SEVERE MATERNAL MORBIDITY IN MONTANA

Near-miss Obstetric Events in a Rural State

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EXECUTIVE SUMMARY

Severe maternal morbidity (SMM) has become the sentinel event through which maternal health is evaluated. SMM refers to the "unintended outcomes of the process of labor and delivery that result in significant short-term or long-term consequences for women's health."[1] The rate of SMM is increasing nationally[2] and is associated with increased cost[3], longer hospital stays[4] and permanent health conditions such as chronic hypertension and heart disease[5]. As the burden of SMM continues to grow, it is important to understand the impact of SMM on the health of Montanans.

This report estimates the rate of SMM among Montana residents 11-50 years who delivered at a hospital in Montana from January 1, 2016 to December 31, 2018, using hospital discharge data collected by the Montana Hospital Association. This study measures the rate of SMM using the Centers for Disease Control and Prevention's (CDC) definition, which identifies cases based on the International Classification of Disease 10th Revision (ICD-10).

This study finds increased risk of SMM by age, patient rurality, Medicaid status, and race. Patients for whom the primary payer for delivery was Medicaid had an increased risk of SMM compared to patients with private insurance, those who paid out-of-pocket for delivery, and those who had other public insurance. Both younger (less than 20 years) and older (35 years or more) patients had an increased risk of SMM compared to patients 20-34 years old. American Indian/Alaska Native (AI/AN) patients were three times more likely to experience SMM compared to white patients; the largest increase in risk among the demographic risk factor groups. Residents of noncore counties, the least populated classification category in the 2013 NCHS Urban-Rural Classification Scheme[6], had a higher risk of SMM compared to small metro residents, the most urban classification category in the sample.

The findings in this report match national-level trends in health disparities and highlight a path forward for improving maternal outcomes in Montana. Creating culturally appropriate and well-targeted maternal health programs for AI/AN and rural Montanans can reduce SMM across the state. AI/AN individuals are more likely to live in rural counties; effective programs must address the "double" burden faced by these communitites. Health providers and public health practitioners should partner with AI/AN and rural populations to develop effective initiatives. Learning from and working with impacted communities will ensure that patients feel empowered and supported throughout their pregnancy and lead to improved obstetric outcomes.

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INTRODUCTION

Preventing adverse obstetric health outcomes is foundational to achieving good community health. As maternal mortality declines globally, severe maternal morbidity (SMM) has become the sentinel event through which maternal health and maternal health programs are evaluated. Fifty times more common than maternal mortality,[7] SMM can lead to lifelong health complications and disability in patients; including cardiovascular disease, chronic hypertension, type II diabetes, increased risk of morbidity in subsequent pregnancies,[3,5] increased cost, and longer hospital stays.[7] Within international health, SMM is often referred to as a "maternal near miss" which the World Health Organization (WHO) defines as "a patient who nearly died but survived a complication that occurred during pregnancy, childbirth, or within 42 days of termination of pregnancy."[8] Unlike maternal mortality, which requires a large sample to calculate accurately due to its rarity, SMM is more common and can therefore more accurately measure trends across subgroups because it requires a smaller sample size. By measuring SMM, clinicians and policy-makers can use evidence-based information to better understand obstetric care, maternal health, and deliveries in Montana and pursue initiatives that effectively target specific health conditions.

In addition to the health burden of SMM, SMM places an enormous financial cost on health systems. Studies have found that a pregnancy with SMM complications can cost the health system up to two times more than an uncomplicated delivery.[8,10] This report takes an important first step in understanding obstetric complications in Montana. This in-depth examination of SMM trends aims to leverage the hospital discharge data system as a vital tool in measuring SMM, which we hope will lead to evidence-based clinical interventions, which improve maternal outcomes for Montanans and the overall health of the state.

BACKGROUND

The American College of Obstetricians and Gynecologists (ACOG), the Society for Maternal-Fetal Medicine (SMFM) and the Centers for Disease Control and Prevention (CDC) define SMM as "the unintended outcomes of the process of labor and delivery that result in significant short-term or long-term consequences for women's health."[11] The CDC, in partnership with the Council on Patient Safety in Women's Health Care, classifies SMM using 21 different indicators based on diagnosis and/or procedure codes from the International Classification of Disease (ICD).[2] The classification system was specifically developed by the CDC to be used on hospital administrative data; the data used in this report.

According to the CDC, over the past twenty years, the rate of SMM increased 400% in the United States from 1993 to 2014, with blood transfusion as the most common indicator.[2] The rate was calculated using the National Inpatient Sample, a 20% stratified nationally representative sample of all discharge data from US community hospitals.[12]

The United States has significant racial disparities in pregnancy-related mortality;[I] Black and American Indian/Alaska Native (AI/AN) individuals are two to three times more likely to die from pregnancy-related complications than non-Hispanic white individuals.[14] Similar to maternal mortality, recent research has found evidence of racial and ethnic disparities at the national level in SMM;[15,16] with rates of SMM lowest among non-Hispanic white individuals and highest among AI/AN and non-Hispanic Black individuals. Nationally, AI/AN have an adjusted SMM incidence of 206.0 (95% CI: 181.2-230.8) per 10,000 delivery hospitalizations compared to 139.2 (95% CI: 136.4-142.0) per 10,000 delivery hospitalizations for non-Hispanic white individuals, with a rate difference of 66.8 (95% CI: 42.1-91.6).[15] One study estimated that if AI/AN patients experienced SMM at the same rate as non-Hispanic white patients nationally, there would be a 43.9% reduction in SMM and maternal mortality among AI/AN individuals.[17]

[I] Pregnancy-related mortality is defined as death during pregnancy or within one year of the pregnancy ending due to pregnancy-related complications[13]

Montana has an estimated population of 1.06 million making it the 9th least populated state,[27] but the 4th largest state in land mass,[28] with a population density of 6.8 per square mile.[29] Based on the 2013 NCHS Urban-Rural Classification Scheme[6], of Montana's 56 counties, five counties are metropolitan (all small metro), and the remaining 51 are non-metropolitan; five micropolitan counties and 46 noncore counties. Montana has a majority non-Hispanic white population at 89.1%, and AI/AN make up the second largest racial/ethnic group at 6.7% of the population.[29] 65% of AI/AN individuals in Montana live within one of Montana's seven Indian Reservations.[30] Montana ranks 5th among the states for AI/AN representation.[30]

Disparities in access to maternal healthcare and obstetric outcomes based on rurality are another source of inequality in maternal health in the United States, particularly in rural areas where patients must travel longer distances to receive care. Previous national level research found that while pregnant residents of nonmetropolitan communities face significant barriers to accessing obstetric and gynecological health services, they did not have significant differences in obstetric outcomes between rural and urban populations.[16] However, more recent research on maternal health disparities found that patients from rural communities have an increased risk of SMM and maternal mortality.[18] Risk factors vary by degree of rurality in many parts of the country, indicating that distance and remoteness—rather than population density alone—must be considered in studies on rural health disparities.[19]

Critical Access Hospitals (CAH) serve a vital role in Montana's health system by providing healthcare access to rural communities. The Balanced Budget Act of 1997 established the Medicare Rural Hospital Flexibility Program (RHFP) to provide grants to states to support rural hospitals and facilitate access for local communities to hospital care. As of January 2021, Montana has 49 CAHs located in 42 different counties.[20] Studies have found that while CAHs perform comparably to non-CAHs among low-risk populations, overall obstetric outcomes at CAHs are worse than those at high-volume hospitals, likely due to larger hospitals having designated obstetric physicians and nurses.[21]

While these disparities exist at the national-level, racial and rural health disparities in SMM in Montana are unknown. Maternal health in Montana faces unique challenges with a large rural population and a distinctive racial distribution. This report seeks to understand trends in SMM to aid in the development of evidence-based improvements to reduce adverse obstetric outcomes.

METHODS

Data

This report uses de-identified data compiled from the Montana Hospital Discharge Data System, administered by the Montana Hospital Association (MHA). These data has been shared with researchers at the University of Montana through a data use agreement, and the study has received approval from the University of Montana Institutional Review Board (IRB #133-20). These data represent all hospitalized deliveries from January 1, 2016 to December 31, 2018 at all hospitals that report to the Montana Hospital Discharge Data System. Hospitals report discharge data quarterly to the MHA. Federally run health facilities, such as those run by Veterans Affairs or Indian Health Services, do not report data to the MHA. Additionally, four other health facilities do not submit data to the MHA: two CAHs, one long-term care hospital, and one psychiatric hospital. Neither excluded CAH offers obstetric services. Per the CDC, this sample excludes all rehabilitation and long-term acute care hospitals from analysis.

Study Population

The study population includes all Montana residents aged 11-50 years who had a hospitalized delivery at a health facility that reports data to the MHA, between January 1, 2016 and December 31, 2018, as identified through the International Classification of Disease 10th Revision (ICD-10) codes using the CDC definition of delivery (Appendix I).

Compared to the Montana 2016-2018 birth records, this dataset represents 87.8% of hospitalized deliveries and 85.6% of all births in Montana 2016-2018 (Table 1.1).[22] Twenty-seven different health facilities contributed delivery data during the study time period, including 17 CAHs, reporting a total of 29,681 hospitalized deliveries in Montana 2016-2018.

Measures

The United States measures and reports SMM as a rate: incident cases of SMM per 10,000 hospitalized deliveries.[2] This report uses the same definition as the CDC to define and calculate the rate of SMM in Montana. This study utilizes the CDC definition because it is recommended when using administrative hospital discharge data.[2]

Incident cases of Severe Maternal Morbidity

The numerator for the rate of SMM is incident cases of SMM which are identified based on ICD-10 code definitions used and developed by the CDC.[2] The CDC defines SMM using 21 indicators, each corresponding to specific ICD-10 diagnosis or procedure codes (Appendix I). Blood transfusion is the most important source of false positives, meaning patients are classified as a case when they are not, when measuring SMM.[23] While the ICD-10-PCS codes for blood transfusion indicate that a transfusion has occurred, it does not specify the amount transfused. Inclusion of delivering individuals whose only criterion was receiving one to two units of blood products falsely inflates the number of incident cases. National and multi-state research studies report SMM rates both with and without cases whose only SMM indication is blood transfusion to account for this measurement error; therefore, this study also calculates the SMM rate both with and without blood transfusion-only cases.

SMM Denominator

The denominator of the rate of SMM is the number of hospitalized deliveries, which is defined as a vaginal delivery, cesarean delivery, or a delivery outcome.[2] All miscarriages are excluded from this sample. This definition excludes all non-facility births; non-facility births only made up 4.1% of all births in Montana from 2016-2018.[22] This denominator matches the CDC definition.

Other characteristics included in this report are Medicaid status, maternal age, patient rurality, and race. For more information on how these variables are measured see Appendix II.

AIM Measures

The analysis presented in this report initiates the process for Montana to join the Alliance for Innovation on Maternal (AIM) Health, a national data-driven maternal safety and quality improvement partnership between the Health Resources and Services Administration (HRSA) and ACOG. AIM offers patient safety bundles based on causal factors for adverse obstetric outcomes to hospitals and healthcare providers to standardize and improve maternal care. The onboarding process for Montana to become an AIM state is being initiated through two patient safety bundles: severe hypertension in pregnancy and obstetric hemorrhage. While severe hypertension in pregnancy and obstetric hemorrhage are not indications of SMM, they are closely associated with indications of SMM. Additional analysis is presented in this report relating SMM to severe hypertension in pregnancy and obstetric hemorrhage.

AIM HYPERTENSION SAFETY BUNDLE

The AIM hypertension bundle specifies four separate outcome measures: SMM, SMM excluding blood transfusion, SMM among preeclampsia cases, and SMM among preeclampsia cases excluding blood transfusion.

The denominator for the SMM outcome measure is all individuals during their birth admission excluding abortive outcomes and the numerator is all cases with any SMM code among the denominator. The denominator for SMM among preeclampsia cases is all individuals during their birth admissions excluding abortive outcomes, with one of the following conditions: severe pre-eclampsia, eclampsia, and/or pre-eclampsia superimposed on pre-existing hypertension.

The numerator for SMM among preeclampsia cases is all deliveries with an indication of SMM among those in the denominator (see Annex I).

AIM HEMORRHAGE SAFETY BUNDLE

The CDC and AIM use five different diagnosis codes and one procedure code to identify hemorrhage[24] (see Appendix I). AIM identifies four different outcome measures for obstetric hemorrhage: SMM, SMM excluding cases with only transfusion, SMM among hemorrhage cases, and SMM excluding cases with only a transfusion code.

The denominator for SMM is all individuals during their delivery admission excluding those with abortive outcomes, and the denominator for hemorrhage cases is all deliveries with one of the following criteria: abruption, previa or antepartum hemorrhage, transfusion procedure without a sickle cell crisis diagnosis, or postpartum hemorrhage.

The numerator for SMM is all cases of SMM or all cases of SMM excluding transfusion-only cases and the numerator of SMM among hemorrhage cases is all cases of SMM among the denominator or all of SMM among the denominator excluding transfusion-only cases.

Analysis

Descriptive statistics were performed on the sample population, determining frequency and proportion (%) within the data by demographic characteristics. Demographic characteristics of interest were determined based on established risk factors in maternal health[25,26] and data availability.

Univariate regression was utilized for sub-analysis to estimate the crude relative risk of SMM by patient characteristics. The outcome for each regression is the relative risk of SMM in comparison to a reference group for each of the following variables in the study: Medicaid status, patient age, patient rurality, and race. All cases that are missing data on a specific characteristic were dropped from the analysis of that specific characteristic. All analyses were conducted using Stata v.16.

RESULTS

Table 1.1 compares the study sample population to all Montana residents who delivered in Montana 2016-2018 based on birth records for the same time period. The general population includes both hospital and non-facility deliveries.

Table 1.1 Demographic characteristics of individuals who delivered in Montana, 2016-2018, comparing the sample population to all deliveries reported in birth records during the same period

Demographic Characteristics	Sample (Hospital-Discharge Data) N=29,681 (%)	General Population (Birth Records) N=34,665 (%)
Number of births		
2016	9,420	12,067
2017	9,844	11,414
2018	10,417	11,184
Payer		
Medicaid	13,335 (44.9)	14,237 (41.1)
Non-Medicaid	16,346 (55.1)	20,428 (58.9)
Age		
<20 years	1,596 (5.4)	1,878 (5.4)
20-34 years	23,862 (80.4)	27,795 (80.2)
≥35 years	4,223 (14.2)	4,992 (14.4)
Patient county residence[i]		
Small metro	10,206 (34.4)	12,168 (35.1)
Micropolitan	9,679 (32.6)	10,361 (29.9)
Noncore	9,796 (33.0)	12,110 (34.9)
Race		
White	16,516 (55.7)	29,305 (84.5)
American Indian/Alaska Native	2,034 (6.9)	4,573 (13.2)
Other	1,462 (4.9)	787 (2.3)
Declined/Missing	9,669 (32.6)	N/A
Race/ethnicity identifier		
Complete	20,012 (67.4)	N/A
Missing	9,669 (32.6)	N/A

[i] Defined using the 2013 NCHS Urban-Rural Classification Scheme

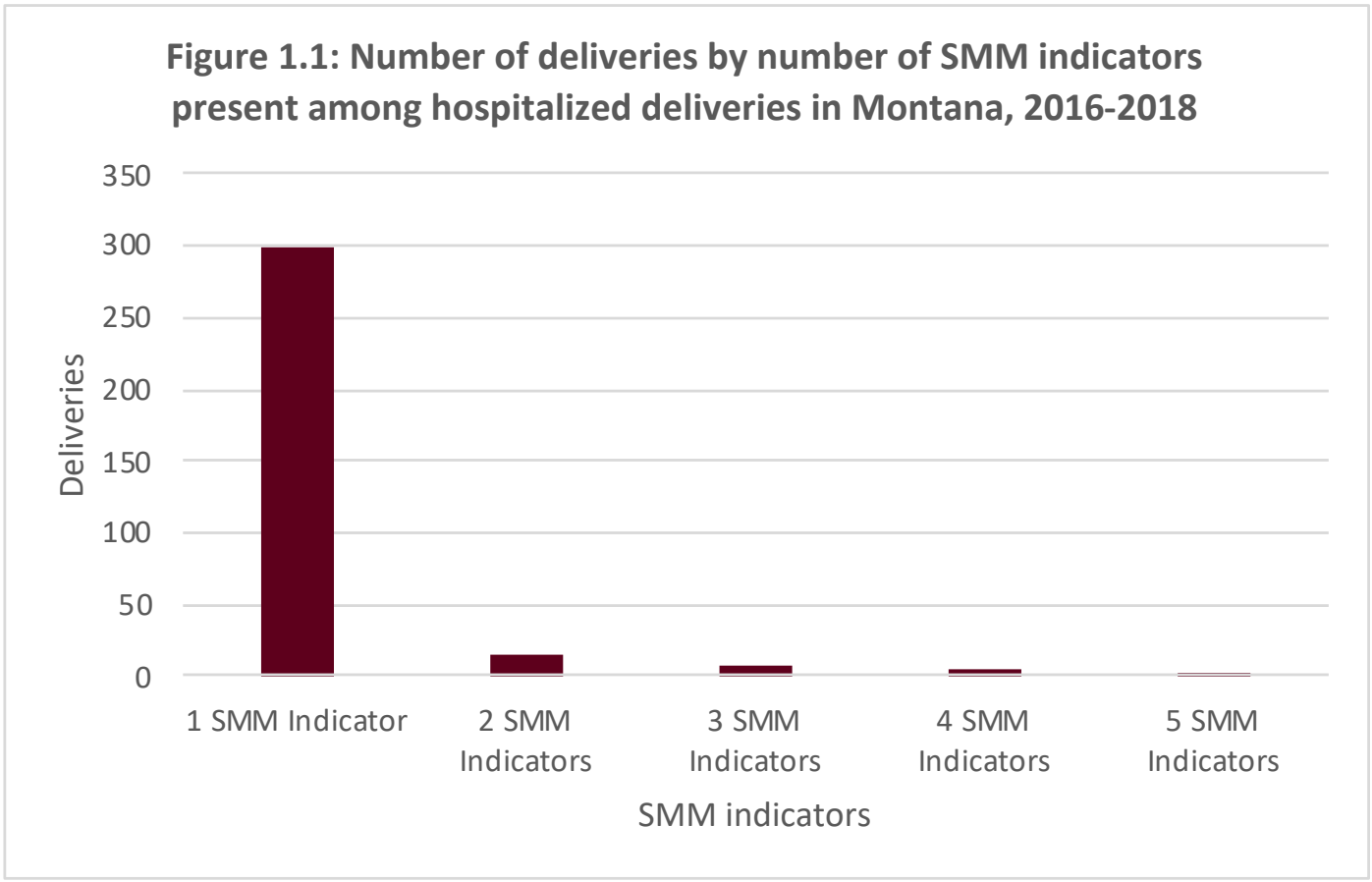
Table 1.1 illustrates that the demographics of the study sample are similar to the demographics of all individuals delivering in Montana. The match is less accurate for racial categories due to significant missing race data in the hospital discharge data. To correct for missing race data, states often conduct a match between birth records and hospital discharge data. This has not been done, to date, in Montana.

Medicaid is the primary payer for slightly less than half of hospitalized deliveries. The sample is almost evenly split among the NCHS rurality categories, with 34.4% of delivery hospitalizations to individuals from small metros areas, 32.6% to individuals from micropolitan areas, and 33.3% to patients from noncore areas. Just over half of hospitalized deliveries were to white individuals, while the AI/AN was the second largest race category. It is notable that 32.6% of hospitalized deliveries either declined to list a race or were missing data on race.

Table 1.2 provides a detailed list of SMM rates and subtypes for Montana. Due to the small number of deliveries in Montana per year, this study presents a combined rate of SMM for deliveries from 2016-2018. The larger sample size gives a more stable estimate and decreases the impact of reporting errors. The larger sample size also increases power which improves detection of statistically significant differences by risk factor.

Table 1.2 Rate of SMM indicators per 10,000 hospitalized deliveries in Montana 2016-2018

SMM Indicator	Montana Rate (2016-2018)
Blood transfusion	84.6
Acute renal failure	4.4
Ventilation	1.3
Sepsis	2.7
Hysterectomy	8.1
Air and thrombotic embolism	2.0
Acute congestive heart failure or pulmonary edema	4.0
Puerperal cerebrovascular disorders	3.7
Eclampsia	3.7
Severe anesthesia complications	2.0
Overall with blood transfusions	110.5
Overall without blood transfusions	32.3



Geographic barriers can adversely impact access to maternal care for rural obstetric patients.[19] Table 1.3 shows that for each NCHS classification category of patients' county of residence in the sample, the majority of patients delivered at a health facility located within the same classification category. The proportion of noncore (pop. <2,499) residents who delivered in a noncore county is smaller than the proportion of small metro (pop. 50,000-249,999) and micropolitan (pop. 2,500-49,999) residents who delivered in a county of the same classification. Over 90% of small metro and micropolitan residents delivered at a health facility in the same classification while only just over half of noncore residents did the same. This finding indicates that noncore residents are more likely to travel out of their home county to deliver compared to small metro and micropolitan residents. Noncore residents who do not deliver in a noncore health facility are more likely to deliver at a small metro health facility than at a micropolitan health facility. Micropolitan residents who did not deliver at a micropolitan health facility were roughly split between delivery at a small metro facility or a noncore facility. The proportion of small metro residents who did not deliver at a small metro health facility was less than 1%.

Table 1.3 Hospitalized deliveries by patients' county of residence and county of delivery facility, defined by the 2013 NCHS Urban-Rural Classification Scheme, Montana 2016-2018

	Health facility county classification		
Patient county of residence classification, n(%)	**Small metro**	**Micropolitan**	**Noncore**
Small metro	10,169 (99.6)	23 (0.2)	14 (0.1)
Micropolitan	295 (3.1)	9,038 (93.4)	346 (3.6)
Noncore	3,466 (35.4)	939 (9.6)	5,391 (55.0)
Total	13,930 (46.9)	10,000 (33.7)	5,751 (19.4)

Bivariate Analysis

Table 1.4 presents results of the Poisson regressions which estimate the unadjusted relative risk for SMM based on the following patient characteristics: payer (Medicaid vs. all other payers), age, rural county designation of patient residence, and race. The last column in Table 1.4 provides these crude relative risks, which can be interpreted as the risk for SMM that the average patient has compared to the reference category. Statistical significance is indicated in the table using*.

Table 1.4 Bivariate Analysis and Sample Population Characteristics by SMM status among hospitalized deliveries in Montana 2016-2018 N=29,681

Patient Characteristics	Severe Maternal Morbidity Present, n (%) 328 (1.1%)	Severe Maternal Morbidity Absent, n (%) 29,353 (98.9%)	Relative Risk (95% CI)
Payer			
Non-Medicaid	160 (1.0)	16,186 (99.0)	Ref
Medicaid	168 (1.3)	13,167 (98.7)	1.3* (1.0 – 1.6)
Age			
20-34 years	235 (71.7%)	23,627 (80.5%)	Ref
<20 years	26 (7.9%)	1,570 (5.4%)	1.7* (1.1-2.5)
≥35 years	67 (20.4%)	4,156 (14.2%)	1.6* (1.2-2.1)
Patient county residence			
Small metro	84 (25.6%)	10,122 (34.5%)	Ref
Micropolitan	88 (26.8%)	9,591 (32.7%)	1.1 (0.8-1.5)
Noncore	156 (47.6%)	9,640 (32.8%)	1.9* (1.5-2.5)
Race			
White	114 (34.8%)	16,402 (55.9%)	Ref
American Indian/ Alaska Native	42 (12.8%)	1,992 (6.8%)	3.0* (2.1-4.2)
Other	14 (4.3%)	1,448 (4.9%)	1.4 (0.8-2.4)

*** p < .001; ** p< .01; * p< .05

Several factors show a statistically significant association with increased risk for SMM. Patients whose primary payer for delivery was Medicaid are 1.3 times more likely to have a SMM event compared to patients who had private insurance, paid out of pocket for their delivery, or had non-Medicaid public health insurance. Compared to patients aged 20-34 years, both younger patients (under 20 years) and older patients (35 years and older) both have an elevated risk for SMM. Younger patients are 1.7 times more likely to experience SMM, and older patients face a 1.6 times greater risk.

Patients who live in very rural counties also experience greater risk for SMM. Individuals who live in noncore counties (rural counties without an urban cluster) are 1.9 times more likely to experience SMM than patients who live in Montana's most populous counties (small metro counties with at least one urbanized area of 50,000 or more).

Finally, racial disparities in SMM present the most dramatic differences. AI/AN individuals have 3 times the risk of SMM compared to white individuals in this sample. However, as previously noted, a third (32.6%) of the individuals in this sample have missing race information, indicating that this relative risk may be inaccurate.

AIM Outcomes: Severe Hypertension in pregnancy and Obstetric hemorrhage

In the study sample, 2.4% of deliveries (n=709) had an AIM-identified indicator for hypertension; of these hypertension cases, 6.3% had an indication for SMM (n=45). Excluding cases that only have an SMM indication for blood transfusion, 4.1% of hypertension cases (n=29) have an indication for SMM. 6.1% of hospitalized deliveries (n=1,817) in the sample had an AIM identified indicator for hemorrhage and of the hemorrhage cases 15.3% (n=275) had an indication for SMM. Excluding cases that only have an indication for blood transfusion, 2.4% of hemorrhage cases (n=43) have an indication for SMM.

Table 1.6 SMM among hospitalized deliveries with hypertension or hemorrhage in Montana, 2016-2018

Outcome Measure	SMM per 10,000
SMM among Hypertension Cases	634.70
SMM among Hypertension Cases, (excluding blood transfusion-only)	409.03
SMM among Hemorrhage Cases	1513.48
SMM among Hemorrhage Cases, (excluding blood transfusion-only)	236.65

DISCUSSION

Health Disparities in SMM

Medicaid status, age, race, and the rurality of a patient's county of residence are all associated with an increased risk of SMM. The association between age and SMM is supported by previous findings that both patients under 20 years and patients over 35 years have an increased risk of SMM.[26] Previous studies found that patients both under 20 years and 35 years and older, have an increased risk of hypertension and pre-eclampsia during pregnancy, which are risk factors in multiple SMM indicators.[31] Additionally, patients of advanced maternal age (35 years and older), are more likely to have gestational diabetes, have multiple births (twins, triplets etc), or require a cesarean birth, all of which are associated with various indicators for SMM.[26,32]

In this sample, AI/AN individuals have triple the risk of SMM compared to white individuals in Montana. The health disparity between AI/AN individuals and white individuals in Montana exceeds those found in other larger multi-state studies which show AI/AN individuals have a risk ratio for SMM of 1.7 (1.5-1.8) and 1.5 (1.3-1.7) compared to white individuals.[15,35] Admon et al found that AI/AN patients have higher rates of blood transfusion, hysterectomy, adult respiratory distress syndrome, ventilation, acute renal failure, shock, and sepsis.[35] Within this sample, both the rates of blood transfusion (159.8 per 10,000 vs. 44.4 per 10,000) and hysterectomy (24.6 per 10,000 vs. 5.5 per 10,000) were higher for AI/AN patients compared to white patients. Higher rates of SMM among AI/AN individuals in the sample may be an indication of poorer underlying health, national level findings show that AI/AN obstetric patients are more likely to have both physical and behavioral health conditions as well as multiple (≥2) chronic conditions.[35] Additionally, 74.2% of AI/AN individuals are residents of noncore areas, indicating that these patients may also be impacted by rural health disparities. Additional research is needed to determine the impact of race, rurality, and the possible effect modification between these risk factors for AI/AN patients.

In 2016 Montana implemented Medicaid expansion under the Affordable Health Care Act, providing access to coverage for nearly 100,000 additional Montanans[38] and cutting Montana's uninsured rate in half.[39] Expanded Medicaid provides continuous access to healthcare beyond the post-pregnancy cutoff of traditional Medicaid. The American College of Obstetricians and Gynecologists (ACOG) recommends that patients who can become pregnant receive continuous medical care from preconception through postpartum to reduce adverse obstetric outcomes, such as hypertension and related SMM types.[40] Improved access to healthcare coverage means that those who may become pregnant in Montana will better be able to access healthcare before, during and after pregnancy. Deliveries for which Medicaid was the primary payer had a statistically significant higher rate of SMM. This finding matches national-level trends which show an increased risk of SMM among those who use public insurance compared to those who have private insurance, a finding which is unsurprising given the significant disparities across many social determinants of health that the Medicaid population faces, including housing and food insecurity and economic instability.[18,41]

The findings presented on patient rurality are consistent with existing literature, which report that rural populations have a 9% greater probability of SMM and mortality.[18] Montanans living in the most rural (noncore) counties have a statistically higher risk for SMM than residents of Montana's most populous counties, but residents in mid-size counties do not carry a statistically significant higher risk for SMM compared to residents of more urban counties. This finding indicates that the increase in risk is primarily among the most rural residents, not all rural residents in general. One possible explanation for the finding is that patients' rurality can delay prenatal care initiation which could be linked to higher rates of SMM.[33] Rural residents are more delayed initiating prenatal care and are less likely to start prenatal care in their first trimester.[33] Many risk factors for SMM, such as hypertension, can be assessed before pregnancy or early in pregnancy and treated effectively, but ongoing care is necessary[34] which may place a larger burden on rural residents. Additionally, rural residents face higher health workforce shortages and have to travel longer distances to access maternity care compared to urban residents.[33] As shown in Table 1.3 the most rural residents are more likely to travel outside of their home county to a health facility for delivery compared to urban and less rural residents.

The sample population is evenly distributed, in terms of patient residence, across three NCHS classifications (small metro, micropolitan, noncore) but only 21.1% of deliveries took place at a CAH, indicating that Montanans are traveling to higher-volume non-CAH for their deliveries. Rural providers often refer high-risk pregnancies to larger facilities in urban areas that have the staff and infrastructure to treat these patients, which this finding supports. Analysis indicates that health facility type is not associated with higher risk of SMM, which may indicate it is not only high-risk patients who are choosing to deliver at larger hospitals, but most pregnant individuals regardless of risk. This also matches with the population distribution and the findings from Table 1.3, that while the majority of people in each NCHS classification choose to deliver in the same classification category, those from noncore areas (the most rural classification) are the most likely to deliver outside of their classification.

ACOG recommends a classification system of levels of risk-appropriate maternal care that supports the delivery of uncomplicated pregnancies in smaller hospitals in a patient's home community and transfer of complex deliveries to higher level facility based on condition severity.[36] To address the maternal health needs of Montanans, the Montana Obstetrics and Maternal Support (MOMS) program is conducting the CDC's Levels of Care Assessment Tool (LOCATe). This web-based tool allows for the standardization of assessments of maternal and neonatal care levels at health facilities and shows the distribution of staff and services throughout the state.[37] LOCATe will help stakeholders make informed decisions about risk-appropriate maternal and neonatal care in Montana to improve maternal outcomes, especially among rural residents.

AIM Safety Bundles

Severe Hypertension in Pregnancy

In the United States, hypertension during pregnancy occurs in about 1 in every 12 to 17 pregnancies among individuals ages 20 to 44,[42] and pre-eclampsia occurs in about 1 in every 25 pregnancies.[42] The rate of hypertensive disorders during pregnancy in the United States has increased from 528.9 per 10,000 delivery hospitalizations in 1993 to 912.4 per 10,000 delivery hospitalizations in 2014, as has the rate of chronic hypertension, from 65.1 per 10,000 delivery hospitalization in 1993 to 166.9 per 10,000 delivery hospitalizations in 2014.[34,42]

Hypertensive disorders include gestational hypertension (high blood pressure that develops during pregnancy after 20 weeks with no protein present in urine), pre-eclampsia, and eclampsia. Chronic hypertension refers to a diagnosis of hypertension before pregnancy. Although gestational hypertension is not included in the definition of SMM, it is a risk factor for SMM and other adverse outcomes. Findings from the 2018 Pregnancy Risk Assessment Monitoring System (PRAMS) in Montana show that 10.2% (95% CI 8.3-12.4%) of individuals reported developing gestational

hypertension in their last pregnancy,[43] putting them at risk for developing more serious morbidities such as chronic hypertension. A patient who is hypertensive during pregnancy has a higher risk for pre-eclampsia, eclampsia, stroke, placental abruption, heart disease, kidney disease, cesarean birth,[34] preterm delivery (delivery before 37 weeks), and low birthweight (below 2,500 grams) for neonates.[34] Hypertension is a risk factor in acute congestive heart failure, puerperal cerebrovascular disorders, and eclampsia, all of which have a higher rate in Montana compared to the national rate.[44] Hypertension is also a risk factor in other SMM indicators such as acute renal failure and disseminated intravascular coagulation.

The CDC recommends that patients with chronic hypertension establish care with their doctor prior to becoming pregnant as there are fewer treatment options available to pregnant patients.[45] Well managed hypertension before pregnancy can reduce the risk of hypertension-related pregnancy complications and some patients may not experience any complications.[34] Additionally, starting prenatal care early and regularly attending every appointment is recommended to monitor for any changes in health.[45] Patients who attend prenatal appointments can be monitored better for signs of pre-eclampsia or eclampsia and educated on signs of pre-eclampsia.[45] The postpartum period is important for individuals who are hypertensive during pregnancy because hypertension during pregnancy is a risk factor for stroke and other complications and post-partum pre-eclampsia can develop.[45] A strong continuum of care before, after, and during pregnancy is important to protect the health of hypertensive patients by preventing more severe complications from developing and ensuring that appropriate care is ready and available.

Hypertension and hemorrhage can be linked in multiple ways. Hypertension is a risk factor for placental abruption which is associated with hemorrhage[46] and gestational hypertension and preeclampsia are both risk factors for postpartum hemorrhage.[47] Hypertension during pregnancy can also lead to gestational diabetes[42] which is a risk factor for excessive birth weight,[31] which is associated with postpartum hemorrhage.[47]

Obstetric Hemorrhage

Hemorrhage is the leading cause of preventable maternal death in the United States and globally.[47] A review of nine maternal mortality review committees estimates that up to 70% of obstetric hemorrhage deaths in the US are preventable.[13] Nationally, the rate of obstetric hemorrhage is increasing[48] and is the most frequent clinical condition necessitating blood transfusion during delivery.[49] From 1994 to 2006, postpartum hemorrhage increased in the

United States from 2.3% of deliveries to 2.9% of deliveries, representing about 125,000 births in 2006.[50] This finding matches evidence that blood transfusion is the most common indicator of SMM and the rate of transfusion is also is increasing.[50] The rates of postpartum hemorrhage (PPH) with blood transfusion and PPH with obstetric procedure to control hemorrhage have increased from 1993 to 2014. PPH with blood transfusion has increased from 7.9 per 10,000 hospitalized deliveries in 1993 to 39.7 per 10,000 hospitalized deliveries in 2013. The rate of PPH with obstetric procedures has increased from 4.3 in 1993 to 21.2 in 2014.[42] Classification of blood transfusion for SMM changed significantly from the ICD-9 classification, where it was identified through a single procedure code, to the ICD-10 classification, which identifies blood transfusion using over 100 procedure codes.[24]

Hemorrhage is associated with numerous causes including placenta previa, placental abruption, placenta accreta, placenta increta, placenta percreta, sickle cell disease, hysterectomy, surgical interventions, uterine artery embolization, and uterine atony, and can occur both antepartum and postpartum.[47,50,51] Hemorrhage is associated with multiple SMM indicators including disseminated intravascular coagulation, sepsis, hysterectomy, and blood transfusion.

Despite being the leading cause of preventable death, hemorrhage is still a rare event, and many health care workers are not trained to recognize the signs or treat it. The California Maternal Quality Care Collaborative developed a training toolkit which it introduced to 126 hospitals to help healthcare providers recognize and treat obstetric hemorrhage and reduced SMM in the hospitals by 20.8% from 2016 to 2018.[52] Training healthcare providers to recognize the risk factors for obstetric hemorrhage and be able to diagnose the condition quickly could lead to a reduction in Montana and improve the lives of patients.

Limitations

Hospital discharge data captures incident cases of SMM at the time of delivery; however, SMM can occur both the antepartum and postpartum periods.[4] Previous research found a 1% postpartum readmission within six weeks of delivery,[53] and 14.2% of postpartum cases had at least one SMM indicator.[4] This indicates that this report potentially underestimates the rate of SMM in Montana 2016-2018. Data which captures the antepartum and postpartum period are needed to develop a more complete understanding of SMM in Montana. However, most incidences of SMM do occur at time of delivery and using discharge data to estimate SMM is standard per the CDC.[2]

Racial health disparities in adverse maternal outcomes are well-established at the national-level in the United States,[35,41] with rates of SMM lower among white individuals compared to black and AI/AN individuals. A third (32.6%) of individuals in the study sample are missing race data, which represents a significant threat to the validity of racial disparity analysis due to selection bias. It is possible that individuals from racial minority groups are more likely to having missing race data. While AI/AN patients represent 6.9% of this study sample, this group comprises 13.2% of all deliveries in Montana during the same time period (Table 1.1). Hospitals should be encouraged to report data on patients' race as identifying populations most impacted by SMM is an important step in reducing it.

Our analysis does not include miscarriage as per the CDC definition of delivery; however, these patients are an important part of overall maternal health. Some indications of SMM can cause miscarriage or necessitate pregnancy termination to save the life of the patient. Individuals who did not carry a pregnancy to term were excluded from the sample. The data from those who are excluded may be different from those who are included. Analysis of those in the sample who had a miscarriage shows a different pattern in SMM indicators (Appendix IV). There are statistically significant differences in risk of SMM between those with public insurance and those who self-paid as compared to those with private insurance. SMM plays an important role in miscarriage and it is important that future research includes this population.

CONCLUSION

Based on the findings in this report, next steps should concentrate on alleviating the burden of SMM, especially among AI/AN and rural residents. AI/AN individuals live at the intersection of both racial and geographical health disparities, and targeted culturally-sensitive care tailored to the specific needs of this community is necessary to reduce SMM in Montana. Early identification of risk factors is a vital step in preventing SMM. Not only is screening for clinical risk factors important, but also screening for social determinants of health such as levels of stress, trauma, food insecurity, and neighborhood violence.[54] Because AI/AN patients have an increased risk of SMM, it is especially important to reach out to these patients to establish a positive relationship before they even become pregnant. Deliveries among AI/AN individuals are more likely to be complicated by hypertension, diabetes, kidney disease and systemic lupus erythematosus (SLE).[35] These are all chronic conditions that can be detected early, and if detected and managed adequately before pregnancy, lead to a reduction in pregnancy complications and SMM. The health system must include tribal leaders and other AI/AN individuals who are directly involved in maternal health to find an appropriate way to ensure that obstetric patients are getting the care that they need to have a healthy a pregnancy, delivery, and postpartum period. Further research on the obstetric health needs of the AI/AN community is necessary to create effective interventions.

ANNEX I

Classifications

Table 4.1 *International Classification of Diseases, 10th Revision*, diagnosis or procedure codes for classification of delivery

	ICD-10-CM/PCS
Included	DX: Z37X, O80, O82, O7582
	PR: 10D00Z0-10D00Z2, 10D07Z3-0D07Z8, 10E0XZZ
Excluded	DX: O00, O01, O02, O03, O04, O07, O08
	PR: 10A0x

Table 4.2 *International Classification of Diseases, 10th Revision*, diagnosis and procedure codes for classification of SMM indicator

Severe Maternal Mortality Indicator	*International Classification of Diseases, 10th Revision*, diagnosis and procedure codes
1. Acute myocardial infarction	DX: I26.x, O88.0x, O88.2x, O88.3x, O88.8x
2. Aneurysm	DX: I171.xx
3. Acute renal failure	DX: N17.x, O90.4
4. Adult respiratory distress syndrome	DX: J80, J95.1, J95.2, J95.3, J95.82x, J96.0x, J96.2x R09.2
5. Amniotic fluid embolism	DX: O88.1x
6. Cardiac arrest/ventricular fibrillation	DX: I46.x, I49.0x
7. Conversion of cardiac rhythm	PR: 5A2204Z, 5A12012
8. Disseminated intravascular coagulation	DX: D65, D68.8, D68.9, O72.3
9. Eclampsia	DX: O15.x
10. Heart failure/arrest during surgery or procedure	DX: I97.12x, I97.13x, I97.710, I97.711
11. Puerperal cerebrovascular disorders	DX: I60.xx-I68.xx, O22.51, O22.52, O22.53, I97.81x, I97.82x, O87.3
12. Pulmonary edema/Acute heart failure	DX: J81.0, I50.1, I50.20, I50.21, I50.23, I50.30, I50.31, I50.33, I50.40, I50.41, I50.43, I50.9
13. Severe anesthesia complications	DX: O74.0 , O74.1 , O74.2, O74.3, O89.0x, O89.1, O89.2
14. Sepsis	DX: O85, O86.04, T80.211A, T81.4XXA, T81.44xx, R65.20, A40.x, A41.x, A32.7
15. Shock	DX: O75.1, R57.x, R65.21, T78.2XXA, T88.2 XXA, T88.6 XXA, T81.10XA , T81.11XA, T81.19XA
16. Sickle cell disease with crisis	DX: D57.0x, D57.21x, D57.41x, D57.81x
17. Air and thrombotic embolism	DX: I26.x, O88.0x, O88.2x, O88.3x, O88.8x

18. Blood products transfusion	PR: 30233H1, 30233L1, 30233K1, 30233M1, 30233N1, 30233P1, 30233R1, 30233T1, 30233H0, 30233L0, 30233K0, 30233M0, 30233N0, 30233P0, 30233R0, 30233T0, 30230H1, 30230L1, 30230K1, 30230M1, 30230N1, 30230P1, 30230R1, 30230T1, 30230H0, 30230L0, 30230K0, 30230M0, 30230N0, 30230P0, 30230R0, 30230T0, 30240H1, 30240L1, 30240K1, 30240M1, 30240N1, 30240P1, 30240R1, 30240T1, 30240H0, 30240L0, 30240K0, 30240M0, 30240N0, 30240P0, 30240R0, 30240T0, 30243H1, 30243L1, 30243K1, 30243M1, 30243N1, 30243P1, 30243R1, 30243T1, 30243H0, 30243L0, 30243K0, 30243M0, 30243N0, 30243P0, 30243R0, 30243T0, 30250H1, 30250L1, 30250K1, 30250M1, 30250N1, 30250P1, 30250R1, 30250T1, 30250H0, 30250L0, 30250K0, 30250M0, 30250N0, 30250P0, 30250R0, 30250T0, 30253H1, 30253L1, 30253K1, 30253M1, 30253N1, 30253P1, 30253R1, 30253T1, 30253H0, 30253L0, 30253K0, 30253M0, 30253N0, 30253P0, 30253R0, 30253T0, 30260H1, 30260L1, 30260K1, 30260M1, 30260N1, 30260P1, 30260R1, 30260T1, 30260H0, 30260L0, 30260K0, 30260M0, 30260N0, 30260P0, 30260R0, 30260T0, 30263H1, 30263L1, 30263K1, 30263M1, 30263N1, 30263P1, 30263R1, 30263T1, 30263H0, 30263L0, 30263K0, 30263M0, 30263N0, 30263P0, 30263R0, 30263T0
19. Hysterectomy	PR: 0UT90ZZ, 0UT94ZZ, 0UT97ZZ, 0UT98ZZ, 0UT9FZZ, 0UT90ZL
20. Temporary tracheostomy	PR: 0B110Z, 0B110F, 0B113, 0B114
21. Ventilation	PR: 5A1935Z, 5A1945Z, 5A1955Z

Table 4.3 *International Classification of Diseases, 10th Revision*, diagnosis and procedure codes for classification of severe hypertension, AIM

Severe Hypertension Indicator	*International Classification of Diseases, 10th Revision*, diagnosis and procedure codes
Severe pre-eclampsia	DX: O14.1x
Eclampsia	DX: O15.x
HELLP syndrome	DX: O14.2x
Pre-eclampsia superimposed on pre-existing hypertension	DX: O11.x

Table 4.4 *International Classification of Diseases, 10th Revision*, diagnosis and procedure codes for classification of hemorrhage, AIM

Hemorrhage Indicator	*International Classification of Diseases, 10th Revision*, diagnosis and procedure codes
Previa diagnosis	DX: O44.10, O44.12, O44.13, O44.30, O44.32, O44.33, O44.50, O44.52, O44.53
Abruption diagnosis	DX: O45.002, O45.003, O45.009, O45.012, O45.013, O45.019, O45.022, O45.023, O45.029, O45.092, O45.093, O45.099, O45.8X2, O45.8X3, O45.8X9, O45.90, O45.92, O45.93
Antepartum hemorrhage diagnosis	DX: O46.002, O46.003, O46.009, O46.012, O46.013, O46.019, O46.022, O46.023, O46.029, O46.092, O46.093, O46.099, O46.8X2, O46.8X3, O46.8X9, O46.92, O46.93, O46.90
Postpartum hemorrhage diagnosis	DX: O43.212, O43.213, O43.219, O43.222, O43.223, O43.229, O43.232, O43.233, O43.239, O72.0, O72.x

Blood transfusion	PR: 30230H0, 30230K0, 30230L0, 30230M0, 30230N0, 30230P0, 30230R0, 30230T0, 30230H1, 30230K1, 30230L1, 30230M1, 30230N1, 30230P1, 30230R1, 30230T1, 30233H0, 30233K0, 30233L0, 30233M0, 30233N0, 30233P0, 30233R0, 30233T0, 30233H1, 30233K1, 30233L1, 30233M1, 30233N1, 30233P1, 30233R1, 30233T1, 30240H0, 30240K0, 30240L0, 30240M0, 30240N0, 30240P0, 30240R0, 30240T0, 30240H1, 30240K1, 30240L1, 30240M1, 30240N1, 30240P1, 30240R1, 30240T1, 30243H0, 30243K0, 30243L0, 30243M0, 30243N0, 30243P0, 30243R0, 30243T0, 30243H1, 30243K1, 30243L1, 30243M1, 30243N1, 30243P1, 30243R1, 30243T1, 30250H0, 30250K0, 30250L0, 30250M0, 30250N0, 30250P0, 30250R0, 30250T0, 30250H1, 30250K1, 30250L1, 30250M1, 30250N1, 30250P1, 30250R1, 30250T1, 30253H0, 30253K0, 30253L0, 30253M0, 30253N0, 30253P0, 30253R0, 30253T0, 30253H1, 30253K1, 30253L1, 30253M1, 30253N1, 30253P1, 30253R1, 30253T1, 30260H0, 30260K0, 30260L0, 30260M0, 30260N0, 30260P0, 30260R0, 30260T0, 30260H1, 30260K1, 30260L1, 30260M1, 30260N1, 30260P1, 30260R1, 30260T1, 30263H0, 30263K0, 30263L0, 30263M0, 30263N0, 30263P0, 30263R0, 30263T0, 302633H1, 30263K1, 30263L1, 30263M1, 30263N1, 30263P1, 30263R1, 30263T1
Sickle cell diagnosis	DX: D57.00, D57.01, D57.02, D57.211, D57.212, D57.219, D57.411, D57.412, D57.419, D57.811, D57.812, D57.819

APPENDIX II

Medicaid status: Medicaid status is defined as the primary payer for the delivery being Medicaid. Categorization is based on guidelines from the Healthcare Cost and Utilization Project under the Agency for Healthcare Research and Quality.[12] "Medicaid" is classified as all deliveries for which in-state and out of state Medicaid and Medicaid Managed Care is the primary payer. Deliveries that have a different primary payer are classified as "Non-Medicaid."

Patient Age: Patient age was categorized based on change in risk due to age.[32] Patients under 20, 35 and older, and 40 and older were at increased risk for SMM. Due to small sample size for patients over 40, 35 years was selected as the cutoff age.

Patient rurality: Patient rurality was determined based on reported county of residence and matching the county FIPS code to the 2013 NCHS Urban-Rural Classification scheme. The 2013 Urban-Rural Classification divides areas into two groups: metropolitan and non-metropolitan. Within the metropolitan areas, metropolitan statistical areas (MSAs) are identified, which are defined as "an area containing a large population nucleus together with adjacent communities having a high degree of economic and social integration with that core."[6] Small metros are defined as counties in MSAs with a population of at least 50,000 but less than 250,000. The nonmetropolitan categories are micropolitan and noncore. Micropolitan counties are those in micropolitan statistical areas, areas with a population of 2,500-49,999, and noncore counties are those with a population of less than 2,500 individuals. A statistical area can encompass multiple counties.

APPENDIX III

Blood transfusion is the most common SMM indicator and rates are significantly higher than other indications of SMM not only in this study but previous research as well.[4,35,41] While the ICD-10-PCS code for blood transfusion indicates that a transfusion has occurred, it does not specify the amount transfused. Delivering individuals who receive only one-two units of blood products as their only criterion are the most important source of false positives off SMM.[23] The inclusion of those whose only indication is blood transfusion may falsely inflate the rate of SMM; therefore rates that include and exclude blood transfusion are both presented. Excluding deliveries in which blood transfusion is the only indicator, 0.003% of the sample has at least one indication of SMM and the rate is 32.3 per 10,000 delivery hospitalizations.

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