we prioritized Medicaid insurance because we are primarily interested in the level of

cost-sharing of pregnant people and its association with postpartum care-seeking. Therefore, we prioritized the insurance type with no cost-sharing.

Outcomes

Our primary outcome was hospital encounters up to 12 months postpartum. We created three outcome measures to assess hospital encounters: inpatient readmission, emergency department visits, and any hospital encounter (including readmissions and emergency department visits). We identified readmission and ED visits using the Oregon Health Authority's "Ambulatory Care: Emergency Department and Outpatient Utilization" quality metrics methodology.[78] We included hospital encounters from one day after delivery discharge up to one year after childbirth hospitalization discharge date. Given that we are conducting a time-to-event analysis, if an individual had multiple hospital encounters, we considered time to their first hospital encounter to define the outcome. Following the quality metric methodology, we classified an ED visit that led to an inpatient stay (i.e., an ED visit the day of or the day before an inpatient stay) as a part of the inpatient readmission rather than a distinct ED encounter. We were interested in *de novo*, non-childbirth hospital encounters after admission from the index childbirth hospitalization, so we further excluded inpatient readmissions for a transfer of the index birth to another facility or a subsequent birth in the follow-up period.

We were primarily interested in postpartum hospital encounters that might reflect maternal morbidity. Still, outpatient postpartum care is an important utilization outcome (and one that is under-utilized and under-studied to date). Therefore, our secondary outcome was postpartum visit attendance within 12 weeks postpartum. We selected 12 weeks of follow-up based on the American College of Obstetricians and Gynecology (ACOG) guidance on optimal

postpartum care, suggesting a comprehensive postpartum visit for all birthing people, regardless of medical profile and risk factors.[19] We identified postpartum visit attendance in medical claims data using CPT codes and ICD-9/10 diagnosis codes. Relevant codes (outlined in Appendix A) are from the NCQA "Prenatal and Postpartum Care" quality metric methodology.[8]

Covariates

In addition, we included maternal demographic, comorbidity, and delivery-related covariates. We included demographic variables such as maternal age (15-19, 20-24, 25-29, 30-34, 40+ years) and maternal residential location (rural or urban based on a rurality indicator provided by the data stewards (Oregon Health Authority) based on the last documented ZIP code[19]).

Maternal mental health and substance use play an important role in overall wellbeing and care-seeking. We included binary indicators for any prenatal mental health diagnoses and any prenatal substance use disorder diagnosis (SUD). For any mental health diagnoses, we also created binary, non-mutually exclusive flags for depression, anxiety, serious mental illness (e.g., schizophrenia, bipolar disorder, psychosis, and major depressive disorder.)[93], and all other mental health diagnoses. The diagnoses codes to identify prenatal SUD[94] and mental health diagnoses[95] are based on HEDIS quality metrics value sets and are outlined in **appendix table A2.1**.

Medical comorbidities are also critical factors in determining postpartum morbidity risk. To measure medical risk, we identified pre-pregnancy diabetes, gestational diabetes, and hypertensive disorders of pregnancy as comorbidities. We identified both comorbidities using ICD-9 and ICD-10 codes outlined in **Appendix Table 2.1**. We created binary flags for each

factor. We also created a mutually exclusive categorical variable for any hypertensive disorders of pregnancy. We included the following categories: chronic hypertension, gestational hypertension, pre-eclampsia/eclampsia, superimposed preeclampsia/eclampsia (preeclampsia/eclampsia among those with existing chronic hypertension), or no evidence.

Finally, features of the childbirth hospitalization might also affect one's risk of future hospital encounters, so we included delivery related variables extended delivery length of stay (categorized as > 90th percentile by mode of delivery)[16], mode of delivery (cesarean versus vaginal birth) and severe maternal morbidity (SMM) at birth. We identified SMM at birth as containing at least one ICD-9 or ICD-10 diagnosis and procedure code from the CDC defintion[79] from delivery admission date through delivery discharge date. The definition of SMM included transfusion of blood products.

Statistical Analysis

Bivariate analysis

First, we assessed demographic, comorbidities, and delivery characteristics by insurance type at delivery. We assessed differences across insurance types at birth using Pearson's chi-square. Next, we described the sequence and the frequency of hospital encounters up to 12 months postpartum by insurance type at delivery. We described the proportion of person-deliveries with hospital encounters for up to 12 months postpartum and whether the first hospital encounter was inpatient readmission or an ED visit. In addition, we described the total number of readmissions and ED visits for each person-delivery up to 12 months postpartum by insurance type. For the primary and secondary outcomes, we examined unadjusted survival curves for

postpartum hospital encounters and postpartum visit attendance by insurance type using the Kaplan-Meier approach.

Multivariable adjusted analysis

Insurance type at birth is not randomly allocated in any population; therefore, we utilized a propensity score-weighted Cox proportional hazards modeling approach to reduce bias in our estimates.[96] Propensity score weighting is one of the propensity score estimators (e.g., matching, weighting, model-based adjustment, or stratifying),[97] and in this approach, treated individuals are weighted by the inverse of their propensity score, and untreated are weighted by the complement (1-PS). This approach reweights the observed study population such that the association between confounding variables and exposure (in this case, insurance at delivery) is weakened or removed (under the assumptions of no unmeasured confounders, accurately measured confounding, and no residual confounding).[97]

Given that our exposure variable had three levels (HDHP, Medicaid, and other commercial plans), we utilized a propensity score weight methodology for multiple nonequivalent groups created by the RAND Corporation.[98] This approach uses generalized boosted models, an ensemble machine learning modeling approach, to estimate the propensity score weights. We utilized the average treatment effect (ATE) estimand[99,100] to calculate our propensity score weights for multiple nonequivalent groups. This approach considers the outcome as if the entire population received one treatment (in our case, one insurance plan type) relative to the whole population having received another treatment.[101] We selected covariates for the propensity score model using a causal diagram-based approach (DAGs).[102] Based on literature and *a priori* knowledge, we included variables associated with the probability of

treatment, in this case, insurance type at delivery. In our propensity score weights for multiple groups, we included maternal age, rurality, substance use disorder, any mental health diagnosis, pre-existing diabetes, gestational diabetes, and any hypertensive disorders of pregnancy. We assessed for overlap of propensity scores and the balance of absolute standardized mean difference across treatment groups (**Appendix Figure 2.2**). Both diagnostics were computed as a part of the 'TWANG' R package created by the RAND Corporation to compute propensity score weights for multiple nonequivalent groups. In addition, we assessed if the relevant confounders were balanced across insurance types at delivery after incorporating propensity score weights using Pearson's Chi-square.

After creating and validating the propensity score weights for multiple nonequivalent groups, we incorporated the sample weights into our survival analysis modeling framework. We utilized weighted Cox Proportional Hazard regression to model the time-to-event of each outcome. We conducted cause-specific hazard models for each outcome of interest.[103] In our approach, individuals could either experience the event of interest (e.g., hospital encounter or postpartum visit), lose insurance coverage, or reach the end of the follow-up period. We considered loss of insurance coverage during the 12 months of follow-up for hospital encounters or 12 weeks of follow-up for comprehensive postpartum visits to be censored, meaning they contributed person-time to our analysis until coverage loss. We tested the proportional hazards assumption using scaled Schoenfeld residuals and graphical tests and assessed outliers. All analyses were conducted in R 4.0.1.

4.4 Results

The final analytic sample included 202,167 hospital births. In our sample, only 1.8% (N=3,693) of births were funded by HDHP, with 61.3% (N=124,020) funded by Medicaid. HDHP-funded births were similar to those with other commercial plans with respect to demographic, clinical, and delivery characteristics (**Table 4.1**). Those with commercial plans exhibited demographic differences from people with Medicaid insurance. Notably, those with a Medicaid funded births tended to be younger (39.5% under 25 compared to 7.9% among HDHP and 10.8% among other commercial plans,$p<0.0001$), more likely to live in a rural area (41.0% compared to 25.9% among HDHP and 26.4% among other commercial plans, $p<0.0001$), and more likely to have a substance use disorder (9.3% compared to <1% among both commercial plan categories, $p<0.0001$). Of the few apparent differences between people with HDHP at birth and those with commercial plans and Medicaid, HDHP-funded births had the highest prevalence of gestational diabetes (11.5%) compared to other commercial plans and Medicaid (9.7% and 10.5%, $p<0.0001$).

After incorporating the propensity score weights, we observed no statistically significant differences across insurance categories for all variables included in the model (**Table 4.1**)**.** We did observe statistically significant differences across insurance types by the extended length of stay at delivery.

Births funded by Medicaid experienced the highest proportion of hospital encounters within 12 months postpartum (32.7%, compared to 10.8% among HDHP and 12.8% among other commercial plans; **Table 4.2**). Across insurance types, 87% of first hospital encounters were ED visits, with only 13% of first encounters occurring as inpatient readmissions. Notably, among Medicaid-funded deliveries, 14.4% had two or more ED visits within 12 months, compared to 1.9% among HDHPs and 2.9% among other commercial plans.

In survival curves without adjustment, we observed statistically significant differences across insurance types ($p<0.0001$) for both inpatient readmissions and ED visits (**Figure 4.1**). Among Medicaid-funded deliveries, 39.6% of inpatient readmissions occur within the first 12 weeks postpartum compared to 66.4% and 55.5% among HDHP and other commercially funded births. The proportions of ED visits within the first 12 weeks postpartum were similar across insurance types (41.0% for Medicaid, 43.8% for HDHPs, and 43.6% for other commercial plans).

The propensity score weighted multivariable model assessing time to first hospital encounter did not show statistically significant differences among HDHPs (aHR: 0.89, 95% CI: 0.76, 1.03, **Table 4.3**) compared to other commercial plans. However, births funded by Medicaid were associated with an increased hazard of any postpartum hospital encounter (aHR: 2.00, 95% CI: 1.94, 2.06), inpatient readmissions (aHR: 1.40, 95% CI: 1.28, 1.54), and ED visits (aHR: 2.05, 95% CI: 1.99, 2.12) compared to other commercial plans.

Finally, our assessment of insurance type at birth and time to postpartum visit attendance similarly observed no statistically significant difference among HDHP-funded births compared to other commercial plans (aHR: 0.96, 95% CI: 0.91, 1.02; **Table 4.4**). We did observe that Medicaid-funded births were associated with a decreased likelihood of postpartum visit attendance (aHR: 0.71, 95% CI: 0.70, 0.72) in comparison to other commercial plans.

Table 4.1 Maternal Demographic and Clinical Characteristics by Insurance Type at Birth Before and After Propensity Score Weighting, Oregon hospital births 2012-2017 (N=202,167)

	Before Propensity Score Weights				After Propensity Score Weights			
	Other Commercial N = 74,454	HDHP N = 3,693	Medicaid N= 124,020		Other Commercial	HDHP	Medicaid	
	%	%	%	p-value	%	%	%	p-value
Maternal Age				<.0001				
15-19	1.3	0.8	9.6		6.1	5.3	6.4	0.9044
20-24	9.5	7.1	30.8		22.7	23.2	22.5	
25-29	27.2	26.1	30.4		29.0	29.0	29.1	
30-34	38.1	39.3	18.8		26.4	26.7	26.3	
35-39	19.8	22.2	8.4		12.9	13.0	12.8	
40+	4.1	4.5	2.1		2.9	2.8	2.9	
Maternal Location				<.0001				
Urban	73.6	74.1	59.0		64.7	64.9	64.6	0.9362
Rural	26.4	25.9	41.0		35.3	35.1	35.4	
Substance Use Disorder	0.6	0.7	9.3	<.0001	5.7	4.7	5.9	0.3129
Mental Health Diagnoses								
Any Mental Health Diagnoses	4.4	4.1	8.8	<.0001	7.2	6.5	7.1	0.5140
Depression	0.7	0.8	1.9	<.0001	1.3	1.4	1.5	0.7548
Anxiety	2.0	1.9	3.9	<.0001	3.4	2.4	3.2	0.0351
SMI	1.6	1.4	3.3	<.0001	2.7	2.4	2.6	0.8349
Other	1.0	0.9	2.0	<.0001	1.8	1.9	1.6	0.6605
Gestational Diabetes	9.7	11.5	10.6	<.0001	10.2	10.1	10.3	0.9541
Pre-existing Diabetes	1.4	1.9	2.4	<.0001	2.0	1.6	2.1	0.0649
Any Hypertensive Disorder of Pregnancy	8.4	9.1	10.5	<.0001	9.6	9.4	9.7	0.8820
Hypertensive Disorders of Pregnancy								
Chronic Hypertension	1.9	2.1	2.5	<.0001	2.0	1.8	2.4	0.0197
Gestational Hypertension	3.9	4.0	4.0	<.0001	4.5	4.2	3.7	
Eclampsia/Pre-eclampsia	1.8	2.0	2.4	<.0001	2.1	2.4	2.2	
Superimposed	0.8	1.1	1.6	<.0001	1.0	1.0	1.5	
Mode of Delivery				<.0001				

Vaginal	70.0	70.1	72.7		72.4	73.2	71.6	0.1767
Cesarean	30.0	29.9	27.3		27.6	26.8	28.4	
Extended Delivery Length of Stay	4.0	9.9	25.1	<.0001	4.4	10.4	24.1	<0.0001
SMM at Delivery	0.6	0.8	1.0	<.0001	0.6	0.8	1.0	0.1350

Note: p-values compared across three insurance categories.

Table 4.2 Hospital Encounter Frequency by Insurance Type at Birth, Oregon hospital births, 2012-2017

	Insurance Type at Delivery					
	Other Commercial N = 74,454		HDHP N = 3,693		Medicaid N= 124,020	
	N	%	N	%	N	%
Any Hospital Encounter	9,507	12.8	400	10.8	40,503	32.7
First Hospital Encounter						
Emergency Department	8,323	87.5	349	87.3	37,201	91.8
Inpatient Readmission	1,184	12.5	51	12.8	3,302	8.2
No. of Emergency Department Encounters						
0	65,458	87.9	3,321	89.9	83,995	67.7
1	6,866	9.2	202	5.5	22,193	17.9
2	1,305	1.8	47	1.3	8,505	6.9
3-5	605	0.8	19	0.5	7,225	5.8
6+	220	0.3	3	0.1	2,102	1.7
No. of Inpatient Readmissions						
0	73,130	98.2	3,638	98.5	120,399	97.1
1	1,207	1.6	51	1.4	3,203	2.6
2+	117	0.2	4	0.1	418	0.3

Table 4.3 Prevalence, Unadjusted and Propensity Score Weighted Hazard Ratios of Insurance Type at Birth and Postpartum Hospital Encounters within 12 Months postpartum, Oregon hospital births 2012-2017

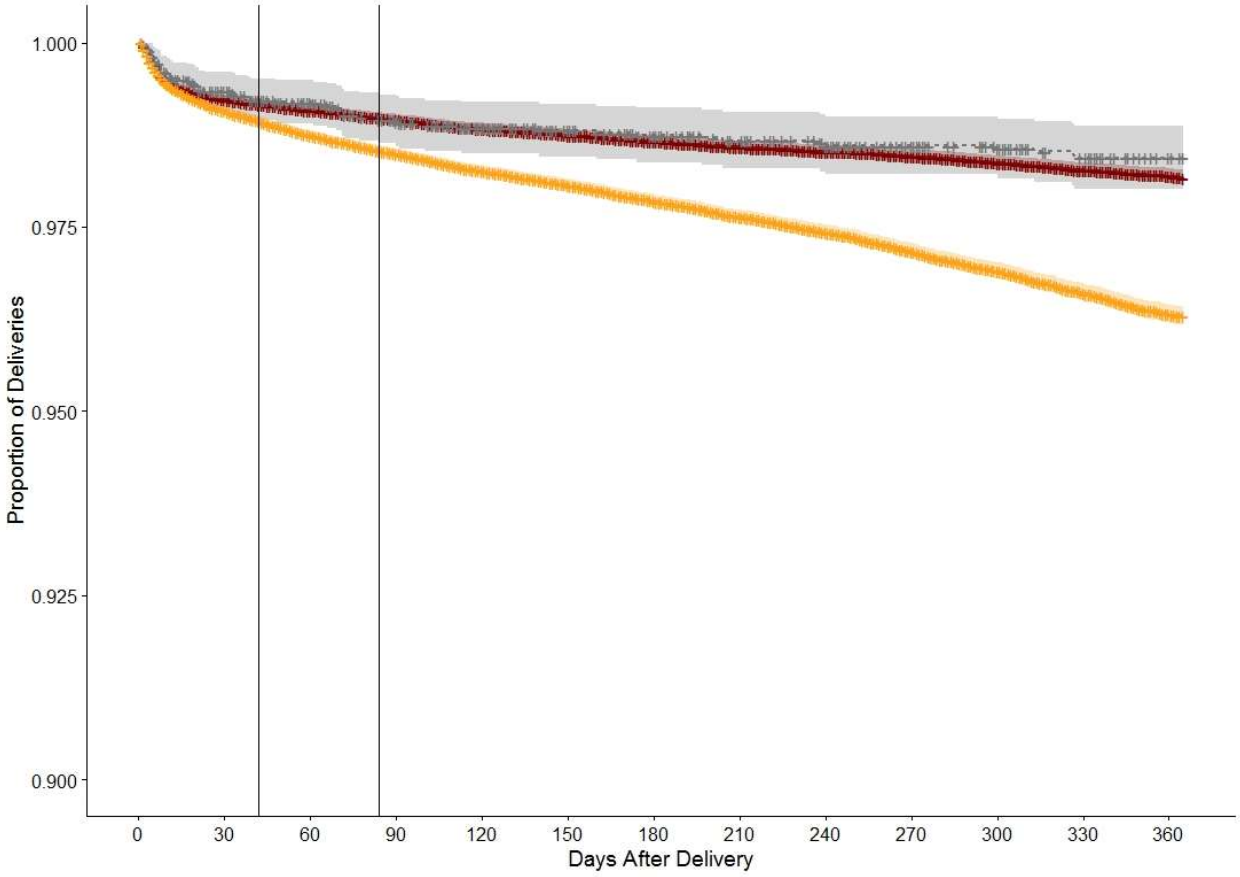
	Prevalence		Hazards, HR (95% CI)			
	N	%	Unadjusted		PS Weighted	
All Hospital Encounters						
Medicaid	40,503	32.7%	**2.96**	**(2.89,3.03)**	**2.00**	**(1.94, 2.06)**
HDHP	405	11.0%	**0.88**	**(0.80,0.97)**	0.89	(0.76,1.03)
Other Commercial	9,532	12.8%	*ref*		*ref*	
Inpatient Readmissions						
Medicaid	3,310	2.7%	**1.94**	**(1.81, 2.06)**	**1.40**	**(1.28, 1.54)**
HDHP	56	1.5%	0.89	(0.67,1.17)	0.99	(0.65,1.51)
Other Commercial	1,210	1.6%	*ref*		*ref*	
Emergency Department Encounters						
Medicaid	37,193	30.0%	**3.08**	**(3.00, 3.15)**	**2.05**	**(1.99,2.12)**
HDHP	349	9.5%	**0.87**	**(0.78,0.96)**	0.88	(0.75,1.02)
Other Commercial	8,322	11.2%	*ref*		*ref*	

Table 4.4 Prevalence, Unadjusted and Propensity Score Weighted Hazard Ratios of Insurance Type at Birth and Postpartum Visit Attendance within 12 Weeks Postpartum, Oregon hospital births 2012-2017

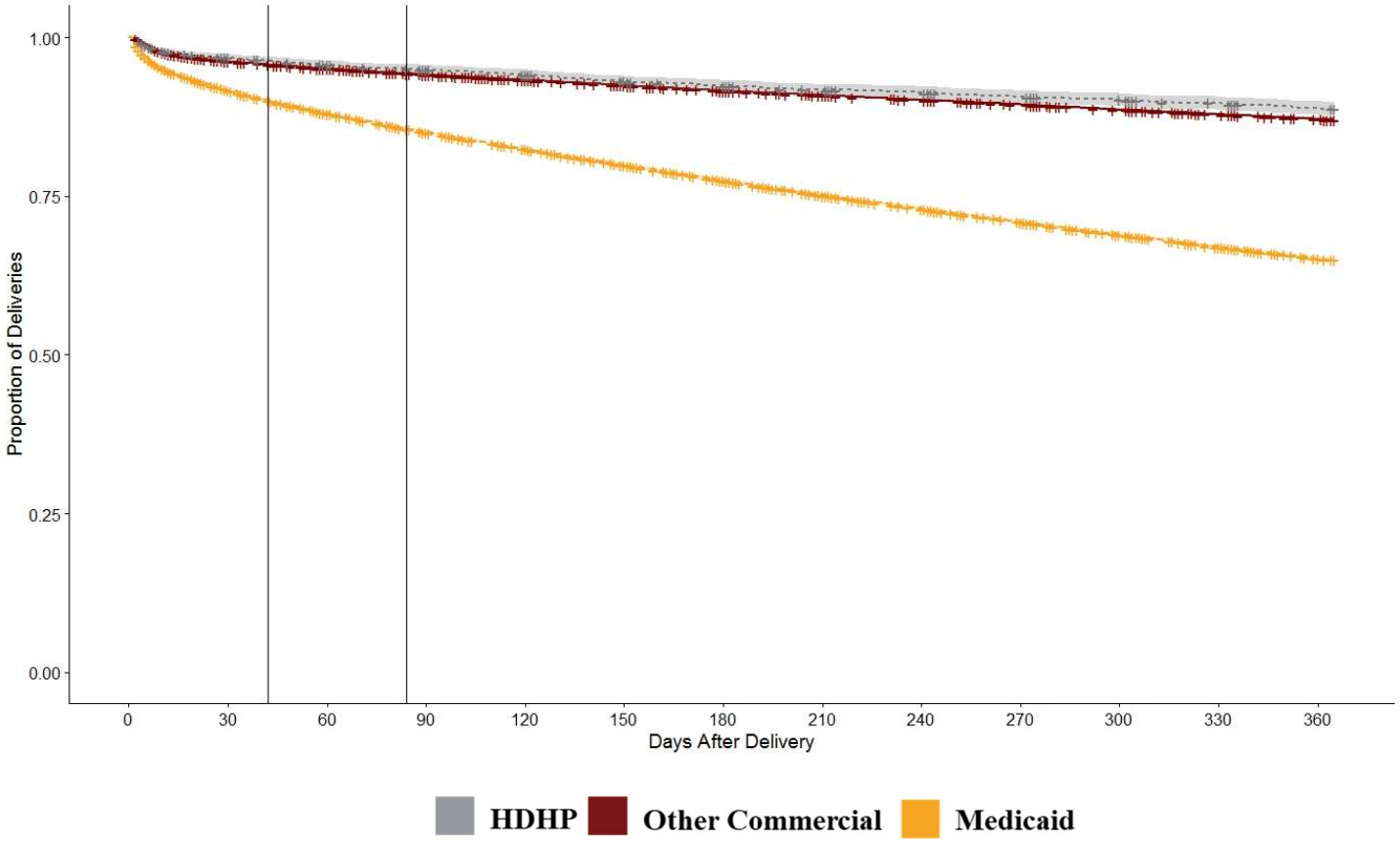
	Prevalence		Hazards, HR (95% CI)			
	N	%	Unadjusted		PS Weighted	
Postpartum Visit Attendance						
Medicaid	63,650	51.3	**0.68**	**(0.67, 0.69)**	**0.71**	**(0.70, 0.72)**
HDHP	2,397	64.9	0.97	(0.93, 1.01)	0.96	(0.91, 1.02)
Other Commercial	49,554	66.6	*ref*		*ref*	

Figure 4.1 Time-to-first Postpartum Hospital Encounter by Insurance Type at Birth within 12 months postpartum (unadjusted).

a. Inpatient Readmissions

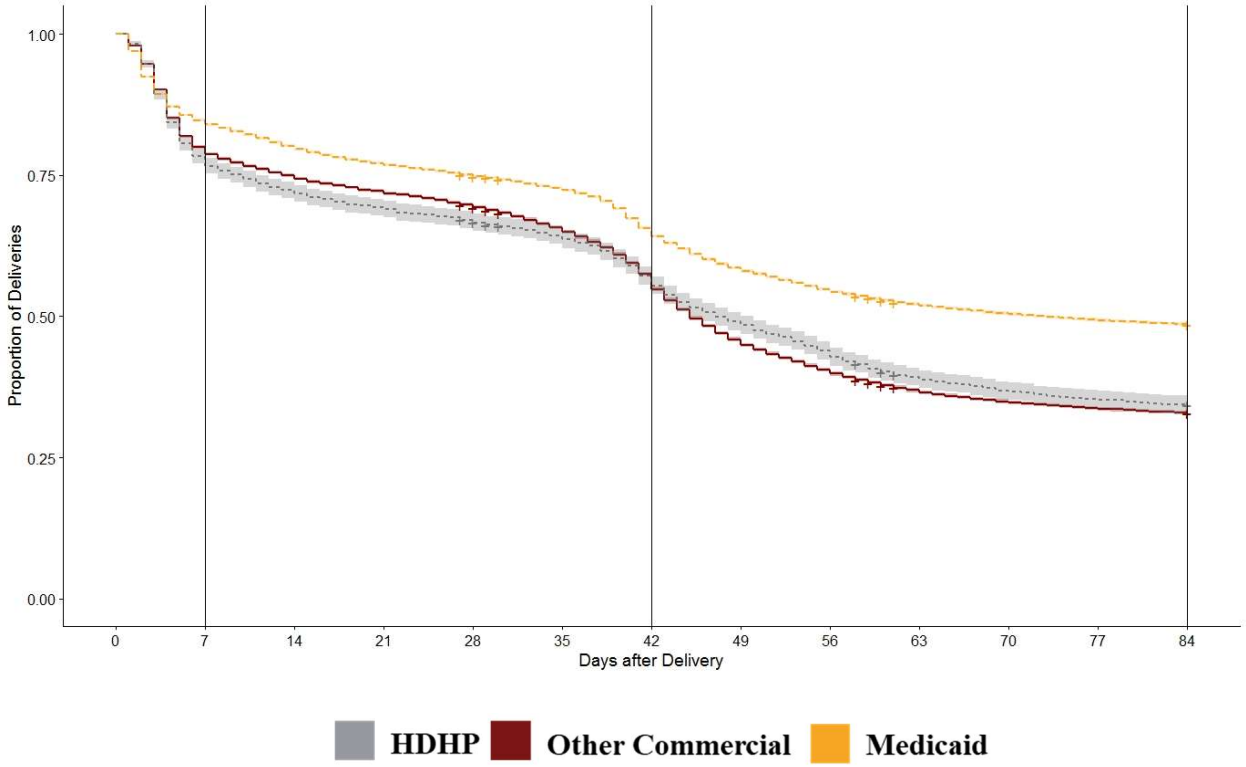


b. Emergency Department Visit



Notes: Vertical lines denote postpartum milestones: 6 weeks and 12 weeks postpartum.

Figure 4.2 Time-to-Postpartum Visit Attendance by Insurance Type at Birth within 12 Weeks Postpartum (unadjusted).



Notes: Vertical lines denote postpartum milestones: 1 week, 6 weeks and 12 weeks postpartum.

4.5 Discussion

We observed significant differences in postpartum care-seeking for Medicaid-funded births compared to HDHPs and other commercial plans. Medicaid-funded births were less likely to attend comprehensive postpartum visits within the first twelve weeks postpartum and more likely to seek care at the ED within the first year postpartum. Taken together, this highlights the unmet health care needs of postpartum people with Medicaid insurance. Also of note, we found that postpartum utilization of preventive care and hospital care does not vary for HDHP-funded births compared to births funded by other commercial plans.

Our findings for birthing people with Medicaid align with the limited prior research on postpartum care-seeking.[7,34,35,104] Our analysis highlighted that not only are Medicaid-funded births more likely to seek care in the ED during the extended postpartum period, they are more likely to repeatedly seek care in the ED compared to births funded by other commercial plans, including HDHPs. Care seeking in the ED is costly to the health care system and the birthing person but is not always an opportunity to provide optimal, patient-centered care for postpartum people. Future research should consider the system-level drivers that result in postpartum people with Medicaid repeatedly seeking care in the ED, as opposed to other outpatient settings.

HDHP insurance plans are becoming increasingly common for employer-sponsored health plans[105], but our study found them relatively rare at birth. We may be observing self-selection of low-risk pregnancies to HDHPs with more personal financial resources to cover higher out-of-pocket health care costs. However, we may also be observing a phenomenon of women with HDHPs preconception gaining Medicaid coverage during pregnancy, given that the income limits to qualify for Medicaid coverage increase for pregnant people. A similar phenomenon has been observed among pregnant people with Marketplace insurance plans

(insurance plans offered to people that may not have access to employer-sponsored health plans or Medicaid). Research found that 50% of people with Marketplace insurance (HDHPs and other commercial plans) either preconception or postpartum shifted to Medicaid insurance during pregnancy.[106]

Our analysis, while novel, is not without limitations. First, we used administrative claims data, which helps enumerate births at the population level but lacks important variables. For example, there are known inequities in maternal morbidity by race and ethnicity, and our data only had race and ethnicity information for 50% of the population. We, therefore, could not reliably include race and ethnicity in our analyses. Second, our data is restricted to postpartum people with any health insurance at birth and postpartum. While evidence shows that a very small percentage of women in Oregon do not have insurance at delivery[107], many postpartum women are uninsured because of loss of Medicaid eligibility 60 days postpartum.[71] Our time to event analysis did consider the loss of insurance as a censored event. Still, we may be missing a vulnerable population with postpartum hospital encounters that lacks health insurance. Further, we used a rigorous propensity score weighting method for categorical exposures that account for differences by insurance type. Given the limitations of our data, we could not account for other hypothesized factors associated with insurance type at delivery, hospital encounters, and postpartum visit attendance. These variables include but are not limited to education, income, occupation, parity, and access to childcare.

Despite the limitations, our study adds crucial knowledge to the limited research on postpartum care-seeking beyond the traditional 6-week postpartum period, particularly regarding ED utilization. We found that HDHPs, despite the high patient cost-sharing, are not associated with a different pattern of postpartum care-seeking compared to other commercial plans with

lower burdens of cost-sharing. The most striking disparities existed for Medicaid-funded deliveries. As states consider expanding Medicaid coverage up to one year postpartum[108], we must also consider strategies to make postpartum outpatient and preventive care more accessible to prevent perpetuating maternal health inequities.

CHAPTER 5. RESEARCH PAPER #3

The Role of Health Care Financial Burden Before and During Birth in Postpartum Care Utilization, Oregon 2012-2017

Menolly Kaufman[a,b], Maria I. Rodriguez[b,c], K. John McConnell[b], Dawn Richardson[a], Jonathan M. Snowden[a,c]

[a] School of Public Health, Oregon Health & Science University and Portland State University

[b] Center for Health Systems Effectiveness, Oregon Health & Science University

[c] Department of Obstetrics and Gynecology, Oregon Health & Science University

Keywords: Postpartum, birth, cost-sharing, high deductible health plans

5.1 Abstract

Background: It is increasingly common for birthing people with commercial insurance to pay high out-of-pocket costs for maternity and birthing care regardless of whether they are in a high deductible health plan. Yet, research is limited on how the financial burden accrued before and during birth affects subsequent morbidity and well-being in the postpartum period. Our study aimed to describe health care financial burden among commercially funded births and examine if an association exists between financial burden and postpartum care receipt.

Methods: We conducted a retrospective cohort study of commercially funded births in Oregon from 2012 to 2017 using an All-Payer All Claims database. Our primary exposure was health care financial burden (i.e., direct costs for health care paid by birthing people, including deductibles, co-payments, and co-insurance) before and during birth in the calendar year of birth. We utilized multivariable robust Poisson regression to estimate the association between financial burden and postpartum visit attendance within 12 weeks postpartum and readmissions and emergency department visits within one year postpartum.

Results: Among our population of commercial insured birthing people (N=63,153), 7.5% (N=4,753) had over $5,000 in health care financial burden during the year of birth. Compared to births with $0 in financial burden, births with over $5,000 were 18% less likely to attend their comprehensive postpartum visit within 12 weeks (risk ratio [RR]: 0.82, 95% confidence interval [CI]: 0.80, 0.84) and 21% less likely to visit the emergency department (RR: 0.79, 95% CI: 0.72, 0.88).

Conclusion: The financial burden of health care may influence care seeking, including for postpartum people. As policymakers and clinicians seek solutions to reduce inequities in

postpartum health outcomes, the financial burden related to maternity care and birth should be considered.

5.2 Introduction

The cost of health care has increased steadily in the United States over the past several decades.[109] One major driver of high health care costs is hospitalizations, and the number one reason for hospitalizations in the US is childbirth.[48] Following this trend, direct costs for maternity care among those with commercial insurance have also increased. Research shows that on average, patient cost-sharing (the amount a patient pays out-of-pocket for their care on top of health insurance premiums) for maternity care increased by nearly 50%, from $3,069 in 2008 to $4,560 in 2015.[110] However, little is known about how the financial burden of cost-sharing for care before and during birth impacts health care used throughout the perinatal period generally and in the postpartum period specifically.

Research does show that when patients face high health care costs, they are less willing to seek appropriate and preventive care.[111,112] Extending this understanding to the childbirth context, it may be that childbirth costs, which depending on the plan, can be excessively high (i.e., thousands of dollars), may also lead postpartum people to avoid care. Birthing people with commercial insurance are at the highest risk for experiencing health care financial burdens throughout the prenatal period, with the highest expense for the birth hospitalization itself. Hospital stays to give birth are subject to the same cost-sharing as any other catastrophic health event requiring hospitalization. Childbirth hospitalization may thus act as an 'economic shock' to a birthing person and their household due to the high costs incurred, one whose impacts would be experienced postpartum.[113] Economic contractions and negative economic shocks contribute to financial insecurity, a social determinant of health whose profound impact on health outcomes is well established.[114] A robust body of research documents the health impacts of various macro-level and micro-level economic shocks (e.g., on health care utilization[115,116] and health

outcomes[117,118]), but we are unaware of research on how childbirth-related costs specifically affect outcomes. While research has yet to establish if the financial burden associated with birth is associated with postpartum morbidity and care-seeking, there is evidence that among birthing people with commercial insurance, 64% found health care to be unaffordable, and up to 18% cited an unmet care need because of health care unaffordability.[91]

Much of the research on health care financial burden has focused on high deductible health plans (HDHPs).[52] HDHPs are commercial insurance plans with deductibles (i.e., the amount a patient has to pay in full for their health care before insurance provides any coverage)[41] above a threshold set annually by the Internal Revenue Service.[44] It is consistently found in the literature that HDHP enrollment leads to lower health care utilization, including the use of preventative and other appropriate care.[119,120,121] However, people can experience high health care financial burdens in other types of commercial plans that are not officially designated HDHPs, if their out-of-pocket limits remain high.[122] For instance, a birthing person, could be enrolled in a low deductible plan but have the federally mandated out-of-pocket health care spending limit and pay up to $8,150 during the year of birth, equivalent to 13% of median household income.[11] To our knowledge, no study has examined if a high financial burden has similar effects on postpartum care utilization as high deductible plans.

To fill these gaps in the literature, our study aimed to describe health care financial burden before and during birth during the year of birth among commercially insured women. We assessed multiple definitions of "health care financial burden," including direct patient costs incurred prenatally and during childbirth (our primary definition) and enrollment in a HDHP. In addition to describing financial burden, we assessed its concordance with HDHP enrollment. We examined the association between health care financial burden and postpartum care utilization as

measured by direct patient costs. Lastly, given that HDHPs are most commonly cited as health insurance with the highest financial burden for patients, we assessed the association between HDHP enrollment and postpartum care utilization. We hypothesized that greater health care financial burden would be associated with decreased postpartum care receipt. To achieve these aims, we leveraged eight years of commercial insurance claims from Oregon's All-Payer All Claims database, allowing us to follow individuals before birth, during birth, and postpartum.

5.3 Methods

Data Source

Our study utilized Oregon All Payer All Claims (APAC) database[72] from 2011to 2018. The APAC database includes medical and pharmacy claims, demographic information, and insurance enrollment data from Oregon Medicaid and commercial health insurance plans that cover at least 5,000 people. The medical claims in APAC include both the cost of health services paid by insurers and direct costs paid by patients. The database includes detailed information on direct costs and differentiates between deductibles, co-payments, and co-insurance. In total, the database covers 3.4-2.9 million people in Oregon per year, approximately 87-99% of the population.[73] This study was approved by the Oregon Health and Science University institutional review board.

Study Population

Our study population included persons between 15 and 44 years of age with a hospital birth in medical claims data and commercial insurance at the time of birth. Hospital births were identified using Current Procedural Terminology (CPT) and Diagnostic Related Group (DRG)

codes from a previously published algorithm[74] and codes identified by the American College of Obstetrics and Gynecology (ACOG).[75] We identified unique birth events based on childbirth hospitalization discharge date. Our study population was restricted from January 1, 2012, to December 31, 2017. Our sampling frame allowed for a 12-month look-back period before childbirth hospitalization to summarize direct patient costs (e.g., financial burden before and during birth in the year of birth) and identify comorbidity diagnoses in the prenatal and pre-conception period. We followed each birth event for 12 months postpartum from the childbirth hospitalization discharge date.

Our study population was restricted to births funded by commercial insurance. We linked the birth data to insurance enrollment data by person-key and calendar month to identify the payer at birth. HDHPs are often considered the health insurance plans with the highest direct costs for patients. To assess this assumption, we classified insurance as HDHPs or other commercial insurance plans. HDHPs were identified using an indicator on the enrollment file provided by the data stewards (Oregon Health Authority). The data stewards rely on insurers to self-report HDHP plan status. Finally, we required each birth to have at least 11 of 12 calendar months of continuous commercial insurance enrollment postpartum. This enrollment restriction did not equate lack of health insurance enrollment, which would result in no recorded health care, with the absence of postpartum care utilization.

Study Variables

Exposure

Our primary interest was how health care financial burden incurred before and during birth impacts postpartum care-seeking. We quantified financial burden, our primary exposure, as

the total amount of direct costs paid by the birthing person for any health care encounter before birth and during birth. Our exposure included all health care encounters, including, if applicable, pre-conception care and non-pregnancy care on Medical claims. We aggregated financial burden into one measure, inclusive of deductibles (the amount a patient pay in full for health care before insurance coverage[41]), copayment (a set dollar amount a patient pays for each health care encounter[40]), and coinsurance (a percentage of the total cost of the health care encounter after the deductible limit is met[123]). We summarized direct patient costs from January 1 of the calendar year of birth through the childbirth hospitalization discharge date. We considered health encounters from January 1 of the calendar year of birth because most commercial insurance plan years follow the calendar year.[124] As a result, at the start of each plan year, a patient's deductible and total out-of-pocket cost accumulation reset to $0, and if their plan is subject to cost-sharing, the patient begins paying for health care regardless of their spending in the prior year. We measured financial burden through the birth hospitalization because most birthing people will reach their deductible and out-of-pocket maximums as a result of the birthing hospital stay and incur the majority of their costs at that time. After summing direct patient costs, we created six mutually exclusive categories for analysis: $0, $1-500, $501-1,000, $1,001-2,500, $2,501-5,000, $5,001+). In our univariate analysis of each cost variable, we did not observe any implausible values for direct patient costs (range: $0 – 40,489). We created an ordinal variable for financial burden and because we did not treat financial burden as a continuous value, we did not trim any of the top values from our analysis.

Outcomes

Our postpartum health care utilization outcomes encompassed both receipt of preventive care and unplanned or urgent care. We measured preventive care receipt as comprehensive postpartum visit attendance within 12 weeks from the childbirth hospitalization. The 12-week follow-up was selected to follow ACOG guidance for optimal postpartum care. Comprehensive postpartum visits are recommended for all birthing people regardless of their medical risk profile.[19] We identified postpartum visit attendance using CPT and diagnosis codes (ICD-9 or ICD-10) from the National Committee for Quality Assurance (NCQA) "Prenatal and Postpartum Care" clinical quality metric methodology.[8]

Unplanned or urgent postpartum care was measured as hospital encounters and included emergency department (ED) visits and inpatient readmissions within 12 months postpartum. We identified readmissions and ED visits using revenue and place of service codes outlined in a clinical quality metric created by the Oregon Health Authority.[78] We included readmissions and ED visits from one day after delivery hospitalization discharge up to one year postpartum. If an ED visit led to readmission (i.e., an ED visit the day of or the day before an inpatient stay), we classified the set of encounters as readmission rather than two distinct encounters. We were interested in subsequent hospital encounters that were markers of maternal morbidity. Therefore, we excluded transfers of the index birth to another facility and inpatient readmissions for a subsequent birth.

Covariates

In addition to financial burden and postpartum utilization outcomes, we included maternal demographic, delivery, and comorbidity-related covariates in our analyses. Demographic variables included maternal age (15-19, 20-24, 25-29, 30-34, 40+ years) and a

binary indicator for residential location (rural or urban based on a rurality indicator provided by the data stewards (Oregon Health Authority) based on the last documented ZIP code.[80]

Many factors related to childbirth hospitalization affect health care financial burden and may also impact postpartum care utilization. To account for those factors, we included extended delivery length of stay (categorized as > 90th percentile by mode of delivery)[16], mode of delivery (cesarean versus vaginal birth), and severe maternal morbidity (SMM) at birth in our analyses. We utilized the CDC definition of SMM[79], given that it is commonly used for maternal morbidity surveillance in the United States. We identified SMM at birth as claims during the childbirth hospitalization containing at least one ICD-9 or ICD-10 diagnosis and procedure code from the childbirth admission date through the childbirth discharge date. The definition of SMM included transfusion of blood products.

Medical comorbidities also affect postpartum morbidity and care-seeking. In our analyses, we included pre-pregnancy diabetes, gestational diabetes, hypertensive disorders of pregnancy, any substance use disorder (SUD)[94], and any mental health diagnoses[95] as comorbidities. We identified all comorbidities using ICD-9 and ICD-10 codes outlined in **Appendix Table A1.1**. We created binary flags for gestational diabetes, pre-pregnancy diabetes, any SUD, and any mental health diagnoses. We also created a mutually exclusive categorical variable for any hypertensive disorders of pregnancy and included the following categories: chronic hypertension, gestational hypertension, pre-eclampsia/eclampsia, superimposed preeclampsia/eclampsia (preeclampsia/eclampsia among those with existing chronic hypertension), or no evidence.

Statistical Analysis

We used multiple approaches to estimate associations between financial burden and postpartum care utilization. First, we conducted univariate analyses of direct patient cost variables to test key assumptions (i.e., the plan year follows the calendar year and out-of-pocket maximums are met as a result of the childbirth hospitalization) and assessed for outliers. Next, we conducted bivariate analyses of demographic, delivery, and clinical characteristics by financial burden categories. Across each financial burden category, we tested differences using Pearson's chi-square.

HDHPs are one potential proxy to measure health care financial burden. Therefore, we calculated what proportion were classified as HDHPs versus other commercial plans within each financial burden category. Our final bivariate analysis assessed unadjusted rates of postpartum visit attendance, ED visit use, and readmissions by financial burden category.

We used robust Poisson regression to estimate the cumulative incidence ratio (relative risk, RR) between financial burden and each postpartum utilization outcome measure.[125] We opted for robust Poisson because of the lack of convergence under the log-binomial modeling approach. We identified confounders for each model by creating Directed Acyclic Graphs, DAGS).[126] This causal modeling approach identifies confounders based on pre-specified assumptions and *a priori* knowledge about how variables are related and the temporal relationships between them.[82] Therefore, the final multivariable models only contain confounders identified by our DAGs. We considered maternal age, mode of delivery, extended delivery length of stay, calendar year, any hypertensive disorders of pregnancy, gestational diabetes, and pre-pregnancy diabetes as confounders for all multivariable models.

Next, we wanted to compare if the association between HDHPs and postpartum care utilization was similar in direction and magnitude to the association between the highest levels of financial burden (i.e., costs over $5,000). We utilized the same modeling approach used for HDHP enrollment and postpartum care utilization as was used to assess financial burden and postpartum care utilization. Finally, to understand if the differences observed in the multivariate model were because of population differences, we assessed differences in population characteristics by commercial plan type using Pearson's chi-square.

For statistical comparisons, we used two-sided tests with a 0.05 alpha level. All analyses were completed in R 4.01.

5.4 Results

Overall, we identified 238,329 hospital births in the Oregon APAC database. Our final study sample included 63,153 commercially funded hospital births that met our enrollment criteria (**Figure 5.1**). Among our study sample, 7.5% (N=4,753) incurred over $5,000 in costs before and during birth in the year of birth, while 31.2% (N=19,744) had less than $500 in costs (including $0). We found that people with a financial burden over $5,000 were more likely to live in rural areas than people with $0 (34.2% vs. 19.6%, $p<0.001$; **Table 5.1**). Further, people with over $5,000 of financial burden were more likely to have had a higher level of childbirth-related care intensity, including cesarean delivery (40.2% vs. 28.2 %, $p<0.001$) and extended length of stay for childbirth hospitalization (15.4% vs. 1.4%, $p<0.001$) as compared to those with $0.

Our bivariate comparison of health care financial burden with HDHP enrollment found that although HDHP enrollment was more common in higher categories of financial burden,

most birthing people with over $5,000 in financial burden were not enrolled in HDHPs. HDHPs accounted for 7.4% of births with $2,501-5,000 and 11.2% of births with financial burden over $5,000 (**Table 5.2**).

Our bivariate analysis of postpartum utilization by financial burden categories found that higher financial burden was associated with lower levels of postpartum care utilization (except for readmissions which saw little change) (**Table 5.3**). We found higher levels of comprehensive postpartum visit attendance among those with less financial burden (71.7% of birthing people with $0 and 72.4% with less than $500) compared to birthing people with over $5,000 in financial burden (60.6% comprehensive postpartum attendance). ED visit use followed a similar trend; as financial burden increased, the rate of ED use decreased. ED visit utilization within 12 months postpartum decreased by 2.3 percentage points from those with $0 in financial burden (13.6%) compared to those with over $5,000 (11.3%).

After controlling for demographic factors, childbirth-related characteristics, and comorbidities, the associations between financial burden and ED utilization and postpartum visit attendance were similar in direction and magnitude. The multivariable models estimated that those with financial burden over $5,000 were 18% less likely to attend their comprehensive postpartum visit within 12 weeks (RR: 0.82, 95% CI: 0.80, 0.84; **Table 5.4**) and 21% less likely to have an ED visit within 12 months postpartum (RR: 0.79, 95% CI: 0.72, 0.88), compared to those with $0. We did not observe statistically significant differences in readmissions within 12 months postpartum among birthing people with financial burden over $5,000 compared to those with $0.

Despite HDHPs being a common marker for health insurance plans with the highest financial burden to patients, we did not observe HDHP enrollment to be statistically significantly

associated with ED visits or readmissions within 12 months postpartum (**Table 5.4**). We observed a minor decrease in comprehensive postpartum visit attendance (RR: 0.98, 95% CI: 0.97, 0.99) after controlling for demographics, childbirth-related factors, and comorbidities. The decrease in postpartum visit attendance, while statistically significant, was smaller in magnitude than birthing people with the highest levels of financial burden

Figure 5.1 Selection of study sample of Oregon commercially funded hospital Births, 2012-2017

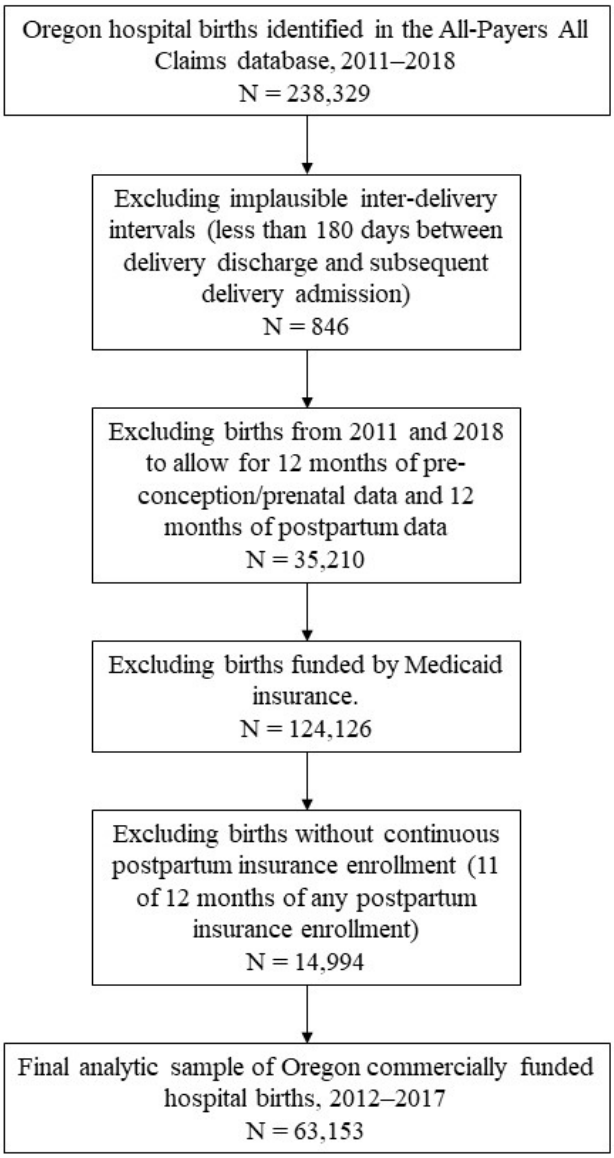


Table 5.1 Demographic, Delivery, and Clinical Characteristics by Financial Burden Categories, Oregon commercially funded hospital births 2012-2017 (N = 63,153)

	Financial Burden Category						
	$0	**$1-500**	**$501-1,000**	**$1,001-2,500**	**$2,501-5,000**	**$5,001+**	
	N=6,817	N=12,927	N=7,461	N=18,309	N=12,886	N=4,753	
	%	%	%	%	%	%	p-value
Maternal Age							<0.001
15-19	1.7	1.6	1.3	1.1	0.8	1.2	
20-24	11.2	8.8	9.2	8.6	8.0	8.9	
25-29	22.8	24.6	25.5	26.1	27.4	28.6	
30-34	37.2	39.0	39.1	39.3	40.0	38.1	
35-39	22.4	21.2	20.5	20.8	20.0	19.2	
40+	4.8	4.8	4.4	4.2	3.8	4.0	
Maternal Location							<0.001
Urban	80.4	78.5	75.3	73.2	69.0	65.8	
Rural	19.6	21.5	24.7	26.8	31.0	34.2	
Missing	-	-	-	0.0	-	-	
Mode of Delivery							<0.001
Vaginal	71.8	71.6	73.6	71.0	67.6	59.8	
Cesarean	28.2	28.4	26.4	29.0	32.4	40.2	
Extended Delivery Length of Stay	1.4	1.4	1.5	2.8	7.5	15.4	<0.001
Pre-term Birth	3.2	4.1	3.9	4.3	3.9	4.8	<0.001
Severe Maternal Morbidity at Birth	0.5	0.6	0.5	0.6	0.7	1.2	<0.001
Gestational Diabetes	9.2	10.6	9.9	10.2	9.0	9.0	<0.001
Pre-existing Diabetes	1.4	1.7	1.4	1.5	1.1	1.4	<0.001
Hypertensive Disorders of Pregnancy							<0.001
Chronic	1.3	1.8	1.9	2.1	2.2	2.0	
Gestational Hypertension	3.4	3.9	4.2	3.7	3.9	4.3	

Pre-eclampsia/Eclampsia	1.4	1.8	1.8	1.6	1.7	2.5	
Superimposed	0.4	0.7	0.8	0.8	0.9	1.4	
No Evidence	93.5	92.5	91.3	91.8	91.3	89.8	
Substance Use Disorder	0.5	0.5	0.6	0.6	0.6	0.7	0.608
Any Mental Health Diagnosis	5.3	5.5	3.5	4.0	4.4	3.6	<0.001

Table 5.2 Financial Burden Categories by Commercial Insurance Type, Oregon commercially funded hospital births 2012-2017 (N=63,153)

Financial Burden Category	High Deductible Health Plan (N=2,613)		Other Commercial Plans (N= 60,540)		Total (N= 63,153)	
	N	%	N	%	N	%
$0	115	1.7	6,702	98.3	6,817	100
$1-500	201	1.6	12,726	98.4	12,927	100
$501-1,000	185	2.5	7,276	97.5	7,461	100
$1,001-2,500	627	3.4	17,682	96.6	18,309	100
$2,501-5,000	953	7.4	11,933	92.6	12,886	100
$5,001+	532	11.2	4,221	88.8	4,753	100

Table 5.3. Unadjusted Rates of Postpartum Care Utilization by Financial Burden Categories, Oregon commercially funded hospital births 2012-2017 (N=63,153)

Financial Burden Category	Comprehensive Postpartum Visit Attendance		Emergency Department Visit		Readmissions	
	N	%	N	%	N	%
$0	4,885	72.9	932	13.9	129	1.9
$1-500	9,204	72.3	1,775	13.9	251	2.0
$501-1,000	4,906	67.4	970	13.3	152	2.1
$1,001-2,500	11,824	66.9	2,185	12.4	258	1.5
$2,501-5,000	7,674	64.3	1,372	11.5	193	1.6
$5,001+	2,546	60.3	485	11.5	73	1.7

Table 5.4 Multivariable Robust Poisson Estimates of Financial Burden and Commercial Plan Type with Postpartum Care Utilization, Oregon commercially funded hospital births 2012-2017 (N=63,153)

	Readmissions		Emergency Department Visit		Comprehensive Postpartum Visit Attendance	
	RR	95% CI	RR	95% CI	RR	95% CI
Financial Burden Category						
$0	ref		ref		ref	
$1-500	1.04	(0.85, 1.29)	1.02	(0.95, 1.10)	0.99	(0.97, 1.01)
$501-1,000	1.10	(0.87, 1.38)	1.00	(0.92, 1.09)	0.93	(0.91, 0.95)
$1,001-2,500	0.76	(0.62, 0.94)	0.92	(0.86, 0.99)	0.92	(0.90, 0.93)
$2,501-5,000	0.82	(0.66, 1.02)	0.86	(0.79, 0.92)	0.88	(0.86, 0.89)
$5,001+	0.77	(0.58, 1.02)	0.79	(0.72, 0.88)	0.82	(0.80, 0.84)
Commercial Plan Type						
HDHP	0.90	(0.66,1.23)	0.91	(0.82, 1.01)	0.98	(0.97, 0.99)
Other Commercial Plans	ref		ref		ref	

Notes: Models adjust for maternal age, mode of delivery, extended delivery length of stay, calendar year, any hypertensive disorders of pregnancy, gestational diabetes, and pre-pregnancy diabetes.

5.5 Discussion

Working with a database that covered commercially funded hospital births with data on patient cost-sharing in a state across eight years, we described the financial burden of health care before and during birth and established an association between the highest financial burden and postpartum care utilization. Further, we found that a substantial portion of birthing people with the highest financial burden are not enrolled in HDHPs. Our findings suggest that financial burden incurred before and during birth may be an important health system driver of disparities in postpartum health outcomes.

Our key finding is that high levels of financial burden before and during birth result in lower postpartum outpatient utilization align with research on cost-sharing and care use in other health contexts. For instance, research on cost-sharing among patients with diabetes has found that high levels of financial burden lead to deferred routine care and monitoring and lower rates of medication adherence.[121] Similar to our findings, high health care financial burden may not only deter patients from engaging in costly or unnecessary care (such as ED visits that could be managed in an outpatient setting), it may also deter patients from engaging in high-value care, or care that improves health and avoids harms.[127,128,129]

The deferred care for postpartum people may or may not have any direct costing sharing for the birthing person if they reached their out-of-pocket maximum at birth. However, one survey found that 37% of people (and up to 50% of people with incomes below 200% of the federal poverty limit) did not know what was and was not considered a preventive or covered service and, as a result, deferred care out of concern that they could incur more cost.[112] Our study provides preliminary evidence that this phenomenon may also be a play for postpartum people.

The strengths of our study include using a multi-year and multi-care setting database that follows individuals prenatally up to one year postpartum. Further, our database captures both health care encounters and the direct cost paid by patients. Our study is not without limitations. First, our study excluded people who had commercial insurance at delivery but did not have at least 11 months of continuous insurance coverage postpartum (18% of commercial births in our sample). Given that most health insurance is provided by employers, we may be excluding an important population of birthing people who lose their commercial insurance postpartum due to employment changes.[130] Next, as a result of a Supreme Court case decision (Gobeille v. Liberty Mutual Insurance Co., Inc.), insurance plans classified as 'self-insured' were no longer required to report to APAC starting in 2016.[131] Self-insured plans are types of commercial plans in which an employer pays directly for health insurance claims rather than contracting with a third party insurance company.[132] As a result of the change in reporting requirements, APAC observed a 20% drop in commercial enrollment statewide.[131] It is unknown if this resulted in a parallel drop in births statewide. Our database is also missing two important sets of factors that influence how health care financial burden impacts overall financial anxiety and health care engagement: maternal race and ethnicity and socioeconomic status. The current scientific evidence demonstrates that interpersonal and structural racism are drivers of maternal health inequities.[88] However, maternal race and ethnicity information was missing for 50% of our study population and could not be reliably used in our analyses. Next, we did not have access information on birthing people's overall financial status (e.g., household income, employment status, existing financial responsibilities, premium costs, etc.). Financial status would allow us to contextualize how an economic shock, such as a high health care bill for the childbirth hospitalization, may impact financial anxiety and care seeking.

The cost of maternity and birthing care in the US is cited as one of the drivers of our maternal mortality crisis.[133,61] Still, extensive research is needed to elucidate how the financial burden of care received before and during birth impact postpartum morbidity and mortality. As noted in our limitations, our study lacked data on birthing people's financial positionality (i.e., occupational status, income, parity, etc.) and other marginalizing experiences (e.g., interpersonal and systemic racism experienced within health care[88,134]) that may impact financial burden and postpartum care engagement. Future research should incorporate maternal race, ethnicity, and socio-economic indicators to examine if the financial burden of maternity care disproportionately affects racially and economically marginalized populations. In addition, future research should consider the combined effect of health insurance premium costs and direct patient costs. Adding these nuances to the literature will improve our causal knowledge of how financial burden may be a driver of maternal health inequities.

Our study established an association between the highest levels of financial burden and postpartum care utilization, particularly the deferment of the universally recommended comprehensive postpartum visit. In addition to guiding future research, our findings highlight the need for clinicians, researchers, and policymakers to consider the role of financial burden when proposing system-level solutions to reduce maternal health inequities. As policymakers advocate for and implement 12 months postpartum Medicaid expansion[135], they should similarly consider cost-sharing regulations for birthing people with commercial insurance.[136]

CHAPTER 6. SYNTHESIS OF RESEARCH

6.1 Summary

Inequities in maternal health outcomes in the United States are a national crisis. Despite half of the maternal deaths occurring up to one year postpartum, we lack foundational knowledge on the drivers of postpartum morbidity beyond the first six weeks following birth (often referred to as the 'traditional' postpartum period). This dissertation sought to fill two high-priority research gaps. The first was to describe maternal morbidity that did not rise to the level of mortality and SMM. The second was to understand morbidity and care-seeking beyond the traditional postpartum period and up to one year after birth. We utilized the Oregon All Payer All Claims database to fill these gaps and followed birthing people up to twelve months postpartum. We examined how clinical factors, health insurance, and health care financial burden impact postpartum morbidity and care-seeking.

The first aim, a retrospective cohort study of Oregon hospital births from 2012-to 2017, estimated associations of demographics, clinical factors, and health insurance with postpartum readmissions. We characterized readmissions as with and without evidence of SMM as well as by the timing of readmissions ($6 \leq$ week and 7-52 weeks). We found that SMM at birth was the strongest risk factor for readmissions with evidence of SMM. In comparison, we found that pre-pregnancy diabetes was the strongest risk factor for readmissions without SMM. We also found that factors such as mental health diagnoses and substance use disorder had similar magnitudes of risk for readmissions without SMM as hypertension and diabetes. Our analyses of readmissions by their timing revealed further nuance. We observed that the association between

SMM at birth risk and PPR with SMM was highest in magnitude within the first six weeks. We found that chronic conditions that require ongoing care, such as pre-pregnancy diabetes, were associated with a higher risk of PPR without SMM after the traditional postpartum period.

The second aim took an in-depth look at the role of insurance on postpartum care-seeking and morbidity. We used a time-to-event approach to examine the role of insurance type at birth (Medicaid, High Deductible Health Plans (HDHPs), and other commercial plans) with readmissions, emergency department visits, and comprehensive postpartum visit attendance. We accounted for population differences in insurance type using multinomial propensity score weights. After incorporating propensity scores, we found that Medicaid-funded births were more likely to readmit to the hospital and seek care at the ED within one year postpartum and less likely to attend the universally recommended postpartum care visit. Notably, we found that Medicaid beneficiaries were more likely to seek the care repeated. Over 7% of Medicaid, funded births had three or more ED visits within the first year. We found no statistically significant differences in postpartum care-seeking among birthing people with HDHPs and other commercial insurances.

The final aim focused on the commercially insured population that is often required to pay high dollar amounts for their maternity and birthing care. We described the health care financial burden incurred by birthing people before birth through the childbirth hospitalization, assessed if the highest levels of financial burden (>$5,000) were primarily among those with HDHPs, and examined if an association existed between financial burden and postpartum care-seeking. We found that most birthing people with over $5,000 in financial burden were not enrolled in an HDHP. A compelling finding is that most research considered HDHPs insurance plans with the highest financial burden. Finally, we found that as financial burden, the less likely

a birthing person was to attend their postpartum visit or seek care in the ED. The missed comprehensive postpartum visit highlights a potential missed opportunity to provide patient-centered care. Lower rates of ED use are perplexing and warrant additional research.

6.2 Future Research Needs

This body of work provided crucial foundational knowledge about postpartum morbidity and care-seeking drivers. It elucidated several future research directions worthy of further consideration. Given the current policy context of postpartum Medicaid Expansion, we must prioritize research that provides clinicians, policymakers, and birthing people with evidence to optimize postpartum health beyond the first six weeks following birth. Within this context, there are two high-priority areas of research I aim to pursue following the conference of my doctoral degree. The first relates to postpartum ED use and its drivers. My second aim found that one in four birthing people with Medicaid Insurance visited the ED at least once within the first year postpartum, and over 7% had more than three ED visits in the same period. Yet we lack research about the drivers of postpartum ED utilization. While it is possible that Medicaid beneficiaries have more medical and social complexities that drive urgent, unplanned care, it may also be the case that the medical, emotional, and social needs of birthing people with Medicaid are not being met within our current model of postpartum care.

The second high priority area of research is to understand in more detail how health care financial burden influences postpartum care-seeking and well-being. How we pay for healthcare in the US is complex and incredibly complex for birthing people. From my lived experience as a birthing person with a vast network of peers who have also given birth, few of us considered that

the childbirth hospitalization would cost us thousands of dollars on top of our premiums and other living expenses. Several factors outside of our health insurance influenced our ability (or inability) to absorb that cost. My lived experience inspired my research question, but I acknowledge that I sit with multiple layers of privilege. Future research on health care financial burden of birthing people should incorporate a rigorous qualitative component that asks birthing people not only what financial burden they experienced but how it impacted how they interacted with the healthcare system and what barriers they faced to care-seeking.

Finally, while our work characterized health care financial burden as direct out-of-pocket costs paid by the patient for their care, future research should consider a much more expansive view of financial burden and the subsequent economic insecurity it may cause. Future research should pursue a more comprehensive view of financial burdens, including, but not limited to, pharmacy costs, premium costs, household income, employment status, family size, debt, and cost of living.

6.3 Impact

My dissertation aimed to fill two important gaps in the research. First, describe postpartum morbidity that does not necessarily rise to the level of mortality and SMM. Second, to describe morbidity and care-seeking past the traditional postpartum period, up to one year after birth. Despite the limitations of our research (noted in each chapter), we described how the US healthcare system, in its current form, may be contributing to the well-documented inequities in postpartum health outcomes. Future research, policies, and interventions must grapple with the complex ways birthing people interact with the healthcare system to mitigate these inequities.

REFERENCES

1. Maternal Mortality Maternity Care US Compared 10 Other Countries | Commonwealth Fund. Accessed April 24, 2022. https://www.commonwealthfund.org/publications/issue-briefs/2020/nov/maternal-mortality-maternity-care-us-compared-10-countries

2. Howell EA. Reducing Disparities in Severe Maternal Morbidity and Mortality. *Clin Obstet Gynecol*. 2018;61(2):387-399.

3. Singh GK. Trends and Social Inequalities in Maternal Mortality in the United States, 1969-2018. *Int J MCH AIDS*. 2021;10(1):29-42. doi:10.21106/ijma.444

4. Gordon SH, Sommers BD, Wilson IB, Trivedi AN. Effects Of Medicaid Expansion On Postpartum Coverage And Outpatient Utilization. *Health Aff (Millwood)*. 2020;39(1):77-84. doi:10.1377/hlthaff.2019.00547

5. Ehrenthal DB, Gelinas K, Paul DA, et al. Postpartum Emergency Department Visits and Inpatient Readmissions in a Medicaid Population of Mothers. *J Womens Health Larchmt*. 2017;26(9):984-991. doi:10.1089/jwh.2016.6180

6. Clapp MA, Little SE, Zheng J, Robinson JN. A multi-state analysis of postpartum readmissions in the United States. *Am J Obstet Gynecol*. 2016;215(1):113 e1-113 e10. doi:10.1016/j.ajog.2016.01.174

7. Batra P, Fridman M, Leng M, Gregory KD. Emergency Department Care in the Postpartum Period: California Births, 2009-2011. *Obstet Gynecol*. 2017;130(5):1073-1081. doi:10.1097/aog.0000000000002269

8. NCQA. Prenatal and Postpartum Care (PPC). HEDIS Measures and Technical Resources. Published 2019. https://www.ncqa.org/hedis/measures/prenatal-and-postpartum-care-ppc/

9. Moniz MH, Fendrick AM, Kolenic GE, Tilea A, Admon LK, Dalton VK. Out-Of-Pocket Spending For Maternity Care Among Women With Employer-Based Insurance, 2008–15. *Health Aff (Millwood)*. 2020;39(1):18-23. doi:10.1377/hlthaff.2019.00296

10. CMS. Out-of-pocket maximum/limit. HealthCare.gov. Accessed April 10, 2022. https://www.healthcare.gov/glossary/out-of-pocket-maximum-limit/

11. Bureau UC. QuickFacts United States. Published 2019. https://www.census.gov/quickfacts/fact/table/US/PST045219

12. UNICEF. Maternal mortality declined by 38 per cent between 2000 and 2017. Published 2019. https://data.unicef.org/topic/maternal-health/maternal-mortality/

13. Stuebe AM Jennifer E; Mittal, Pooja; Reddy, Lakshmi; Low, Lisa Kane; Brown, Haywood. Extending Medicaid Coverage For Postpartum Moms. Health Affairs Blog. doi:10.1377/hblog20190501.254675

14. Trost SL, Beauregard JL, Smoots AN, et al. Preventing Pregnancy-Related Mental Health Deaths: Insights From 14 US Maternal Mortality Review Committees, 2008–17. *Health Aff (Millwood)*. 2021;40(10):1551-1559. doi:10.1377/hlthaff.2021.00615

15. Petersen EE, Davis NL, Goodman D, et al. Racial/Ethnic Disparities in Pregnancy-Related Deaths - United States, 2007-2016. *MMWR Morb Mortal Wkly Rep*. 2019;68(35):762-765.

16. Snowden JM, Lyndon A, Kan P, El Ayadi A, Main E, Carmichael SL. Severe Maternal Morbidity: A Comparison of Definitions and Data Sources. *Am J Epidemiol*. Published online March 23, 2021. doi:10.1093/aje/kwab077

17. Creanga AA, Berg CJ, Ko JY, et al. Maternal mortality and morbidity in the United States: where are we now? *J Womens Health Larchmt*. 2014;23(1):3-9.

18. Leonard SA, Main EK, Scott KA, Profit J, Carmichael SL. Racial and ethnic disparities in severe maternal morbidity prevalence and trends. *Ann Epidemiol*. 2019;33:30-36.

19. ACOG. ACOG Committee Opinion No. 736: Optimizing Postpartum Care. *Obstet Gynecol*. 2018;131(5):e140-e150. doi:10.1097/aog.0000000000002633

20. National Academies of Sciences E, Medicine. *Birth Settings in America: Outcomes, Quality, Access, and Choice*. The National Academies Press; 2020. doi:10.17226/25636

21. Wilcox A, Levi EE, Garrett JM. Predictors of Non-Attendance to the Postpartum Follow-up Visit. *Matern Child Health J*. 2016;20(Suppl 1):22-27. doi:10.1007/s10995-016-2184-9

22. Martin JH Brady; Osterman, Michelle; Driscoll, Anne; Drake, Patrick. *Births: Final Data for 2016*. Vol 67.; 2018. https://www.cdc.gov/nchs/data/nvsr/nvsr67/nvsr67_01.pdf

23. Gifford KW Jenna; Ranji, Usha ; Salganicoff, Alina ; Gomez, Ivette. *Medicaid Coverage of April 2017 Pregnancy and Perinatal Benefits: RESULTS FROM A STATE SURVEY*.; 2017. http://files.kff.org/attachment/Report-Medicaid-Coverage-of-Pregnancy-and-Perinatal-Benefits

24. Medicaid's Role for Women. Published 2019. https://www.kff.org/womens-health-policy/fact-sheet/medicaids-role-for-women/

25. Ranji U, Gomez I, Salganicoff. Expanding Postpartum Medicaid Coverage. KFF Women's Health Policy. Published March 9, 2021. Accessed April 13, 2022. https://www.kff.org/womens-health-policy/issue-brief/expanding-postpartum-medicaid-coverage/

26. Combs CA, Goffman D, Pettker CM. Society for Maternal-Fetal Medicine Special Statement: A critique of postpartum readmission rate as a quality metric. *Am J Obstet Gynecol*. 2022;226(4):B2-B9. doi:10.1016/j.ajog.2021.11.1355

27. Overview of the National (Nationwide) Inpatient Sample (NIS). Published 2019. https://www.hcup-us.ahrq.gov/nisoverview.jsp

28. Aziz A, Gyamfi-Bannerman C, Siddiq Z, et al. Maternal outcomes by race during postpartum readmissions. *Am J Obstet Gynecol*. 2019;220(5):484 e1-484 e10.

29. Small MJ, James AH, Kershaw T, Thames B, Gunatilake R, Brown H. Near-miss maternal mortality: cardiac dysfunction as the principal cause of obstetric intensive care unit admissions. *Obstet Gynecol*. 2012;119(2 Pt 1):250-255. doi:10.1097/AOG.0b013e31824265c7

30. Ranji U, Salganicoff A, Gomez I. Postpartum Coverage Extension in the American Rescue Plan Act of 2021. KFF. Published March 18, 2021. Accessed May 18, 2022. https://www.kff.org/policy-watch/postpartum-coverage-extension-in-the-american-rescue-plan-act-of-2021/

31. Wheelock S, Zezza MA. To Provide Seamless Postpartum Insurance Coverage, Keep It In The Medicaid Family | Health Affairs Forefront. Accessed May 18, 2022. https://www.healthaffairs.org/do/10.1377/forefront.20211022.658362/full/

32. ACOG. Extend Postpartum Medicaid Coverage. Accessed May 18, 2022. https://www.acog.org/en/advocacy/policy-priorities/extend-postpartum-medicaid-coverage

33. Wen T, Krenitsky NM, Clapp MA, et al. Fragmentation of postpartum readmissions in the United States. *Am J Obstet Gynecol*. Published online January 18, 2020.

34. Sheen JJ, Smith HA, Tu B, Liu Y, Sutton D, Bernstein PS. Risk Factors for Postpartum Emergency Department Visits in an Urban Population. *Matern Child Health J*. 2019;23(4):557-566. doi:10.1007/s10995-018-2673-0

35. Brousseau EC, Danilack V, Cai F, Matteson KA. Emergency Department Visits for Postpartum Complications. *J Womens Health Larchmt*. 2018;27(3):253-257.

36. Berchick ER; B Jessica C; Upton, Rachel D. *Health Insurance Coverage in the United States: 2018*. Vol P60-267(RV). US Census Bureau; 2019.

37. Berchick ER Jessica C Barnett,and Rachel D Upton. *Current Population Reports in the United States: 2018*. Vol P60-267(RV).; 2019.

38. health insurance premium. healthinsurance.org. Accessed May 18, 2022. https://www.healthinsurance.org/glossary/health-insurance-premium/

39. CMS. *Patient Protection and Affordable Care Act; HHS Notice of Benefit and Payment Parameters for 2020*., 115 (Department of Health and Human Services 2019). https://www.federalregister.gov/documents/2019/04/25/2019-08017/patient-protection-and-affordable-care-act-hhs-notice-of-benefit-and-payment-parameters-for-2020

40. CMS. Copayment. HealthCare.gov. Accessed April 9, 2022. https://www.healthcare.gov/glossary/co-payment/

41. CMS. Deductible. HealthCare.gov. Accessed April 9, 2022. https://www.healthcare.gov/glossary/deductible/

42. IRS. Publication 969 (2021), Health Savings Accounts and Other Tax-Favored Health Plans | Internal Revenue Service. Accessed May 18, 2022. https://www.irs.gov/publications/p969

43. CMS. High Deductible Health Plan (HDHP). Glossary. Published 2020. https://www.healthcare.gov/glossary/high-deductible-health-plan/#:~:text=For%202019%2C%20the%20IRS%20defines,or%20%242%2C700%20for%20a%20family.&text=For%202020%2C%20the%20IRS%20defines,or%20%242%2C800%20for%20a%20family.

44. Internal Revenue Service. Health Savings Accounts and Other Tax-Favored Health Plans. Published 2021. Accessed April 10, 2022. https://www.irs.gov/publications/p969

45. Cohen RA, Zammitti EP. High-deductible Health Plan Enrollment Among Adults Aged 18-64 With Employment-based Insurance Coverage. *NCHS Data Brief*. 2018;(317):1-8.

46. Papanicolas I, Woskie LR, Jha AK. Health Care Spending in the United States and Other High-Income Countries. *JAMA*. 2018;319(10):1024-1039. doi:10.1001/jama.2018.1150

47. Chen A, Oster E, Williams H. Why Is Infant Mortality Higher in the United States Than in Europe? *Am Econ J Econ Policy*. 2016;8(2):89-124. doi:10.1257/pol.20140224

48. Kozhimannil KB, Shippee TP, Adegoke O, Vemig BA. Trends in hospital-based childbirth care: the role of health insurance. *Am J Manag Care*. 2013;19(4):e125-132.

49. ROTHBAUM J; E ASHLEY. Survey Redesigns Make Comparisons to Years Before 2017 Difficult. Income and Poverty. Published 2019. https://www.census.gov/library/stories/2019/09/us-median-household-income-not-significantly-different-from-2017.html#:~:text=The%20U.S.%20median%20household%20income,Census%20Bureau%20statistics%20released%20today.

50. Preventive care benefits for women. HealthCare.gov. Accessed May 18, 2022. https://www.healthcare.gov/preventive-care-women/

51. Wharam JF, Graves AJ, Kozhimannil KB. Navigating the Rise of High-Deductible Health Insurance: Childbirth in the Bronze Age. *JAMA*. 2015;313(3):245-246. doi:10.1001/jama.2014.16085

52. Kozhimannil KB, Huskamp HA, Graves AJ, Soumerai SB, Ross-Degnan D, Wharam JF. High-deductible health plans and costs and utilization of maternity care. *Am J Manag Care*. 2011;17(1):e17-25.

53. Wharam JF, Zhang F, Eggleston EM, Lu CY, Soumerai S, Ross-Degnan D. Diabetes Outpatient Care and Acute Complications Before and After High-Deductible Insurance Enrollment: A Natural Experiment for Translation in Diabetes (NEXT-D) Study. *JAMA Intern Med*. 2017;177(3):358-368.

54. Wharam JF, Zhang F, Lu CY, et al. Breast Cancer Diagnosis and Treatment After High-Deductible Insurance Enrollment. *J Clin Oncol*. 2018;36(11):1121-1127.

55. Cole MB, Ellison JE, Trivedi AN. Association Between High-Deductible Health Plans and Disparities in Access to Care Among Cancer Survivors. *JAMA Netw Open*. 2020;3(6):e208965.

56. Clapp MA, Little SE, Zheng J, Kaimal AJ, Robinson JN. Hospital-Level Variation in Postpartum Readmissions. *JAMA*. 2017;317(20):2128-2129.

57. Mourad M, Wen T, Friedman AM, Lonier JY, D'Alton ME, Zork N. Postpartum Readmissions Among Women With Diabetes. *Obstet Gynecol*. 2020;135(1):80-89.

58. Wagner JL, White RS, Tangel V, Gupta S, Pick JS. Socioeconomic, Racial, and Ethnic Disparities in Postpartum Readmissions in Patients with Preeclampsia: a Multi-state Analysis, 2007-2014. *J Racial Ethn Health Disparities*. 2019;6(4):806-820. doi:10.1007/s40615-019-00580-1

59. Wen T, Overton EE, Sheen JJ, et al. Risk for postpartum readmissions and associated complications based on maternal age. *J Matern Fetal Neonatal Med*. Published online July 4, 2019:1-7.

60. Rossen LM, Womack LS, Hoyert DL, Anderson RN, Uddin SFG. The Impact of the Pregnancy Checkbox and Misclassification on Maternal Mortality Trends in the United States, 1999-2017. *Vital Health Stat 3*. 2020;(44):1-61.

61. Shaw D, Guise JM, Shah N, et al. Drivers of maternity care in high-income countries: can health systems support woman-centred care? *Lancet*. 2016;388(10057):2282-2295. doi:10.1016/s0140-6736(16)31527-6

62. Hoyert DL. Maternal mortality rates in the United States, 2019. Published online January 2020. https://stacks.cdc.gov/view/cdc/103855

63. Gray KE, Wallace ER, Nelson KR, Reed SD, Schiff MA. Population-based study of risk factors for severe maternal morbidity. *Paediatr Perinat Epidemiol*. 2012;26(6):506-514. doi:10.1111/ppe.12011

64. CDC. Severe Maternal Morbidity after Delivery Discharge among U.S. Women, 2010-2014. Reproductive Health. Published 2021. https://www.cdc.gov/reproductivehealth/maternalinfanthealth/smm/smm-after-delivery-discharge-among-us-women/index.htm

65. Harvey EM, Ahmed S, Manning SE, Diop H, Argani C, Strobino DM. Severe Maternal Morbidity at Delivery and Risk of Hospital Encounters Within 6 Weeks and 1 Year Postpartum. *J Womens Health Larchmt*. 2018;27(2):140-147. doi:10.1089/jwh.2017.6437

66. Matas JL, Mitchell LE, Sharma SV, Louis JM, Salemi JL. Severe maternal morbidity at delivery and postpartum readmission in the United States. *Paediatr Perinat Epidemiol*. 2021;35(6):627-634. doi:10.1111/ppe.12762

67. Clapp MA, Little SE, Zheng J, Robinson JN, Kaimal AJ. The relative effects of patient and hospital factors on postpartum readmissions. *J Perinatol*. 2018;38(7):804-812. doi:10.1038/s41372-018-0125-8

68. Cartus AR, Jarlenski MP, Himes KP, James AE, Naimi AI, Bodnar LM. Adverse Cardiovascular Events Following Severe Maternal Morbidity. *Am J Epidemiol*. Published online 2021. doi:10.1093/aje/kwab208

69. Chen J, Cox S, Kuklina EV, Ferre C, Barfield W, Li R. Assessment of Incidence and Factors Associated With Severe Maternal Morbidity After Delivery Discharge Among Women in the US. *JAMA Netw Open*. 2021;4(2):e2036148.

70. Girsen AI, Sie L, Carmichael SL, et al. Rate and causes of severe maternal morbidity at readmission: California births in 2008-2012. *J Perinatol*. 2020;40(1):25-29.

71. Daw JH Laura; Swartz, Katherine; Sommers, Benjamin. Women In The United States Experience High Rates Of Coverage 'Churn' In Months Before And After Childbirth. *Health Aff (Millwood)*. 2017;36(4):598-606. doi:10.1377/hlthaff.2016.1241

72. OHA. Oregon All Payer All Claims Database (APAC): An Overview. Published 2018. https://www.oregon.gov/oha/HPA/ANALYTICS/APAC%20Page%20Docs/APAC-Overview.pdf

73. OHA. Oregon All Payer All Claims Database (APAC): Frequently Asked Questions. Published 2018. https://www.oregon.gov/oha/HPA/ANALYTICS/APAC%20Page%20Docs/APAC-FAQ.pdf

74. Ailes EC, Simeone RM, Dawson AL, Petersen EE, Gilboa SM. Using insurance claims data to identify and estimate critical periods in pregnancy: An application to antidepressants. *Birt Defects Res A Clin Mol Teratol*. 2016;106(11):927-934. doi:10.1002/bdra.23573

75. ACOG. What are the documentation requirements for vaginal deliveries? Coding Library. https://www.acog.org/practice-management/coding/coding-library/documentation-requirements-for-vaginal-deliveries

76. Ballard D. Simplify coding by knowing what is packaged into obstetrics care. Published 2013. https://www.aapc.com/blog/25857-from-antepartum-to-postpartum-get-the-cpt-ob-basics/

77. D'Angelo DV, Le B, O'Neil ME, et al. Patterns of Health Insurance Coverage Around the Time of Pregnancy Among Women with Live-Born Infants--Pregnancy Risk Assessment Monitoring System, 29 States, 2009. *MMWR Surveill Summ*. 2015;64(4):1-19.

78. Ambulatory Care: Emergency Department and Outpatient Utilization. CCO Incentive Measure Specification Sheet for 2019 Measurement Year. Published 2018. https://www.oregon.gov/oha/HPA/ANALYTICS/CCOMetrics/2019-Ambulatory-Care-Outpatient-ED-Utilization.pdf

79. CDC. How Does CDC Identify Severe Maternal Morbidity? Reproductive Health. Published 2019. https://www.cdc.gov/reproductivehealth/maternalinfanthealth/smm/severe-morbidity-ICD.htm

80. Economic Research Service U. Rural-Urban Commuting Area Codes. https://www.ers.usda.gov/data-products/rural-urban-commuting-area-codes/documentation/

81. Austin PC. Balance diagnostics for comparing the distribution of baseline covariates between treatment groups in propensity-score matched samples. *Stat Med*. 2009;28(25):3083-3107.

82. Greenland S, Pearl J, Robins JM. Causal diagrams for epidemiologic research. *Epidemiology*. 1999;10(1):37-48.

83. Hernán MA, Hernández-Díaz S, Werler MM, Mitchell AA. Causal knowledge as a prerequisite for confounding evaluation: an application to birth defects epidemiology. *Am J Epidemiol*. 2002;155(2):176-184. doi:10.1093/aje/155.2.176

84. Leonard SA, Carmichael SL, Main EK, Lyell DJ, Abrams B. Risk of severe maternal morbidity in relation to prepregnancy body mass index: Roles of maternal co-morbidities and caesarean birth. *Paediatr Perinat Epidemiol*. 2020;34(4):460-468. doi:10.1111/ppe.12555

85. Main EK, Abreo A, McNulty J, et al. Measuring severe maternal morbidity: validation of potential measures. *Am J Obstet Gynecol*. 2016;214(5):643 e1-643 e10. doi:10.1016/j.ajog.2015.11.004

86. Daw JR, Winkelman TNA, Dalton VK, Kozhimannil KB, Admon LK. Medicaid Expansion Improved Perinatal Insurance Continuity For Low-Income Women. *Health Aff (Millwood)*. 2020;39(9):1531-1539. doi:10.1377/hlthaff.2019.01835

87. Snowden JM, Tilden EL, Snyder J, Quigley B, Caughey AB, Cheng YW. Planned Out-of-Hospital Birth and Birth Outcomes. *N Engl J Med*. 2015;373(27):2642-2653. doi:10.1056/NEJMsa1501738

88. Taylor JK. Structural Racism and Maternal Health Among Black Women. *J Law Med Ethics*. 2020;48(3):506-517. doi:10.1177/1073110520958875

89. Murray Horwitz ME, Rodriguez MI, Dissanayake M, Carmichael SL, Snowden JM. Postpartum health risks among women with hypertensive disorders of pregnancy, California 2008–2012. *J Hypertens*. 2021;39(5). https://journals.lww.com/jhypertension/Fulltext/2021/05000/Postpartum_health_risks_among_women_with.26.aspx

90. Gingrey JP. Maternal Mortality: A US Public Health Crisis. *Am J Public Health*. 2020;110(4):462-464. doi:10.2105/AJPH.2019.305552

91. Taylor K, Compton S, Kolenic GE, et al. Financial Hardship Among Pregnant and Postpartum Women in the United States, 2013 to 2018. *JAMA Netw Open*. 2021;4(10):e2132103-e2132103. doi:10.1001/jamanetworkopen.2021.32103

92. Yabroff KR, Valdez S, Jacobson M, Han X, Fendrick AM. The Changing Health Insurance Coverage Landscape in the United States. *Am Soc Clin Oncol Educ Book*. 2020;(40):e264-e274. doi:10.1200/EDBK_279951

93. SAMHSA. Living Well with Serious Mental Illness. Published 2021. https://www.samhsa.gov/serious-mental-illness

94. NCQA. Initiation and Engagement of Alcohol and Other Drug Abuse or Dependence Treatment (IET). HEDIS Measures and Technical Resources. https://www.ncqa.org/hedis/measures/initiation-and-engagement-of-alcohol-and-other-drug-abuse-or-dependence-treatment/

95. NCQA. Mental Health Utilization (MPT). https://www.ncqa.org/hedis/measures/mental-health-utilization/

96. ROSENBAUM PR, RUBIN DB. The central role of the propensity score in observational studies for causal effects. *Biometrika*. 1983;70(1):41-55. doi:10.1093/biomet/70.1.41

97. Stürmer T, Schneeweiss S, Brookhart MA, Rothman KJ, Avorn J, Glynn RJ. Analytic strategies to adjust confounding using exposure propensity scores and disease risk scores: nonsteroidal

antiinflammatory drugs and short-term mortality in the elderly. *Am J Epidemiol*. 2005;161(9):891-898.

98. Ridgeway GM Dan; Morral, Andrew; Burgette, Lane; Griffin, Beth Ann. *Toolkit for Weighting and Analysis of Nonequivalent Groups: A Tutorial for the Twang Package*.; 2020. https://cran.r-project.org/web/packages/twang/vignettes/twang.pdf

99. Schapire RE. The Boosting Approach to Machine Learning: An Overview. In: Denison DD, Hansen MH, Holmes CC, Mallick B, Yu B, eds. *Nonlinear Estimation and Classification*. Springer New York; 2003:149-171. doi:10.1007/978-0-387-21579-2_9

100. Lesko CR, Buchanan AL, Westreich D, Edwards JK, Hudgens MG, Cole SR. Generalizing Study Results: A Potential Outcomes Perspective. *Epidemiology*. 2017;28(4):553-561.

101. McCaffrey DF, Griffin BA, Almirall D, Slaughter ME, Ramchand R, Burgette LF. A tutorial on propensity score estimation for multiple treatments using generalized boosted models. *Stat Med*. 2013;32(19):3388-3414. doi:10.1002/sim.5753

102. Glass TA, Goodman SN, Hernán MA, Samet JM. Causal Inference in Public Health. *Annu Rev Public Health*. 2013;34(1):61-75. doi:10.1146/annurev-publhealth-031811-124606

103. Austin Peter C, Lee Douglas S, Fine Jason P. Introduction to the Analysis of Survival Data in the Presence of Competing Risks. *Circulation*. 2016;133(6):601-609. doi:10.1161/CIRCULATIONAHA.115.017719

104. Mitchell KA, Haddock AJ, Husainy H, et al. Care of the Postpartum Patient in the Emergency Department: A Systematic Review with Implications for Maternal Mortality. *Am J Perinatol*. ///;(EFirst).

105. Miller GE, Vistnes JP, Rohde F, Keenan PS. High-Deductible Health Plan Enrollment Increased From 2006 To 2016, Employer-Funded Accounts Grew In Largest Firms. *Health Aff Proj Hope*. 2018;37(8):1231-1237. doi:10.1377/hlthaff.2018.0188

106. Gordon SH, Alger CL, Declercq ER, Garrido MM. The Association Between Continuity Of Marketplace Coverage During Pregnancy And Receipt Of Prenatal Care. *Health Aff (Millwood)*. 2021;40(10):1618-1626. doi:10.1377/hlthaff.2021.00581

107. Medical and health characteristics of birth by race/ethnicity, Oregon residents, 2015-2017. Medical or Health Characteristics of Birth. Published 2018. https://www.oregon.gov/oha/PH/BIRTHDEATHCERTIFICATES/VITALSTATISTICS/BIRTH/Documents/Outcomes/2015-2017/TOTALChar1517.pdf

108. KFF. Medicaid Postpartum Coverage Extension Tracker. Published 2021. https://www.kff.org/medicaid/issue-brief/medicaid-postpartum-coverage-extension-tracker/

109. CMS. National Health Expenditure Fact Sheet. Published 2021. Accessed April 9, 2022. https://www.cms.gov/Research-Statistics-Data-and-Systems/Statistics-Trends-and-Reports/NationalHealthExpendData/NHE-Fact-Sheet

110. Moniz MH, Fendrick AM, Kolenic GE, Tilea A, Admon LK, Dalton VK. Out-Of-Pocket Spending For Maternity Care Among Women With Employer-Based Insurance, 2008–15. *Health Aff (Millwood)*. 2020;39(1):18-23. doi:10.1377/hlthaff.2019.00296

111. Otaliza J, Fox L, Claxton G, Amin K. How does cost affect access to care? Peterson-KFF Health System Tracker. Accessed April 10, 2022. https://www.healthsystemtracker.org/chart-collection/cost-affect-access-care/

112. Collins SR, Gunja M, Doty MM, Buetel S. How High is America's Health Care Cost Burden? Findings from the Commonwealth Fund Health Care Affordability Tracking Survey, July-August 2015. *Issue Brief Commonw Fund*. 2015;32:1-15.

113. Peterson JA, Albright BB, Moss HA, Bianco A. Catastrophic Health Expenditures With Pregnancy and Delivery in the United States. *Obstet Gynecol*. Published online 2022. https://journals.lww.com/greenjournal/Fulltext/9900/Catastrophic_Health_Expenditures_With_Pregnancy.414.aspx

114. Weida EB, Phojanakong P, Patel F, Chilton M. Financial health as a measurable social determinant of health. *PloS One*. 2020;15(5):e0233359-e0233359. doi:10.1371/journal.pone.0233359

115. Grafova I, Monheit A, Kumar R. *How Do Economic Shocks Affect Family Health Care Spending Burdens?* National Bureau of Economic Research; 2019:w26443. doi:10.3386/w26443

116. Lusardi A, Schneider D, Tufano P. The Economic Crisis and Medical Care Use. *Soc Sci Q*. 2015;96(1):202-213.

117. Zilko CEM. Economic contraction and birth outcomes: an integrative review. *Hum Reprod Update*. 2010;16(4):445-458. doi:10.1093/humupd/dmp059

118. Parmar D, Stavropoulou C, Ioannidis JPA. Health outcomes during the 2008 financial crisis in Europe: systematic literature review. *BMJ*. 2016;354:i4588. doi:10.1136/bmj.i4588

119. Agarwal R, Mazurenko O, Menachemi N. High-Deductible Health Plans Reduce Health Care Cost And Utilization, Including Use Of Needed Preventive Services. *Health Aff Proj Hope*. 2017;36(10):1762-1768. doi:10.1377/hlthaff.2017.0610

120. Waters TM, Chang CF, Cecil WT, Kasteridis P, Mirvis D. Impact of high-deductible health plans on health care utilization and costs. *Health Serv Res*. 2011;46(1 Pt 1):155-172. doi:10.1111/j.1475-6773.2010.01191.x

121. Jiang DH, Mundell BF, Shah ND, McCoy RG. Impact of High Deductible Health Plans on Diabetes Care Quality and Outcomes: Systematic Review. *Endocr Pract Off J Am Coll Endocrinol Am Assoc Clin Endocrinol*. 2021;27(11):1156-1164. doi:10.1016/j.eprac.2021.07.001

122. Glied SA, Zhu B. Catastrophic Out-of-Pocket Health Care Costs: A Problem Mainly for Middle-Income Americans with Employer Coverage. doi:10.26099/x0cx-cp48

123. CMS. Coinsurance. HealthCare.gov. Accessed April 9, 2022. https://www.healthcare.gov/glossary/co-insurance/

124. CMS. Plan Year. Glossary. https://www.healthcare.gov/glossary/plan-year/#:~:text=A%2012%2Dmonth%20period%20of,documents%20or%20ask%20your%20employer.

125. Zou G. A modified poisson regression approach to prospective studies with binary data. *Am J Epidemiol*. 2004;159(7):702-706. doi:10.1093/aje/kwh090

126. Greenland S, Morgenstern H. Confounding in health research. *Annu Rev Public Health*. 2001;22:189-212. doi:10.1146/annurev.publhealth.22.1.189

127. Rosenberg A, Agiro A, Gottlieb M, et al. Early Trends Among Seven Recommendations From the Choosing Wisely Campaign. *JAMA Intern Med*. 2015;175(12):1913-1920. doi:10.1001/jamainternmed.2015.5441

128. Razmaria AA. High-Value Care. *JAMA*. 2015;314(22):2462-2462. doi:10.1001/jama.2015.16990

129. Baicker K. Rethinking Health Insurance Design. *JAMA Health Forum*. 2021;2(5):e211440-e211440. doi:10.1001/jamahealthforum.2021.1440

130. ACOG. Employment Considerations During Pregnancy and the Postpartum Period. Committee Opinion. Accessed April 10, 2022. https://www.acog.org/en/clinical/clinical-guidance/committee-opinion/articles/2018/04/employment-considerations-during-pregnancy-and-the-postpartum-period

131. Office of Health Analytics. *Impact of Gobeille v. Liberty Mutual Decision*. Oregon Health Authority; 2017:4. https://www.oregon.gov/oha/HPA/ANALYTICS/APAC%20Page%20Docs/Gobeille-v-Liberty-Mutual-Decision.pdf

132. CMS. Self-Insured Plan. HealthCare.gov. Accessed April 10, 2022. https://www.healthcare.gov/glossary/self-insured-plan/

133. Eric C. Schneider, Arnav Shah, Michelle M. Doty, Roosa Tikkanen, Katharine Fields, Reginald D. Williams II. Mirror, Mirror 2021: Reflecting Poorly - Health Care in the U.S. Compared to Other High-Income Countries. The Commonwealth Fund. doi:10.26099/01dv-h208

134. Association of Women's Health, Obstetric and Neonatal Nurses. Racism and Bias in Maternity Care Settings. *J Obstet Gynecol Neonatal Nurs*. 2021;50(5):e6-e8. doi:10.1016/j.jogn.2021.06.004

135. Eckert E. Preserving the Momentum to Extend Postpartum Medicaid Coverage. *Womens Health Issues Off Publ Jacobs Inst Womens Health*. 2020;30(6):401-404. doi:10.1016/j.whi.2020.07.006

136. Albright BB, Nitecki R, Chino F, et al. Catastrophic health expenditures, insurance churn, and nonemployment among gynecologic cancer patients in the United States. *Am J Obstet Gynecol*. 2022;226(3):384.e1-384.e13. doi:10.1016/j.ajog.2021.09.034

APPENDICES

Appendix 1. Supplemental materials for Chapter 3. Postpartum Readmissions with and without Severe Maternal Morbidity within One Year of Birth, Oregon 2012-2017

Appendix Table A1.1 ICD 9/10 and CPT Codes used to Capture Postpartum Visit Attendance and Covariates in Medical Claims Data

Category	ICD-9	ICD-10

Substance Use Disorder (excluding cannabis use)	291.0-291.5, 291.81, 291.82, 291.89, 291.9, 292.0, 292.11, 292.12, 292.2, 292.81-292.85, 292.89, 292.9, 303.00-303.03, 303.90-303.93, 304.00-304.03, 304.10-304.13, 304.11, 304.12, 304.20-304.23, 304.21, 304.22, 304.30-304.33, 304.31, 304.32, 304.40-304.43, 304.41, 304.42, 304.50-304.53, 304.60-304.63, 304.70-304.73, 304.80-304.83, 304.90-304.93, 305.00-305.03, 305.1, 305.20-305.23, 305.30-305.33, 305.40-305.43, 305.41, 305.42, 305.50-305.53, 305.60-305.63, 305.70-305.73, 305.80-305.83, 305.90-305.93	F10.10, F10.120, F10.121, F10.129, F10.14, F10.150, F10.151, F10.159, F10.180, F10.181, F10.182, F10.188, F10.19, F10.20, F10.21, F10.220, F10.221, F10.229, F10.230-F10.232, F10.239, F10.24,F10.250, F10.251, F10.259, F10.26, F10.27, F10.280-F10.282, F10.288, F10.29, F10.920, F10.921, F10.929, F10.94, F10.950, F10.951, F10.959, F10.96, F10.97, F10.980-F10.982, F10.988, F10.99, F11.10, F11.120-F11.122, F11.129, F11.14, F11.150, F11.151, F11.159, F11.181, F11.182, F11.188, F11.19-F11.21, F11.220-F11.222, F11.229, F11.23, F11.24, F11.250, F11.251, F11.259, F11.281, F11.282, F11.288, F11.29, F11.90, F11.920-F11.922, F11.929, F11.93, F11.94, F11.950, F11.951, F11.959, F11.981, F11.982, F11.988, F11.99, F13.10, F13.120, F13.121, F13.129, F13.14, F13.150, F13.151, F13.159, F13.180-F13.182, F13.188, F13.19-F13.21, F13.220, F13.221, F13.229, F13.230-F13.232, F13.239, F13.24, F13.250, F13.251, F13.259, F13.26, F13.27, F13.280-F13.282, F13.288, F13.29, F13.90, F13.920, F13.921, F13.929, F13.930-F13.932, F13.939, F13.94, F13.950, F13.951, F13.959, F13.96, F13.97, F13.980-F13.982, F13.988, F13.99, F14.10, F14.120-F14.122, F14.129, F14.14, F14.150, F14.151, F14.159, F14.180-F14.182, F14.188, F14.19-F14.21, F14.220-F14.222, F14.229, F14.23, F14.24, F14.250, F14.251, F14.259, F14.280-F14.282, F14.288, F14.29, F14.90, F14.920-F14.922, F14.929, F14.94, F14.950, F14.951, F14.959, F14.980-F14.982, F14.988, F14.99, F15.10, F15.120-F15.122, F15.129, F15.14, F15.150, F15.151, F15.159, F15.180-F15.182, F15.188, F15.19-F15.21, F15.220-F15.222, F15.229, F15.23, F15.24, F15.250, F15.251, F15.259, F15.280-F15.282, F15.288, F15.29, F15.90, F15.920-F15.922,F15.929, F15.93, F15.94, F15.950, F15.951,

		F15.959, F15.980-F15.982, F15.988, F15.99, F16.10, F16.120-F16.122, F16.129, F16.14, F16.150, F16.151, F16.159, F16.180, F16.183, F16.188, F16.19-F16.21, F16.220, F16.221, F16.229, F16.24, F16.250, F16.251, F16.259, F16.280, F16.283, F16.288, F16.29, F16.90, F16.920, F16.921, F16.929, F16.94, F16.950, F16.951, F16.959, F16.980, F16.983, F16.988, F16.99, F17.200, F17.201, F17.203, F17.208-F17.211, F17.213, F17.218-F17.221, F17.223, F17.228, F17.229, F17.290-F17.293, F17.298, F17.299, F18.10, F18.120, F18.121, F18.129, F18.14, F18.150, F18.151, F18.159, F18.17, F18.180, F18.188, F18.19-F18.21, F18.220, F18.221, F18.229, F18.24, F18.250, F18.251, F18.259, F18.27, F18.280, F18.288, F18.29, F18.90, F18.920, F18.921, F18.929, F18.94, F18.950, F18.951, F18.959, F18.97, F18.980, F18.988, F18.99, F19.10, F19.120-F19.122, F19.129, F19.14, F19.150, F19.151, F19.159, F19.16, F19.17, F19.180-F19.182, F19.188, F19.19-F19.21, F19.220-F19.222, F19.229, F19.230-F19.232, F19.239, F19.24, F19.250, F19.251, F19.259, F19.26, F19.27, F19.280-F19.282,F19.288, F19.29, F19.90, F19.920-F19.922, F19.929, F19.930-F19.932, F19.939, F19.94, F19.950, F19.951, F19.959, F19.96, F19.97, F19.980-F19.982, F19.988, F19.99, F55.0-F55.4, F55.8

Substance Use Disorder: Cannabis Use	304.30-304.33, 305.20-305.23	F12.10, F12.120-F12.122, F12.129, F12.150, F12.151, F12.159, F12.180, F12.188, F12.19, F12.20, F12.21, F12.220-F12.222, F12.229, F12.250, F12.251, F12.259, F12.280, F12.288, F12.29, F12.90, F12.920-F12.922, F12.929, F12.950, F12.951, F12.959, F12.980, F12.988, F12.99
Mental Health: Depressive (Not Major Depression Disorder)*	290.13, 290.21, 296.82, 301.12, 309.1, 311	F25.1, F32.8, F33.8
Mental Health: Anxiety	293.84, 300.00-300.02, 300.09, 300.10, 300.20-300.23, 300.29, 300.3	F40.00-F40.02, F40.10, F40.11, F40.210, F40.218, F40.220, F40.228, F40.230-F40.233, F40.240-F40.243, F40.248, F40.290, F40.291, F40.298, F40.8, F40.9, F41.0, F41.1, F41.3, F41.8, F41.9, F42,F45.20, F45.21, F45.29, F40.00, F40.01, F40.02, F40.10, F40.11, F40.210, F40.218, F40.220, F40.228, F40.230-F40.233, F40.240-F40.243, F40.248, F40.290, F40.291, F40.298, F40.8, F40.9, F41.0, F41.1, F41.3, F41.8, F41.9, F42
Mental Health: Serious Mental Illness (includes bipolar conditions, major depressive disorders, schizophrenia, and psychoses)	293.0, 293.1, 293.81, 293.82, 295.00-295.05, 295.10-295.15, 295.20-295.25, 295.30-295.35, 295.40-295.45, 295.50-295.55, 295.60-295.65,295.70-295.75, 295.80-295.85, 295.90-295.95, 296.00-296.06, 296.10-296.16, 296.20-296.26, 296.30-296.36, 296.40-296.46, 296.50-296.56, 296.60-296.66, 296.7, 296.80, 296.81, 296.89, 296.90, 296.99, 297.3, 298.0, 298.1, 298.4, 298.8, 298.9, 301.13	F20.0-F20.3, F20.5, F20.81, F20.89, F20.9, F21, F22, F23, F24, F25.0, F25.1, F25.8, F25.9, F28, F29, F30.10-F30.13, F30.2-F30.4, F30.8, F30.9, F31.0, F31.10-F31.13, F31.2, F31.30-F31.32, F31.4, F31.5, F31.60-F31.64,F31.70-F31.78, F31.81, F31.89, F31.9, F32.0-F32.5, F32.9, F33.0-F33.3, F33.40-F33.42, F33.9, F34.0

Mental Health: Other	290.0, 290.10-290.12, 290.20, 290.3, 290.40-290.43, 290.8, 290.9, 293.0, 293.1, 293.81-293.83, 293.89, 293.9, 294.0, 294.10, 294.11, 294.20, 294.21, 294.8, 294.9, 297.0-297.3, 297.8, 297.9, 298.2, 298.3, 299.00, 299.01, 299.10, 299.11, 299.80, 299.81, 299.90, 299.91, 300.11-300.16, 300.19, 300.5-300.7, 300.81, 300.82, 300.89, 300.9, 301.0, 301.10, 301.11, 301.20-301.22, 301.3, 301.4, 301.50, 301.51, 301.59, 301.6, 301.7, 301.81-301.84, 301.89, 301.9, 302.0-302.4, 302.50-302.53, 302.6, 302.70-302.76, 302.79, 302.81-302.85, 302.89, 302.9, 306.0-306.4, 306.50-306.53, 306.59, 306.6-306.9, 307.0, 307.1, 307.20, 307.21, 307.22, 307.23, 307.3, 307.4-307.54, 307.59, 307.6,307.7, 307.80, 307.81, 307.89, 307.9, 308.0-308.4, 308.9, 309.0, 309.21-309.24, 309.28, 309.29, 309.3, 309.4, 309.81-309.83, 309.89, 309.9, 310.0-310.2, 310.81, 310.89, 310.9, 312.00-312.03, 312.10-312.13, 312.20-312.23, 312.30-312.35, 312.39, 312.4, 312.81, 312.82, 312.89, 312.9, 313.0, 313.1, 313.21-313.23, 313.3, 313.81-313.83, 313.89, 313.9, 314.00, 314.01, 314.1, 314.2, 314.8, 314.9, 315.00-315.02, 315.09, 315.1, 315.2, 315.31-315.35, 315.39, 315.4, 315.5, 315.8, 315.9, 316	F03.90, F03.91, F34.8, F34.9, F39, F42, F43.0, F43.10-F43.12, F43.20-F43.25, F43.29, F43.8, F43.9, F44.0-F44.2, F44.4-F44.7, F44.81, F44.89, F44.9, F45.0, F45.1, F45.20-F45.22, F45.29, F45.41, F45.42, F45.8, F45.9, F48.1, F48.2, F48.8, F48.9, F50.00-F50.02, F50.2,F50.8, F50.9, F51.01-F51.05, F51.09, F51.11-F51.13, F51.19, F51.3-F51.5, F51.8, F51.9, F52.0, F52.1, F52.21, F52.22, F52.31, F52.32, F52.4-F52.6, F52.8, F52.9, F53, F59, F60.0-F60.7, F60.81, F60.89, F60.9, F63.0-F63.3, F63.81, F63.89, F63.9, F64.1, F64.2, F64.8, F64.9, F65.0-F65.4, F65.50-F65.52, F65.81, F65.89, F65.9, F66, F68.10, F68.11, F68.12, F68.13, F68.8, F69, F80.0-F80.2, F80.4, F80.81, F80.89, F80.9, F81.0, F81.2, F81.81, F81.89, F81.9, F82, F84.0, F84.2, F84.3, F84.5, F84.8, F84.9, F88, F89, F90.0-F90.2, F90.8, F90.9, F91.0-F91.3, F91.8, F91.9, F93.0, F93.8, F93.9, F94.0-F94.2, F94.8, F94.9, F95.0-F95.2, F95.8, F95.9, F98.0, F98.1, F98.21, F98.29, F98.3-F98.5, F98.8, F98.9, F99

Pre-pregnancy Diabetes	250.00-250.03, 250.10-250.13, 250.20-250.23, 250.30-250.33, 250.40-250.43,250.50-250.53, 250.60-250.63, 250.70-250.73, 250.80-250.81, 250.82, 250.83, 250.90-250.93, 357.2, 362.01-362.04, 362.05-362.07, 366.41, 648.00-648.04	E10.10, E10.11, E10.21,E10.22, E10.29, E10.311, E10.319, E10.321, E10.3211-E10.3213, E10.3219, E10.329, E10.3291-E10.3293, E10.3299, E10.331, E10.3311-E10.3313, E10.3319, E10.339, E10.3391-E10.3393, E10.3399, E10.341, E10.3411-E10.3413, E10.3419, E10.349, E10.3491-E10.3493, E10.3499, E10.351, E10.3511-E10.3513, E10.3519, E10.3521-E10.3523, E10.3529, E10.3531-E10.3533, E10.3539, E10.3541-E10.3543, E10.3549, E10.3551-E10.3553, E10.3559, E10.359, E10.3591-E10.3593, E10.3599, E10.36, E10.37X1-E10.37X3, E10.37X9, E10.39, E10.40-E10.44, E10.49, E10.51, E10.52, E10.59, E10.610, E10.618, E10.620-E10.622, E10.628, E10.630, E10.638, E10.641, E10.649, E10.65, E10.69, E10.8, E10.9, E11.00, E11.01, E11.10, E11.11, E11.21, E11.22, E11.29, E11.311, E11.319, E11.321, E11.3211-E11.3213, E11.3219, E11.329, E11.3291-E11.3293, E11.3299, E11.331, E11.3311-E11.3313, E11.3319, E11.339, E11.3391-E11.3393, E11.3399, E11.341, E11.3411-E11.3413, E11.3419, E11.349, E11.3491-E11.3493, E11.3499, E11.351, E11.3511-E11.3513, E11.3519, E11.3521-E11.3523, E11.3529, E11.3531-E11.3533, E11.3539, E11.3541-E11.3543, E11.3549, E11.3551-E11.3553, E11.3559, E11.359, E11.3591-E11.3593, E11.3599, E11.36, E11.37X1-E11.37X3, E11.37X9, E11.39, E11.40-E11.44, E11.49, E11.51, E11.52, E11.59, E11.610, E11.618, E11.620-E11.622, E11.628, E11.630, E11.638, E11.641, E11.649, E11.65, E11.69, E11.8, E11.9, E13.00E13.01, E13.10, E13.11, E13.21, E13.22, E13.29, E13.311, E13.319, E13.321, E13.3211-E13.3213, E13.3219, E13.329, E13.3291-E13.3293, E13.3299, E13.331, E13.3311-E13.3313, E13.3319, E13.339, E13.3391-E13.3393, E13.3399, E13.341, E13.3411-E13.3413, E13.3419,

		E13.349, E13.3491-E13.3493, E13.3499, E13.351, E13.3511-E13.3513, E13.3519, E13.3521-E13.3523, E13.3529, E13.3531-E13.3533, E13.3539, E13.3541-E13.3543, E13.3549, E13.3551-E13.3553, E13.3559, E13.359, E13.3591-E13.3593, E13.3599, E13.36, E13.37X1-E13.37X3, E13.37X9, E13.39-E13.44, E13.49, E13.51, E13.52, E13.59, E13.610, E13.618, E13.620E13.621, E13.622, E13.628, E13.630, E13.638, E13.641, E13.649, E13.65, E13.69, E13.8, E13.9, O24.011-O24.013, O24.019,O24.02,O24.03, O24.111-O24.113, O24.119, O24.12, O24.13, O24.311-O24.313, O24.319, O24.32, O24.33, O24.811-O24.813, O24.819, O24.82, O24.83
Gestational Diabetes	648.8, 648.80-648.84	O24.4, O24.41, O24.410, O24.414, O24.415, O24.419, O24.42, O24.420, O24.424, O24.425, O24.429, O24.43, O24.430, O24.434, O24.435, O24.439
Chronic Hypertension	642.00-642.04, 642.10-642.14, 642.20-642.24	O10.011-O10.013, O10.019, O10.02, O10.03, O10.111-O10.113, O10.119, O10.12, O10.13, O10.211-O10.213, O10.219, O10.22, O10.23, O10.311-O10.313, O10.319, O10.32, O10.33, O10.411-O10.413, O10.419, O10.42, O10.43, O10.911-O10.913, O10.919, O10.92, O10.93
Gestational Hypertension	642.30-642.34	O13.1-O13.3, O13.9, O16.1-O16.3, O16.9
Eclampsia/Pre-eclampsia	642.40-642.44, 642.50-642.54, 642.60-642.64	O14.00-O14.03,O14.10-O14.13, O14.20-O14.23,O14.90-O14.93,O15.00,O15.03, O15.1, O15.2, O15.9
Superimposed	642.71-642.74	O11.1-O11.3, O11.9

Appendix Table A1.2 Maternal Demographic, Birth, and Clinical Characteristics by Inclusion and Exclusion in the Analytic Sample

	Included in Analytic Sample (≥11 months of postpartum insurance enrollment) **N=158,653 N (%)**	**Excluded From Analytic Sample** (<11 months of postpartum insurance enrollment) **N=43,592 N (%)**	*p-value*
Maternal Age			<0.001
15-19	9853 (6.2%)	2981 (6.8%)	
20-24	34417 (21.7%)	11114 (25.5%)	
25-29	45085 (28.4%)	13780 (31.6%)	
30-34	43043 (27.1%)	10112 (23.2%)	
35-39	21460 (13.5%)	4542 (10.4%)	
40+	4795 (3.0%)	1063 (2.4%)	
Maternal Residential Location			<0.001
Urban	103353 (65.1%)	27329 (62.7%)	
Rural	55297 (34.9%)	16263 (37.3%)	
Missing	3 (0.0%)	0 (0%)	
Insurance Type at Delivery			<0.001
Commercial	64165 (40.4%)	13982 (32.1%)	
Medicaid	94488 (59.6%)	29610 (67.9%)	
Mode of Delivery			0.0144
Vaginal	113496 (71.5%)	31445 (72.1%)	
Cesarean	45157 (28.5%)	12147 (27.9%)	
Extended Delivery Length of Stay	26344 (16.6%)	8134 (18.7%)	<0.001
SMM at Delivery	1366 (0.9%)	381 (0.9%)	0.8076
Pre-pregnancy Diabetes	3380 (2.1%)	778 (1.8%)	<0.001
Gestational Diabetes	16577 (10.4%)	4175 (9.6%)	<0.001
Any Hypertensive Disorders of Pregnancy	15459 (9.7%)	4118 (9.4%)	0.0644
Hypertensive Disorders of Pregnancy			<0.001
Chronic	3676 (2.3%)	847 (1.9%)	
Gestational Hypertension	6315 (4.0%)	1718 (3.9%)	

Pre-eclampsia/Eclampsia	3416 (2.2%)	967 (2.2%)	
Superimposed	2052 (1.3%)	586 (1.3%)	
No Evidence	143194 (90.3%)	39474 (90.6%)	
Substance Use Disorder			
Any	9686 (6.1%)	2322 (5.3%)	<0.001
Any (excluding cannabis)	8200 (5.2%)	1871 (4.3%)	<0.001
Mental Health Diagnosis			
Any	11877 (7.5%)	2544 (5.8%)	<0.001
Depressive	2356 (1.5%)	519 (1.2%)	<0.001
Anxiety	5347 (3.4%)	1131 (2.6%)	<0.001
Serious Mental Illness	4786 (3.0%)	1001 (2.3%)	<0.001
Other	2414 (1.5%)	468 (1.1%)	<0.001

Appendix Table A1.3 Unadjusted and Adjusted Cumulative Incidence Ratios for Any Postpartum Readmissions within 12 months of delivery with and without Evidence of Severe Maternal Morbidity (SMM), Oregon Hospital Births, 2012-2017 (N=158,653)

	Postpartum Readmission *With* Evidence of SMM				**Postpartum Readmission *Without* Evidence of SMM**			
	RR	95% CI	Adj. RR	95% CI	RR	95% CI	Adj. RR	95% CI
Maternal Age								
15-19	1.27	(0.96 , 1.68)	1.27	(0.97 , 1.68)	1.58	(1.40 , 1.79)	1.58	(1.40 , 1.79)
20-24	0.93	(0.76 , 1.13)	0.93	(0.76 , 1.14)	1.15	(1.05 , 1.26)	1.15	(1.05 , 1.26)
25-29			*ref*		*ref*		*ref*	
30-34	0.85	(0.70 , 1.03)	0.85	(0.70, 1.03)	0.86	(0.79 , 0.95)	0.86	(0.79 , 0.95)
35-39	1.11	(0.89 , 1.38)	1.11	(0.89 , 1.38)	0.91	(0.81 , 1.02)	0.91	(0.81 , 1.02)
40+	1.33	(0.93 , 1.91)	1.33	(0.93 , 1.92)	1.00	(0.82 , 1.23)	1.00	(0.82 , 1.23)
Maternal Residential Location[1]								
Urban	*ref*		*ref*		*ref*		*ref*	
Rural	1.14	(0.99 , 1.32)	1.15	(0.99 , 1.32)	1.09	(1.01 , 1.16)	1.05	(0.97 , 1.12)
Insurance Type at Delivery[2]								
Commercial	*ref*		*ref*		*ref*		*ref*	
Medicaid	2.12	(1.80 , 2.48)	2.06	(1.73 , 2.45)	1.79	(1.66 , 1.93)	1.56	(1.43 , 1.69)
Mode of Delivery[3]								
Vaginal	*ref*		*ref*		*ref*		*ref*	
Cesarean	1.64	(1.43 , 1.89)	1.49	(1.29 , 1.72)	1.43	(1.33 , 1.53)	1.38	(1.28 , 1.48)
Extended Delivery Length of Stay[4]	2.33	(2.01 , 2.70)	1.87	(1.60 , 2.18)	1.84	(1.70 , 1.98)	1.45	(1.34 , 1.57)
SMM at Delivery[5]	7.49	(5.62 , 9.97)	5.55	(4.14 , 7.44)	2.40	(1.89 , 3.04)	1.89	(1.49 , 2.40)
Pre-pregnancy Diabetes[6]	2.95	(2.20 , 3.95)	2.84	(2.12 , 3.82)	1.22	(1.09 , 1.36)	2.85	(2.47 , 3.30)
Gestational Diabetes[6]	1.02	(0.80 , 1.30)	1.03	(0.81 , 1.31)	2.83	(2.45 , 3.27)	1.31	(1.17 , 1.46)
Hypertensive Disorders of Pregnancy[7]								
Any	2.31	(1.94 , 2.74)	2.26	(1.90 , 2.69)	1.87	(1.71 , 2.04)	1.83	(1.68 , 2.01)
No evidence	*ref*		*ref*		*ref*		*ref*	
Hypertensive Disorders of Pregnancy[7]								
Chronic Hypertension	2.82	(2.10 , 3.80)	2.76	(2.05 , 3.72)	2.15	(1.83 , 2.52)	2.17	(1.85 , 2.55)
Gestational Hypertension	1.76	(1.32 , 2.34)	1.72	(1.29 , 2.30)	1.30	(1.11 , 1.53)	1.29	(1.10 , 1.51)
Preeclampsia/Eclampsia	2.97	(2.20 , 4.00)	2.91	(2.15 , 3.93)	2.04	(1.72 , 2.42)	1.97	(1.66 , 2.34)

Superimposed	2.01	(1.26 , 3.20)	1.96	(1.23 , 3.12)	2.80	(2.33 , 3.37)	2.68	(2.23 , 3.22)
No evidence	*ref*		*ref*		*ref*		*ref*	
Substance Use Disorder[8]								
Any	2.80	(2.31 , 3.39)	2.72	(2.23 , 3.31)	2.22	(2.01 , 2.46)	1.91	(1.72 , 2.12)
Any (excluding cannabis)	3.00	(2.46 , 3.66)	2.90	(2.36 , 3.56)	2.33	(2.10 , 2.59)	2.01	(1.80 , 2.24)
Mental Health Diagnosis[9]								
Any MH	1.51	(1.21 , 1.88)	1.50	(1.20 , 1.87)	2.16	(1.96 , 2.37)	2.10	(1.91 , 2.30)
Depressive	2.08	(1.39 , 3.12)	2.06	(1.37 , 3.09)	2.23	(1.85 , 2.69)	2.14	(1.78 , 2.58)
Anxiety	1.49	(1.08 , 2.05)	1.48	(1.07 , 2.04)	2.06	(1.80 , 2.35)	2.02	(1.77 , 2.31)
Serious Mental Illness	1.28	(0.89 , 1.84)	1.27	(0.88 , 1.83)	2.42	(2.12 , 2.75)	2.37	(2.08 , 2.69)
Other	1.71	(1.10 , 2.66)	1.69	(1.08 , 2.63)	2.89	(2.45 , 3.40)	2.74	(2.33 , 3.23)

Notes:

1. Model adjusts for maternal age;
2. Model adjusts for maternal age, maternal residential location, any substance use disorder (SUD), and any mental health (MH) diagnosis;
3. Model adjusts for maternal age, maternal residential location, insurance type at delivery, any SUD, any MH, any diabetes, and any hypertensive disorders of pregnancy (HDP);
4. Model adjusts for maternal age, maternal residential location, insurance type at delivery, any SUD, any MH, any diabetes, HDP, and mode of delivery;
5. model adjusts for maternal age, maternal residential location, insurance type at delivery, any diabetes, and HDP;
6. Model adjusts for maternal age, maternal residential location, any SUD, and any MH;
7. Models adjust for maternal age, maternal residential location, any SUD, and any MH;
8. Model adjusts for maternal age, maternal residential location, and any MH;
9. Model adjusts for maternal age and maternal residential location.

Appendix Table A1.4 Unadjusted and Adjusted Cumulative Incidence Ratios for Postpartum Readmissions with and without Evidence of Severe Maternal Morbidity (SMM) excluding Blood Transfusions in SMM definition, Oregon hospital deliveries, 2012-2017 (N=158,653)

	Postpartum Readmission *With* Evidence of SMM				Postpartum Readmission *Without* Evidence of SMM			
	RR	95% CI	Adj. RR	95% CI	RR	95% CI	Adj. RR	95% CI
Maternal Age								
15-19	1.25	(0.94 , 1.67)	1.25	(0.94 , 1.67)	1.58	(1.39 , 1.79)	1.58	(1.39 , 1.79)
20-24	0.91	(0.74 , 1.12)	0.91	(0.74 , 1.12)	1.15	(1.05 , 1.26)	1.15	(1.05 , 1.26)
25-29	*ref*		*ref*		*ref*		*ref*	
30-34	0.87	(0.72 , 1.06)	0.87	(0.72 , 1.06)	0.86	(0.78 , 0.95)	0.86	(0.78 , 0.95)
35-39	1.10	(0.88 , 1.38)	1.10	(0.88 , 1.38)	0.91	(0.81 , 1.02)	0.91	(0.81 , 1.02)
40+	1.37	(0.95 , 1.99)	1.37	(0.95 , 1.99)	1.00	(0.81 , 1.22)	1.00	(0.81 , 1.22)
Maternal Residential Location[1]								
Urban	*ref*		*ref*		*ref*		*ref*	
Rural	1.12	(0.96 , 1.29)	1.12	(0.97 , 1.30)	1.09	(1.02 , 1.17)	1.05	(0.98 , 1.13)
Insurance Type at Delivery[2]								
Commercial	*ref*		*ref*		*ref*		*ref*	
Medicaid	2.14	(1.81 , 2.53)	2.11	(1.76 , 2.52)	1.78	(1.65 , 1.92)	1.55	(1.42 , 1.68)
Mode of Delivery[3]								
Vaginal	*ref*		*ref*		*ref*		*ref*	
Cesarean	1.65	(1.43 , 1.91)	1.48	(1.27 , 1.72)	1.43	(1.33 , 1.53)	1.37	(1.28 , 1.48)
Extended Delivery Length of Stay[4]	2.23	(1.92 , 2.60)	1.77	(1.51 , 2.08)	1.84	(1.71 , 1.99)	1.46	(1.35 , 1.58)
SMM at Delivery (no blood transfusion)[5]	8.37	(5.94 , 11.78)	5.73	(4.04 , 8.14)	2.54	(1.92 , 3.37)	1.97	(1.48 , 2.61)
Pre-pregnancy Diabetes[6]	3.05	(2.27 , 4.09)	2.92	(2.17 , 3.93)	2.76	(2.39 , 3.18)	2.78	(2.41 , 3.21)
Gestational Diabetes[6]	1.07	(0.84 , 1.37)	1.08	(0.84 , 1.38)	1.20	(1.08 , 1.34)	1.29	(1.15 , 1.44)
Hypertensive Disorders of Pregnancy[7]								
Any	2.37	(1.99 , 2.83)	2.32	(1.95 , 2.77)	1.84	(1.68 , 2.01)	1.81	(1.65 , 1.98)
No evidence	*ref*		*ref*		*ref*		*ref*	
Hypertensive Disorders of Pregnancy[7]								
Chronic Hypertension	2.90	(2.14 , 3.92)	2.82	(2.08 , 3.81)	2.11	(1.80 , 2.48)	2.13	(1.82 , 2.50)
Gestational Hypertension	1.80	(1.34 , 2.41)	1.77	(1.32 , 2.37)	1.29	(1.11 , 1.51)	1.28	(1.09 , 1.50)

Preeclampsia/Eclampsia	3.05	(2.25 , 4.13)	2.99	(2.21 , 4.06)	2.01	(1.69 , 2.38)	1.94	(1.64 , 2.30)
Superimposed	2.08	(1.30 , 3.31)	2.02	(1.27 , 3.23)	2.75	(2.28 , 3.30)	2.63	(2.19 , 3.16)
No evidence	*ref*		*ref*		*ref*		*ref*	
Substance Use Disorder[8]								
Any	2.83	(2.33 , 3.44)	2.76	(2.26 , 3.38)	2.19	(1.98 , 2.42)	1.89	(1.70 , 2.09)
Any (excluding cannabis)	3.01	(2.45 , 3.68)	2.92	(2.37 , 3.60)	2.30	(2.07 , 2.56)	1.98	(1.78 , 2.21)
Mental Health Diagnosis[9]								
Any	1.52	(1.21 , 1.90)	1.51	(1.20, 1.90)	2.13	(1.94 , 2.34)	2.07	(1.89 , 2.28)
Depression	1.98	(1.30 , 3.02)	1.96	(1.29 , 3.00)	2.23	(1.85 , 2.69)	2.14	(1.78 , 2.58)
Anxiety	1.55	(1.12 , 2.14)	1.55	(1.12 , 2.14)	2.02	(1.77 , 2.31)	1.98	(1.74 , 2.27)
Serious Mental Illness	1.32	(0.92 , 1.90)	1.28	(0.92 , 1.90)	2.38	(2.09 , 2.71)	2.33	(2.04 , 2.65)
Other	1.66	(1.05 , 2.61)	1.64	(1.04 , 2.59)	2.86	(2.43 , 3.36)	2.71	(2.31 , 3.20)

Notes:
1. Model adjusts for maternal age;
2. Model adjusts for maternal age, maternal residential location, any substance use disorder (SUD), and any mental health (MH) diagnosis;
3. Model adjusts for maternal age, maternal residential location, insurance type at delivery, any SUD, any MH, any diabetes, and any hypertensive disorders of pregnancy (HDP);
4. Model adjusts for maternal age, maternal residential location, insurance type at delivery, any SUD, any MH, any diabetes, HDP, and mode of delivery;
5. model adjusts for maternal age, maternal residential location, insurance type at delivery, any diabetes, and HDP;
6. Model adjusts for maternal age, maternal residential location, any SUD, and any MH;
7. Models adjust for maternal age, maternal residential location, any SUD, and any MH;
8. Model adjusts for maternal age, maternal residential location, and any MH;
9. Model adjusts for maternal age and maternal residential location.

Appendix Table A1.5 Unadjusted and Adjusted Cumulative Incidence Ratios for Postpartum Readmissions with and without Evidence of Severe Maternal Morbidity (SMM) within 60 days of childbirth discharge, Oregon hospital births, 2012-2017 (N=201,048)

	Postpartum Readmission *With* Evidence of SMM				**Postpartum Readmission *Without* Evidence of SMM**			
	RR	95% CI	Adj. RR	95% CI	RR	95% CI	Adj. RR	95% CI
Maternal Age								
15-19	1.29	(0.89, 1.86)	1.29	(0.89, 1.87)	1.72	(1.45, 2.05)	1.72	(1.45, 2.05)
20-24	0.91	(0.70, 1.19)	0.91	(0.70, 1.19)	1.11	(0.97, 1.27)	1.11	(0.97, 1.27)
25-29	*ref*		*ref*		*ref*		*ref*	
30-34	0.99	(0.77, 1.27)	0.99	(0.77, 1.27)	0.9	(0.78, 1.03)	0.9	(0.78, 1.03)
35-39	1.61	(1.24, 2.11)	1.61	(1.24, 2.11)	1.19	(1.01, 1.39)	1.19	(1.01, 1.39)
40+	1.17	(0.69, 1.99)	1.17	(0.69, 2.00)	1.30	(0.99, 1.70)	1.30	(0.99, 1.70)
Maternal Location[1]								
Urban	*ref*		*ref*		*ref*		*ref*	
Rural	1.04	(0.86, 1.25)	1.07	(0.89, 1.30)	1.04	(0.95, 1.15)	1.03	(0.93, 1.14)
Insurance Type at Delivery[2]								
Commercial	*ref*		*ref*		*ref*		*ref*	
Medicaid	1.72	(1.41, 2.11)	1.79	(1.43, 2.22)	1.25	(1.13, 1.38)	1.11	(0.99, 1.24)
Mode of Delivery[3]								
Vaginal	*ref*		*ref*		*ref*		*ref*	
Cesarean	1.86	(1.56, 2.24)	1.67	(1.38, 2.01)	1.71	(1.55, 1.88)	1.61	(1.46, 1.78)
Extended Delivery Length of Stay[4]	2.27	(1.88, 2.76)	1.84	(1.50, 2.26)	1.95	(1.75, 2.16)	1.52	(1.36, 1.70)
SMM at Delivery (no blood transfusion)[5]	9.65	(6.90, 13.51)	7.04	(4.99, 9.93)	3.39	(2.55, 4.51)	2.54	(1.90, 3.39)
Pre-pregnancy Diabetes[6]	2.09	(1.32, 3.31)	1.95	(1.23, 3.10)	2.54	(2.04, 3.16)	2.53	(2.03, 3.14)
Gestational Diabetes[6]	1.25	(0.94, 1.67)	1.21	(0.91, 1.62)	1.11	(0.94, 1.30)	1.14	(0.97, 1.34)
Hypertensive Disorders of Pregnancy[7]								
Any	2.70	(2.18, 3.35)	2.65	(2.14, 3.29)	2.4	(2.13, 2.69)	2.36	(2.09, 2.65)
No evidence	*ref*		*ref*		*ref*		*ref*	
Hypertensive Disorders of Pregnancy[7]								

Chronic Hypertension	2.99	(2.03, 4.42)	2.87	(1.95, 4.25)	2.71	(2.20, 3.35)	2.70	(2.19, 3.34)
Gestational Hypertension	1.85	(1.27, 2.68)	1.82	(1.25, 2.64)	1.83	(1.51, 2.22)	1.81	(1.49, 2.20)
Preeclampsia/Eclampsia	4.21	(3.01, 5.90)	4.20	(3.00, 5.88)	2.43	(1.94, 3.05)	2.35	(1.87, 2.95)
Superimposed	2.3	(1.30, 4.09)	2.29	(1.29, 4.07)	3.52	(2.77, 4.47)	3.41	(2.68, 4.34)
No evidence	*ref*		*ref*		*ref*		*ref*	
Substance Use Disorder[8]								
Any	2.68	(2.08, 3.46)	2.76	(2.12, 3.59)	1.72	(1.47, 2.02)	1.58	(1.34, 1.86)
Any (excluding cannabis)	3.02	(2.32, 3.92)	3.09	(2.36, 4.05)	1.87	(1.58, 2.21)	1.72	(1.45, 2.03)
Mental Health Diagnosis[9]								
Any	1.35	(0.99, 1.84)	1.36	(1.00, 1.86)	1.71	(1.48, 1.99)	1.68	(1.45, 1.95)
Depressive	1.68	(0.92, 3.05)	1.71	(0.94, 3.10)	1.73	(1.27, 2.35)	1.69	(1.24, 2.30)
Anxiety	1.42	(0.92, 2.20)	1.43	(0.92, 2.21)	1.76	(1.43, 2.17)	1.74	(1.42, 2.15)
Sevrious Mental Illness	1.21	(0.74, 1.99)	1.22	(0.74, 2.00)	2.07	(1.69, 2.54)	2.04	(1.67, 2.50)
Other	1.39	(0.72, 2.68)	1.40	(0.72, 2.70)	2.25	(1.72, 2.95)	2.16	(1.65, 2.84)

Notes:
1. Model adjusts for maternal age;
2. Model adjusts for maternal age, maternal location, any substance use disorder (SUD), and any Mental Health (MH) diagnosis;
3. Model adjusts for maternal age, maternal location, insurance type at delivery, any SUD, any MH, diabetes, and any HDP;
4. Model adjusts for maternal age, maternal location, insurance type at delivery, any SUD, any MH, diabetes, HDP, and mode of delivery;
5. model adjusts for maternal age, maternal location, insurance type at delivery, diabetes, and HDP;
6. Model adjusts for maternal age, maternal location, any SUD, and any MH;
7. Models adjust for maternal age, maternal location, any SUD, and any MH;
8. Model adjusts for maternal age, maternal location, and any MH;
9. Model adjusts for maternal age and maternal location.

Appendix 2. Supplemental Materials for Chapter 4. Postpartum Care Utilization within One Year across Insurace Types, Oregon 2012-2017

Appendix Table A2.1. ICD 9/10 Codes used to Capture Covariates in Medical Claims Data

Category	ICD-9	ICD-10	CPT
Comprehensive Postpartum Visit Attendance	V24.1, V24.2, V25.11, V25.12, V25.13, V72.31, V72.32, V76.2	Z01.411, Z01.419, Z01.42, Z30.430, Z39.1, Z39.2	99214, 57170, 58300, 59430, 99501

Substance Use Disorder	291.0-291.5, 291.81, 291.82, 291.89, 291.9, 292.0, 292.11, 292.12, 292.2, 292.81-292.85, 292.89, 292.9, 303.00-303.03, 303.90-303.93, 304.00-304.03, 304.10-304.13, 304.11, 304.12, 304.20-304.23, 304.21, 304.22, 304.30-304.33, 304.31, 304.32, 304.40-304.43, 304.41, 304.42, 304.50-304.53, 304.60-304.63, 304.70-304.73, 304.80-304.83, 304.90-304.93, 305.00-305.03, 305.1, 305.20-305.23, 305.30-305.33, 305.40-305.43, 305.41, 305.42, 305.50-305.53, 305.60-305.63, 305.70-305.73, 305.80-305.83, 305.90-305.93, 304.30-304.33, 305.20-305.23	F10.10, F10.120, F10.121, F10.129, F10.14, F10.150, F10.151, F10.159, F10.180, F10.181, F10.182, F10.188, F10.19, F10.20, F10.21, F10.220, F10.221, F10.229, F10.230-F10.232, F10.239, F10.24,F10.250, F10.251, F10.259, F10.26, F10.27, F10.280-F10.282, F10.288, F10.29, F10.920, F10.921, F10.929, F10.94, F10.950, F10.951, F10.959, F10.96, F10.97, F10.980-F10.982, F10.988, F10.99, F11.10, F11.120-F11.122, F11.129, F11.14, F11.150, F11.151, F11.159, F11.181, F11.182, F11.188, F11.19-F11.21, F11.220-F11.222, F11.229, F11.23, F11.24, F11.250, F11.251, F11.259, F11.281, F11.282, F11.288, F11.29, F11.90, F11.920-F11.922, F11.929, F11.93, F11.94, F11.950, F11.951, F11.959, F11.981, F11.982, F11.988, F11.99, F13.10, F13.120, F13.121, F13.129, F13.14, F13.150, F13.151, F13.159, F13.180-F13.182, F13.188,	

		F13.19-F13.21, F13.220, F13.221, F13.229, F13.230-F13.232, F13.239, F13.24, F13.250, F13.251, F13.259, F13.26, F13.27, F13.280-F13.282, F13.288, F13.29, F13.90, F13.920, F13.921, F13.929, F13.930-F13.932, F13.939, F13.94, F13.950, F13.951, F13.959, F13.96, F13.97, F13.980-F13.982, F13.988, F13.99, F14.10, F14.120-F14.122, F14.129, F14.14, F14.150, F14.151, F14.159, F14.180-F14.182, F14.188, F14.19-F14.21, F14.220-F14.222, F14.229, F14.23, F14.24, F14.250, F14.251, F14.259, F14.280- F14.282, F14.288, F14.29, F14.90, F14.920-F14.922, F14.929, F14.94, F14.950, F14.951, F14.959, F14.980-F14.982, F14.988, F14.99, F15.10, F15.120-F15.122, F15.129, F15.14, F15.150, F15.151, F15.159, F15.180-F15.182, F15.188, F15.19-F15.21, F15.220-F15.222, F15.229, F15.23, F15.24, F15.250, F15.251, F15.259, F15.280-F15.282,	

		F15.288, F15.29, F15.90, F15.920-F15.922,F15.929, F15.93, F15.94, F15.950, F15.951, F15.959, F15.980-F15.982, F15.988, F15.99, F16.10, F16.120-F16.122, F16.129, F16.14, F16.150, F16.151, F16.159, F16.180, F16.183, F16.188, F16.19-F16.21, F16.220, F16.221, F16.229, F16.24, F16.250, F16.251, F16.259, F16.280, F16.283, F16.288, F16.29, F16.90, F16.920, F16.921, F16.929, F16.94, F16.950, F16.951, F16.959, F16.980, F16.983, F16.988, F16.99, F17.200, F17.201, F17.203, F17.208-F17.211, F17.213, F17.218-F17.221, F17.223, F17.228, F17.229, F17.290-F17.293, F17.298, F17.299, F18.10, F18.120, F18.121, F18.129, F18.14, F18.150, F18.151, F18.159, F18.17, F18.180, F18.188, F18.19-F18.21, F18.220, F18.221, F18.229, F18.24, F18.250, F18.251, F18.259, F18.27, F18.280, F18.288, F18.29, F18.90, F18.920, F18.921, F18.929,	

		F18.94, F18.950, F18.951, F18.959, F18.97, F18.980, F18.988, F18.99, F19.10, F19.120-F19.122, F19.129, F19.14, F19.150, F19.151, F19.159, F19.16, F19.17, F19.180-F19.182, F19.188, F19.19-F19.21, F19.220-F19.222, F19.229, F19.230-F19.232, F19.239, F19.24, F19.250, F19.251, F19.259, F19.26, F19.27, F19.280-F19.282,F19.288, F19.29, F19.90, F19.920-F19.922, F19.929, F19.930-F19.932, F19.939, F19.94, F19.950, F19.951, F19.959, F19.96, F19.97, F19.980-F19.982, F19.988, F19.99, F55.0-F55.4, F55.8, F12.10, F12.120-F12.122, F12.129, F12.150, F12.151, F12.159, F12.180, F12.188, F12.19, F12.20, F12.21, F12.220-F12.222, F12.229, F12.250, F12.251, F12.259, F12.280, F12.288, F12.29, F12.90, F12.920-F12.922, F12.929, F12.950, F12.951, F12.959, F12.980, F12.988, F12.99	

Mental Health: Depressive (Not Major Depression Disorder)*	290.13, 290.21, 296.82, 301.12, 309.1, 311	F25.1, F32.8, F33.8	
Mental Health: Anxiety	293.84, 300.00-300.02, 300.09, 300.10, 300.20-300.23, 300.29, 300.3	F40.00-F40.02, F40.10, F40.11, F40.210, F40.218, F40.220, F40.228, F40.230-F40.233, F40.240-F40.243, F40.248, F40.290, F40.291, F40.298, F40.8, F40.9, F41.0, F41.1, F41.3, F41.8, F41.9, F42,F45.20, F45.21, F45.29, F40.00, F40.01, F40.02, F40.10, F40.11, F40.210, F40.218, F40.220, F40.228, F40.230-F40.233, F40.240-F40.243, F40.248, F40.290, F40.291, F40.298, F40.8, F40.9, F41.0, F41.1, F41.3, F41.8, F41.9, F42	
Mental Health: Serious Mental Illness (includes bipolar conditions, major depressive disorders, schizophrenia, and psychoses)	293.0, 293.1, 293.81, 293.82, 295.00-295.05, 295.10-295.15, 295.20-295.25, 295.30-295.35, 295.40-295.45, 295.50-295.55, 295.60-295.65,295.70-295.75, 295.80-295.85, 295.90-295.95, 296.00-296.06, 296.10-296.16, 296.20-296.26, 296.30-296.36, 296.40-296.46, 296.50-296.56, 296.60-296.66, 296.7,	F20.0-F20.3, F20.5, F20.81, F20.89, F20.9, F21, F22, F23, F24, F25.0, F25.1, F25.8, F25.9, F28, F29, F30.10-F30.13, F30.2-F30.4, F30.8, F30.9, F31.0, F31.10-F31.13, F31.2, F31.30-F31.32, F31.4, F31.5, F31.60-F31.64,F31.70-F31.78, F31.81, F31.89, F31.9, F32.0-F32.5, F32.9, F33.0-F33.3, F33.40-F33.42, F33.9, F34.0	

	296.80, 296.81, 296.89, 296.90, 296.99, 297.3, 298.0, 298.1, 298.4, 298.8, 298.9, 301.13		
Mental Health: Other	290.0, 290.10-290.12, 290.20, 290.3, 290.40-290.43, 290.8, 290.9, 293.0, 293.1, 293.81-293.83, 293.89, 293.9, 294.0, 294.10, 294.11, 294.20, 294.21, 294.8, 294.9, 297.0-297.3, 297.8, 297.9, 298.2, 298.3, 299.00, 299.01, 299.10, 299.11, 299.80, 299.81, 299.90, 299.91, 300.11-300.16, 300.19, 300.5-300.7, 300.81, 300.82, 300.89, 300.9, 301.0, 301.10, 301.11, 301.20-301.22, 301.3, 301.4, 301.50, 301.51, 301.59, 301.6, 301.7, 301.81-301.84, 301.89, 301.9, 302.0-302.4, 302.50-302.53, 302.6, 302.70-302.76, 302.79, 302.81-302.85, 302.89, 302.9, 306.0-306.4, 306.50-306.53, 306.59, 306.6-306.9, 307.0, 307.1, 307.20, 307.21, 307.22, 307.23, 307.3, 307.4-307.54, 307.59, 307.6,307.7, 307.80, 307.81, 307.89, 307.9, 308.0-308.4,	F03.90, F03.91, F34.8, F34.9, F39, F42, F43.0, F43.10-F43.12, F43.20-F43.25, F43.29, F43.8, F43.9, F44.0-F44.2, F44.4-F44.7, F44.81, F44.89, F44.9, F45.0, F45.1, F45.20-F45.22, F45.29, F45.41, F45.42, F45.8, F45.9, F48.1, F48.2, F48.8, F48.9, F50.00-F50.02, F50.2,F50.8, F50.9, F51.01-F51.05, F51.09, F51.11-F51.13, F51.19, F51.3-F51.5, F51.8, F51.9, F52.0, F52.1, F52.21, F52.22, F52.31, F52.32, F52.4-F52.6, F52.8, F52.9, F53, F59, F60.0-F60.7, F60.81, F60.89, F60.9, F63.0-F63.3, F63.81, F63.89, F63.9, F64.1, F64.2, F64.8, F64.9, F65.0-F65.4, F65.50-F65.52, F65.81, F65.89, F65.9, F66, F68.10, F68.11, F68.12, F68.13, F68.8, F69, F80.0-F80.2, F80.4, F80.81, F80.89, F80.9, F81.0, F81.2, F81.81, F81.89, F81.9, F82, F84.0, F84.2, F84.3, F84.5, F84.8, F84.9, F88, F89, F90.0-F90.2, F90.8, F90.9, F91.0-F91.3, F91.8, F91.9, F93.0, F93.8, F93.9, F94.0-F94.2, F94.8, F94.9, F95.0-F95.2,	

	308.9, 309.0, 309.21-309.24, 309.28, 309.29, 309.3, 309.4, 309.81-309.83, 309.89, 309.9, 310.0-310.2, 310.81, 310.89, 310.9, 312.00-312.03, 312.10-312.13, 312.20-312.23, 312.30-312.35, 312.39, 312.4, 312.81, 312.82, 312.89, 312.9, 313.0, 313.1, 313.21-313.23, 313.3, 313.81-313.83, 313.89, 313.9, 314.00, 314.01, 314.1, 314.2, 314.8, 314.9, 315.00-315.02, 315.09, 315.1, 315.2, 315.31-315.35, 315.39, 315.4, 315.5, 315.8, 315.9, 316	F95.8, F95.9, F98.0, F98.1, F98.21, F98.29, F98.3-F98.5, F98.8, F98.9, F99	

Pre-pregnancy Diabetes	250.00-250.03, 250.10-250.13, 250.20-250.23, 250.30-250.33, 250.40-250.43,250.50-250.53, 250.60-250.63, 250.70-250.73, 250.80-250.81, 250.82, 250.83, 250.90-250.93, 357.2, 362.01-362.04, 362.05-362.07, 366.41, 648.00-648.04	E10.10, E10.11, E10.21,E10.22, E10.29, E10.311, E10.319, E10.321, E10.3211-E10.3213, E10.3219, E10.329, E10.3291-E10.3293, E10.3299, E10.331, E10.3311-E10.3313, E10.3319, E10.339, E10.3391-E10.3393, E10.3399, E10.341, E10.3411-E10.3413, E10.3419, E10.349, E10.3491-E10.3493, E10.3499, E10.351, E10.3511-E10.3513, E10.3519, E10.3521-E10.3523, E10.3529, E10.3531-E10.3533, E10.3539, E10.3541-E10.3543, E10.3549, E10.3551-E10.3553, E10.3559, E10.359, E10.3591-E10.3593, E10.3599, E10.36, E10.37X1-E10.37X3, E10.37X9, E10.39, E10.40-E10.44, E10.49, E10.51, E10.52, E10.59, E10.610, E10.618, E10.620-E10.622, E10.628, E10.630, E10.638, E10.641, E10.649, E10.65, E10.69, E10.8, E10.9, E11.00, E11.01, E11.10, E11.11, E11.21, E11.22, E11.29, E11.311, E11.319, E11.321, E11.3211-E11.3213, E11.3219, E11.329, E11.3291-E11.3293, E11.3299, E11.331, E11.3311-E11.3313, E11.3319, E11.339, E11.3391-	

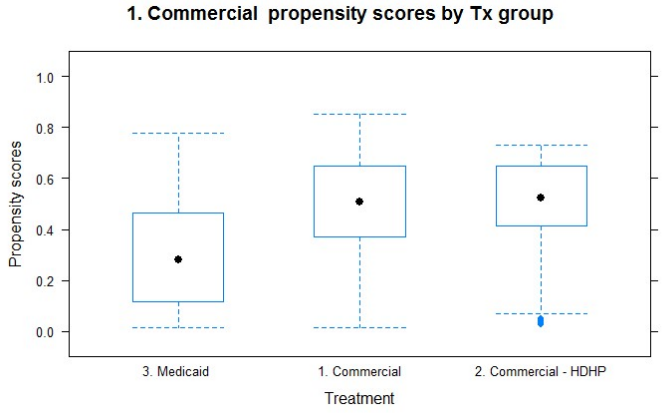
		E11.3393, E11.3399, E11.341, E11.3411-E11.3413, E11.3419, E11.349, E11.3491-E11.3493, E11.3499, E11.351, E11.3511-E11.3513, E11.3519, E11.3521-E11.3523, E11.3529, E11.3531-E11.3533, E11.3539, E11.3541-E11.3543, E11.3549, E11.3551-E11.3553, E11.3559, E11.359, E11.3591-E11.3593, E11.3599, E11.36, E11.37X1-E11.37X3, E11.37X9, E11.39, E11.40-E11.44, E11.49, E11.51, E11.52, E11.59, E11.610, E11.618, E11.620-E11.622, E11.628, E11.630, E11.638, E11.641, E11.649, E11.65, E11.69, E11.8, E11.9, E13.00E13.01, E13.10, E13.11, E13.21, E13.22, E13.29, E13.311, E13.319, E13.321, E13.3211-E13.3213, E13.3219, E13.329, E13.3291-E13.3293, E13.3299, E13.331, E13.3311-E13.3313, E13.3319, E13.339, E13.3391-E13.3393, E13.3399, E13.341, E13.3411-E13.3413, E13.3419, E13.349, E13.3491-E13.3493, E13.3499, E13.351, E13.3511-E13.3513, E13.3519, E13.3521-E13.3523, E13.3529, E13.3531-E13.3533, E13.3539,	

		E13.3541-E13.3543, E13.3549, E13.3551-E13.3553, E13.3559, E13.359, E13.3591-E13.3593, E13.3599, E13.36, E13.37X1-E13.37X3, E13.37X9, E13.39-E13.44, E13.49, E13.51, E13.52, E13.59, E13.610, E13.618, E13.620E13.621, E13.622, E13.628, E13.630, E13.638, E13.641, E13.649, E13.65, E13.69, E13.8, E13.9, O24.011-O24.013, O24.019,O24.02,O24.03, O24.111-O24.113, O24.119, O24.12, O24.13, O24.311-O24.313, O24.319, O24.32, O24.33, O24.811-O24.813, O24.819, O24.82, O24.83	
Gestational Diabetes	648.8, 648.80-648.84	O24.4, O24.41, O24.410, O24.414, O24.415, O24.419, O24.42, O24.420, O24.424, O24.425, O24.429, O24.43, O24.430, O24.434, O24.435, O24.439	
Chronic Hypertension	642.00-642.04, 642.10-642.14, 642.20-642.24	O10.011-O10.013, O10.019, O10.02, O10.03, O10.111-O10.113, O10.119, O10.12, O10.13, O10.211-O10.213, O10.219, O10.22, O10.23, O10.311-O10.313, O10.319, O10.32, O10.33, O10.411-O10.413,	

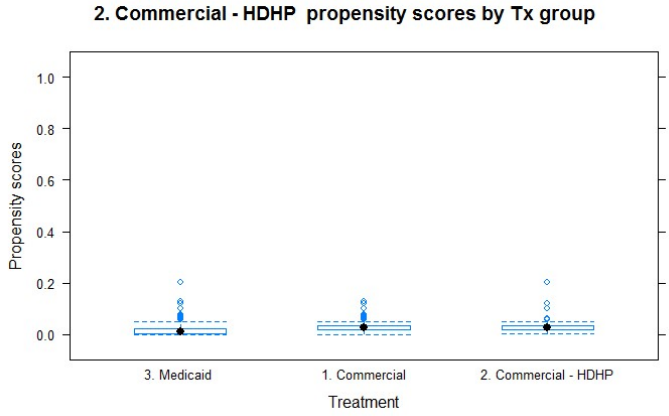
		O10.419, O10.42, O10.43, O10.911-O10.913, O10.919, O10.92, O10.93	
Gestational Hypertension	642.30-642.34	O13.1-O13.3, O13.9, O16.1-O16.3, O16.9	
Eclampsia/Pre-eclampsia	642.40-642.44, 642.50-642.54, 642.60-642.64	O14.00-O14.03,O14.10-O14.13, O14.20-O14.23,O14.90-O14.93,O15.00,O15.03, O15.1, O15.2, O15.9	
Superimposed	642.71-642.74	O11.1 - O11.3, O11.9	

Appendix Figure A2.2 Model Fit Diagnostics
A. Graphical assessments of balance

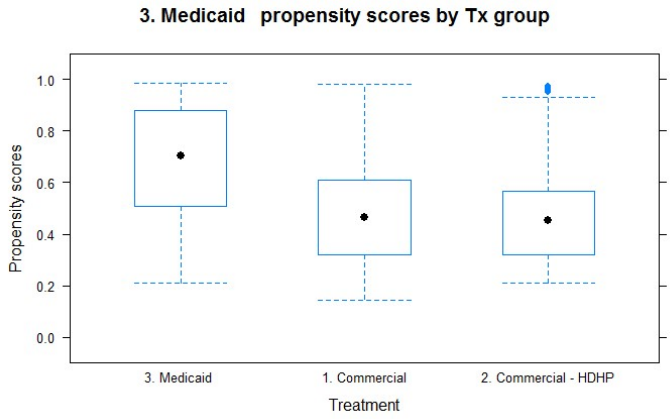
1.



2.

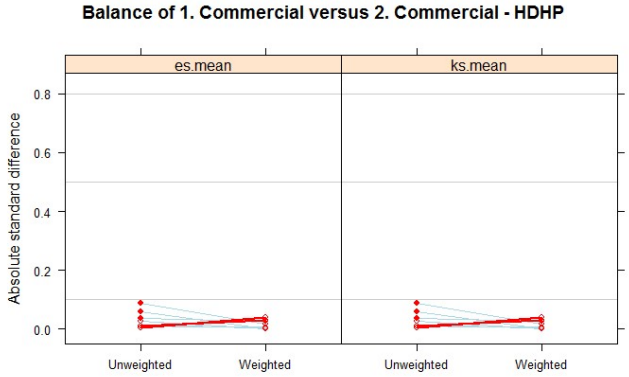


3.

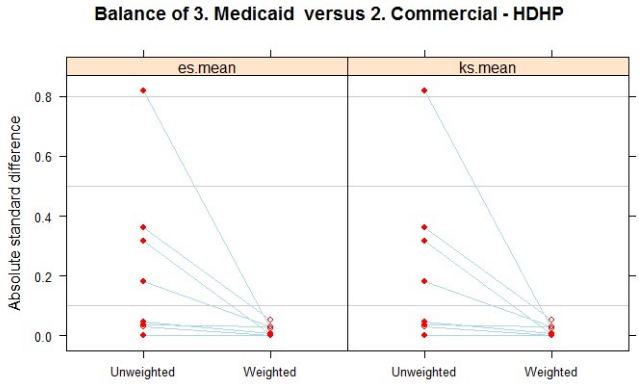


B. Absolute Standardized Mean Differences (ASMD) between insurance types on the "Pre-Treatment" Covariates.

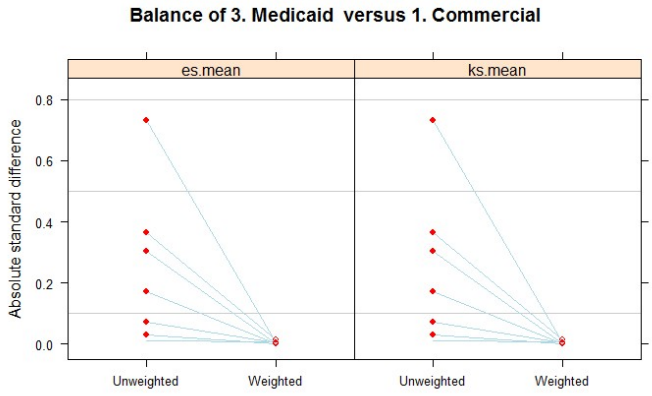
1.



2.



3.



Appendix 3. Supplemental materials for Chapter 5. The Role of Health Care Financial Burden Before and During Birth in Postpartum Care Utilization, Oregon 2012-2017

Supplemental Table A3.1 Demographic, Delivery, and Clinical Characteristics by Commercial Insurance Type, Oregon commercially funded hospital births 2012-2017 (N = 63,153)

	High Deductible Health Plans N = 2,613 %	**Other Commercial Plans** N = 60,540 %	p-value
Maternal Age			<0.001
15-19	0.8	1.2	
20-24	6.7	9.0	
25-29	24.9	25.9	
30-34	39.8	39.0	
35-39	23.1	20.6	
40+	4.7	4.3	
Maternal Location			0.909
Urban	73.8	73.9	
Rural	26.2	26.1	
Missing	-	0.0	
Mode of Delivery			0.955
Vaginal	69.9	70.0	
Cesarean	30.1	30.0	
Extended Delivery Length of Stay	11.4	3.8	<0.001
Pre-term Birth	4.1	4.0	0.999
Severe Maternal Morbidity at Birth	0.8	0.6	0.424
Gestational Diabetes	11.7	9.7	0.001
Pre-existing Diabetes	1.8	1.4	0.084
Hypertensive Disorders of Pregnancy			0.368
Chronic	2.3	1.9	
Gestational Hypertension	3.6	3.9	
Pre-eclampsia/Eclampsia	1.9	1.7	
Superimposed	1.0	0.8	
No Evidence	91.2	91.7	
Substance Use Disorder	0.5	0.6	0.891
Any Mental Health Diagnosis	4.2	4.4	0.702