Research Brief ■ No. 1 ■ November 2021

Severe Maternal Morbidity

Delaware Profile 2010-2019

This research brief provides an update on the incidence of severe maternal morbidity (SMM) among Delaware residents using the Hospital Discharge Data (HDD) and linked birth certificate data. A previous data brief identified 693 cases of SMM in Delaware during the 2010-2014 time-period. The case identification of SMM was based on the Centers for Disease Control and Prevention (CDC) algorithm that primarily used International Classification of Diseases – Ninth Revision – Clinical Modification (ICD-9-CM) during delivery hospitalizations. However, beginning October 2015, ICD-9-CM transitioned to ICD-10-CM, which resulted in greater sensitivity and specificity of diagnosis coding and posed methodological challenges to identify SMM cases specifically those that related to maternal transfusions after the ICD-10-CM transition. This research brief uses the algorithm from the American College of Obstetricians and Gynecologists' (ACOG) Alliance for Innovation on Maternal Health (AIM) to re-estimate the incidence of SMM during 2010-2019.

Overview

Maternal morbidity that adversely effects women's health includes physical and psychological conditions that result from or are aggravated by pregnancy.[1] According to the Centers for Disease Control and Prevention (CDC), there is no clear indication why severe maternal morbidity (SMM) is increasing.[1] However, the overall health of the population of women giving birth may be a contributing factor and the consequences of the increasing SMM prevalence not only include adverse outcomes for women but also increased medical costs and longer hospitalization stays.[2] The ACOG considers SMM as a "near miss for maternal mortality because without identification and treatment, in some cases,

Importance

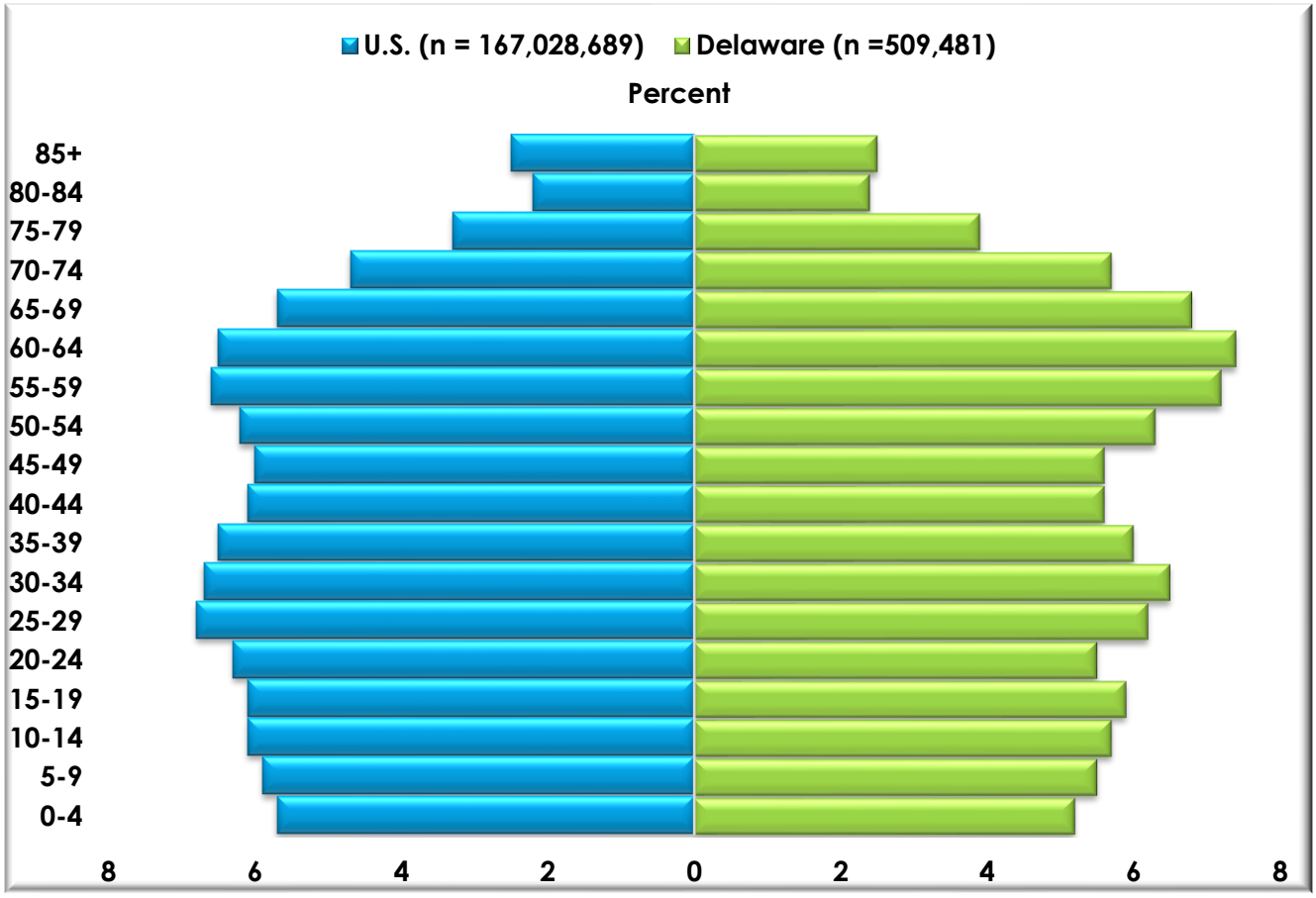
Every year, about 50,000 women in the United States are impacted by severe complications of pregnancy, generally referred to as severe maternal morbidity (SMM). These are typically managed in a hospital setting. Recent trends suggests that the burden of SMM has steadily increased in the U.S. The purpose of this research brief is to reassess SMM trend using AIM in Delaware for 2010-2019.

Key findings

- There were 591 SMM cases without blood transfusions during 2010-2019 and 214 SMM cases after ICD-10-CM transition (i.e., 1st October 2015). The overall rate for 2010-2019 was 55.2 (95%CI: 50.9-59.9) and post-transition the estimated rate was 51.4 (95%CI: 44.8-58.8) per 10,000 delivery hospitalizations.
- The estimated national SMM rate was 17.4 per 1,000 delivery hospitalizations (95%CI: 17.2-17.6) during 1st October 2015 to 31st December 2017. During the same time-period the Delaware SMM rate was 7.1 (95%CI: 6.1-8.3) and as such, the Delaware SMM rate was significantly lower than the national estimate.

these conditions would lead to maternal death."[3] This research brief provides the extent of SMM burden among Delaware resident women (i.e., note the distinction of occurrence – place where an event occurred versus residence – place of residence such as births, deaths, and other vital events). In the U.S., women of reproductive age (i.e., childbearing ages) have been grouped either as 15-44 years of age[4] or 16-49 years as in the National Health and Nutrition Examination (NHANES),[5] and 15-49 years by World Health Organization (WHO).[6] For purposes of this brief, women of childbearing ages are referred to as women in the age ranges 15-44 years of age. Figure 1 provides an overview of the age-distribution of U.S. and Delaware females. As evident from Figure 1 the percentage of women of childbearing ages in Delaware were generally lower as compared to the U.S. percentage of women of childbearing ages. Perhaps the most notable difference was among women 35 to 44 years where there was a one-percentage point difference (i.e., 12.6 % in the U.S. vs. 11.6% in Delaware, 6.5% in the U.S. versus 6.0% in Delaware for 35-39 years and 6.1% in the U.S. and 5.6% in Delaware for 40-44 years).

Figure 1. Age-distribution of U.S. and Delaware females, 2020

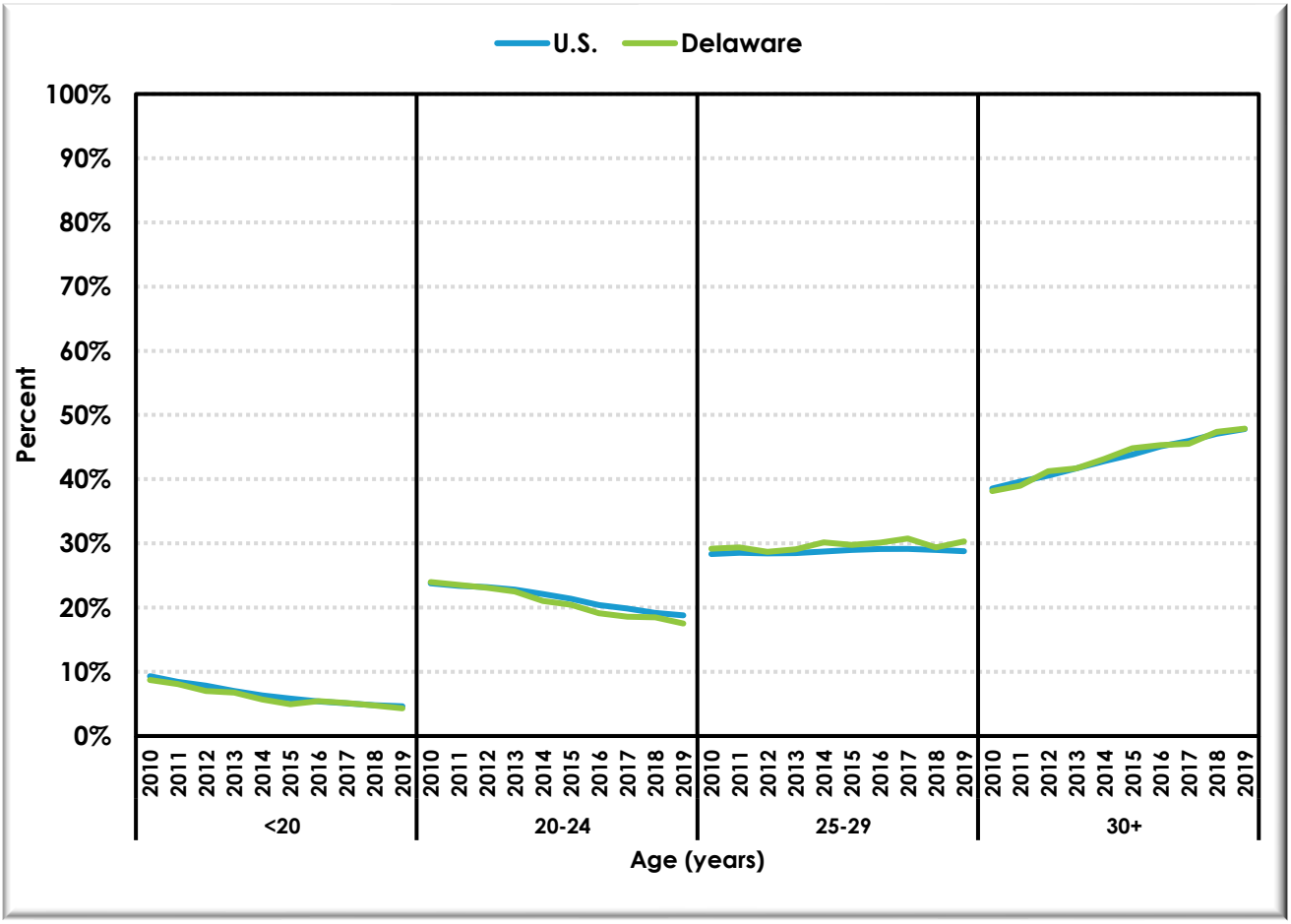


Source: U.S. Census Bureau, 2020. Available at: https://www.census.gov/programs-surveys/popest/technical-documentation/research/evaluation-estimates/2020-evaluation-estimates/2010s-state-detail.html

Figure 2 displays the percentage of women who gave birth in the U.S. and in Delaware during 2010 to 2019 based on the latest vital statistics data available. During 2010-2019, the percentage

of births among women less than 25 years of age generally declined in both the U.S. and Delaware, while the percentage of births among women 30 and older increased. Although the Delaware percentage of births among women 25-29 years of age was slightly higher than the U.S., the Delaware trend remained relatively flat during 2010-2019.

Figure 2. Percentage of births in the U.S. and Delaware, by maternal age, 2010-2019



Source: Delaware Department of Health and Social Services, Division of Public Health, Delaware Health Statistics Center, 2010-2019

Severe maternal morbidity and case ascertainment

SMM has been previously ascertained using the CDC-definition of SMM from hospital discharge procedure and diagnosis codes (i.e., ICD-9-CM) that indicate a potentially life-threatening condition or maternal complication.[1] A systematic review by England et al.[7] for monitoring near miss (MNM) – a term coined by the WHO working group on maternal mortality and morbidity, and SMM mostly used in the U.S. and Canada – highlight significant variations and inconsistencies in surveillance and monitoring practices. In particular, England et al.[7] note that eclampsia was the only indicator that was assessed in more than 80% of the 178 papers that were reviewed. Apart from eclampsia, transfusion, cerebrovascular disorders, hysterectomy, sepsis or septicemia, ventilation, cardiac arrest, uterine rupture, intensive care unit (ICU or equivalent) admission, shock (general or

unspecified), coma, prolonged unconsciousness, or loss of consciousness, and pre-eclampsia were included. In the U.S., Snowden et al.[8] compared commonly used SMM definitions and concluded that there was "low agreement between administrative data-based definitions of SMM" and in particular, the "low concordance was particularly driven by presence/absence of transfusion and claims data versus birth certificate definitions."

In Delaware, SMM was previously identified using Callaghan et al.'s algorithm[2] (see Table 1) and CDC guidelines using ICD-9-CM diagnosis and procedure codes. Based on this method, Delaware's overall SMM rates for 2010-2014 was 137.1 per 10,000 delivery hospitalizations (95%CI: 126.9-147.3). SMM rates increased by 37% from 114.1 per 10,000 delivery hospitalizations in 2010 (95%CI: 93.5-134.7) to 156.8 per 10,000 delivery hospitalizations in 2014 (95%CI: 132.2-181.4). During the same timeframe, ACOG consensus based on ICD-9-CM suggested that administrative measures had high specificity and low positive predictive value, and blood transfusion was a major driver for SMM.[3] For instance, in Delaware, 77.6% of the SMM cases were attributable to blood transfusion during 2010-2014. However, ICD-9-CM codes do not identify the number of blood products transfused and some amount of blood loss is physiologically normal.[8] The U.S. transitioned from ICD-9-CM coding to ICD-10-CM coding in October of 2015.[9] Prior to the transition, most hospitals used ICD-9-CM procedure codes to document blood transfusions. However, following transition, ICD-10 transfusion procedure codes were no longer required for reimbursement.

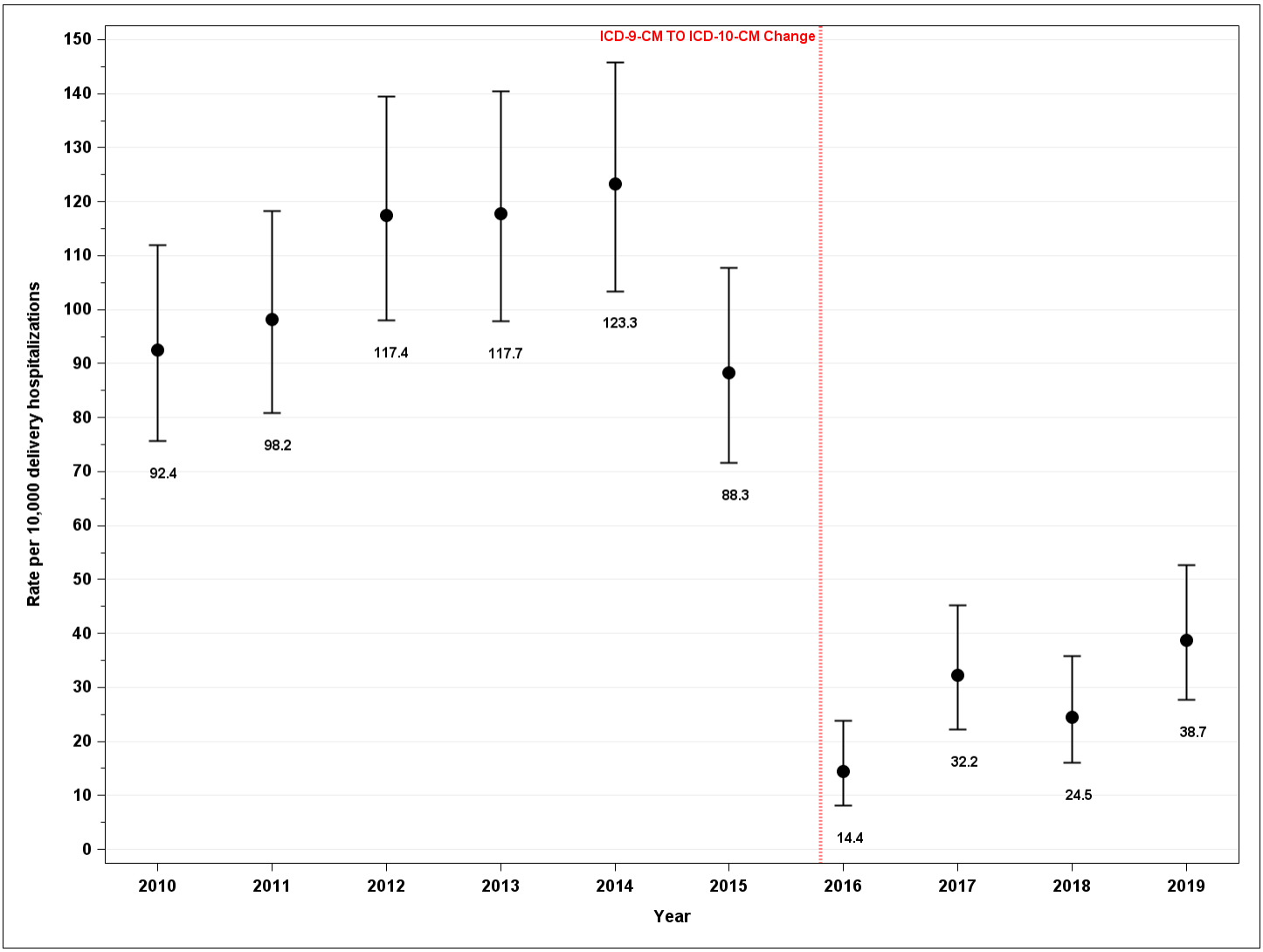
Table 1. Severe Maternal Morbidity Indicators

Diagnoses	**Procedures**
1. Acute myocardial infarction	18. Thrombotic embolism
2. Acute renal failure	19. Blood transfusion
3. Adult respiratory distress syndrome	20. Cardio monitoring*
4. Amniotic fluid embolism	21. Conversion of cardiac rhythm
5. Aneurysm	22. Hysterectomy
6. Cardiac arrest/ventricular fibrillation	23. Operations on heart and pericardium*
7. Disseminated intravascular coagulation	24. Temporary tracheostomy
8. Eclampsia	25. Mechanical ventilation
9. Heart failure during procedure or surgery	
10. Internal injuries of thorax, abdomen, and pelvis*	
11. Intracranial injuries*	
12. Puerperal cerebrovascular disorders	
13. Pulmonary edema	
14. Severe anesthesia complications	
15. Sepsis	
16. Shock	
17. Sickle cell anemia with crisis	

Source: Callaghan WM, Creanga AA, Kuklina EV. Severe maternal morbidity among delivery and postpartum hospitalizations in the United States. *Obstet Gynecol*. 2012;120(5):1029-1036. doi:10.1097/aog.0b013e31826d60c5.
*SMM indicators dropped by CDC and Alliance for Innovation for Maternal Health (AIM) in subsequent revisions

The increased specificity of ICD-10-coding, the increased number of transfusion codes specific to ICD-10, and specificity of documentation (i.e., vein or artery, approach to administer transfusion percutaneous vs. open, type of blood product e.g., red blood cells, platelets, etc.) decreased coding of blood transfusions.[10] To highlight the impact of ICD-9-CM to ICD-10-CM changes, Figure 3 displays blood transfusion rates (i.e., one of the SMM indicators) during 2010 to 2019. It is evident that there was a statistically significant drop in coding of blood transfusions after 2015.

Figure 3. Blood transfusion rates using procedure codes among women age 15-44 years, per 10,000 delivery hospitalizations in Delaware, 2010-2019



Source: Delaware Health and Social Services, Division of Public Health, Delaware Health Statistics Center, Hospital Discharge Data, 2010-2019. Fourth quarter data (i.e., 1st October) in 2015 includes ICD-9-CM and ICD-10-CM codes generalized equivalence mappings.

To assess SMM in Delaware, we used the Alliance of Innovation for Maternal Health (AIM) algorithm,[11] which is based on an updated list of 21 indicators from CDC (see Table 1 that excludes internal injuries of thorax, abdomen, and pelvis, intracranial injuries, cardio monitoring, and operations on heart and pericardium) and incorporates ICD-9-CM to ICD-10-CM changes. There

were 1,322 cases of SMM during 2010-2019 with 106,984 delivery hospitalizations. Table 2 provides the total counts and the incidence rates with 95% confidence intervals (CI) for each of the 21 SMM indicators and the overall SMM rate during 2010-2019.

Table 2. Severe maternal morbidity indicators among women age 15-44 years, per 10,000 delivery hospitalizations in Delaware, 2010-2019

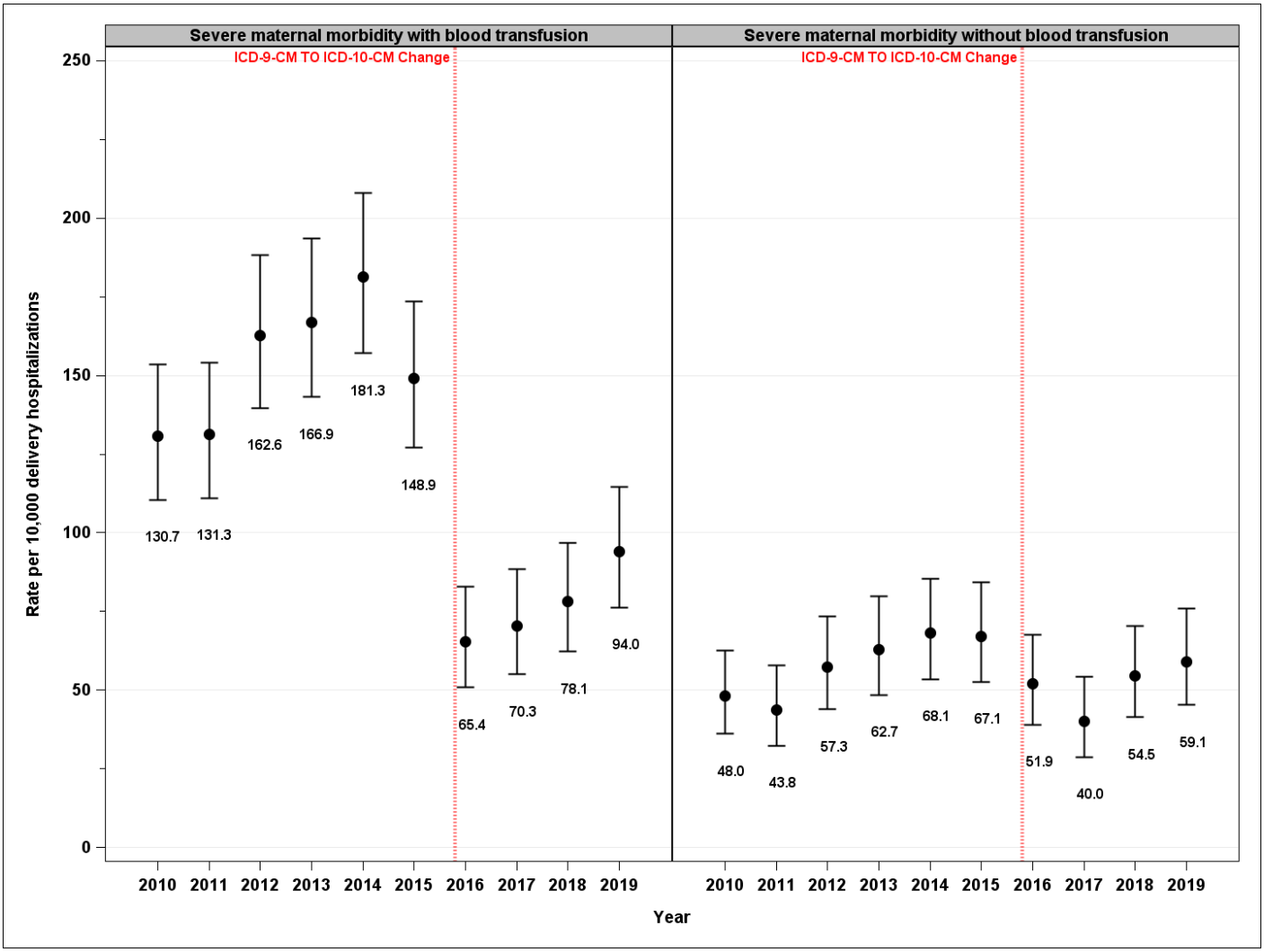
Severe Maternal Morbidity (SMM) Indicators	Count	Rate per 10,000 delivery hospitalizations (95% CI)
Total delivery hospitalizations*	**106,984**	**N/A**
1. Acute myocardial infarction	2 (0.1%)	0.2 (0.0-0.7)
2. Acute renal failure	2 (0.1%)	0.2 (0.0-0.7)
3. Adult respiratory distress syndrome	97 (6.2%)	9.1 (7.4-11.1)
4. Amniotic fluid embolism	75 (4.8%)	7.0 (5.5-8.8)
5. Aneurysm	3 (0.2%)	0.3 (0.1-0.8)
6. Cardiac arrest/ventricular fibrillation	6 (0.4%)	0.6 (0.2-1.2)
7. Conversion of cardiac rhythm	6 (0.4%)	0.6 (0.2-1.2)
8. Disseminated intravascular coagulation	154 (9.8%)	14.4 (12.2-16.9)
9. Eclampsia	101 (6.5%)	9.4 (7.7-11.5)
10. Heart failure during procedure or surgery	7 (0.4%)	0.7 (0.3-1.3)
11. Puerperal cerebrovascular disorders	18 (1.2%)	1.7 (1.0-2.7)
12. Pulmonary edema	37 (2.4%)	3.5 (2.4-4.8)
13. Severe anesthesia complications	12 (0.8%)	1.1 (0.6-2.0)
14. Sepsis	47 (3.0%)	4.4 (3.2-5.8)
15. Shock	55 (3.5%)	5.1 (3.9-6.7)
16. Sickle cell anemia with crisis	17 (1.1%)	1.6 (0.9-2.5)
17. Air and thrombotic embolism	15 (1.0%)	1.4 (0.8-2.3)
18. Blood transfusion	807 (51.6%)	75.4 (70.3-80.8)
19. Hysterectomy	71 (4.5%)	6.6 (5.2-8.4)
20. Temporary tracheostomy	3 (0.2%)	0.3 (0.1-0.8)
21. Mechanical ventilation	22 (1.4%)	2.1 (1.3-3.1)
Any SMM†	**1,322 (N/A)**	**123.6 (117.0-130.4)**

Source: Delaware Health and Social Services, Division of Public Health, Delaware Health Statistics Center, Hospital Discharge Data, 2010-2019. Fourth quarter data (i.e., 1st October) in 2015 includes ICD-9-CM and ICD-10-CM codes generalized equivalence mappings.
*Codes that are not mutually exclusive.
†Any SMM includes one or more of the 21 indicators above that appear in any of the diagnoses and procedure codes and are not mutually exclusive.

Figure 4 provides an overview of annual SMM rates with and without blood transfusion for 2010 to 2019 time-period. It is evident from Figure 4 that the drop in SMM rates were an artifact of the ICD-9-CM and ICD-10-CM changes especially when we include blood transfusions. There was a statistically significant drop in SMM rates with blood transfusion included. Using 2015 as the new baseline for SMM (see Figure 3), we find that SMM rates with blood transfusion increased 44% from 65.4 per 10,000 hospitalizations (95%CI: 50.8-82.8) in 2015 to 94.0 per 10,000 hospitalizations (95%CI:

76.3-114.5) in 2019. With the exception of 2017, SMM rates without blood transfusions also increased 14% from 51.9 per 10,000 hospitalizations (95%CI: 39.0-67.7) in 2015 to 59.1 per 10,000 hospitalizations (95%CI: 45.2-75.8) in 2019. Using National Inpatient Sample (NIS) dataset Metcalfe et al.[12] estimated SMM rates and found that SMM rates decreased significantly after transition from ICD-9-CM to ICD-10-CM. Metcalfe et al.[12] concluded that SMM rates using ICD-9-CM and ICD-10-CM may not be comparable. The estimated national SMM rate was 17.4 per 1,000 delivery hospitalizations (95%CI: 17.2-17.6) or 174.0 per 10,000 delivery hospitalizations post transition (i.e., 1st October 2015 to 31st December 2017).[12] For the same time-period (i.e., 1st October 2015 to 31st December 2017) the Delaware SMM rate was 7.1 (95%CI: 6.1-8.3) per 1,000 delivery hospitalizations or 71.0 (95%CI: 60.6-82.6) per 10,000 delivery hospitalizations and as such, the Delaware SMM rate was significantly lower than the national estimate. These large differences in SMM rates at the national and state level suggest the variability in coding for SMM.

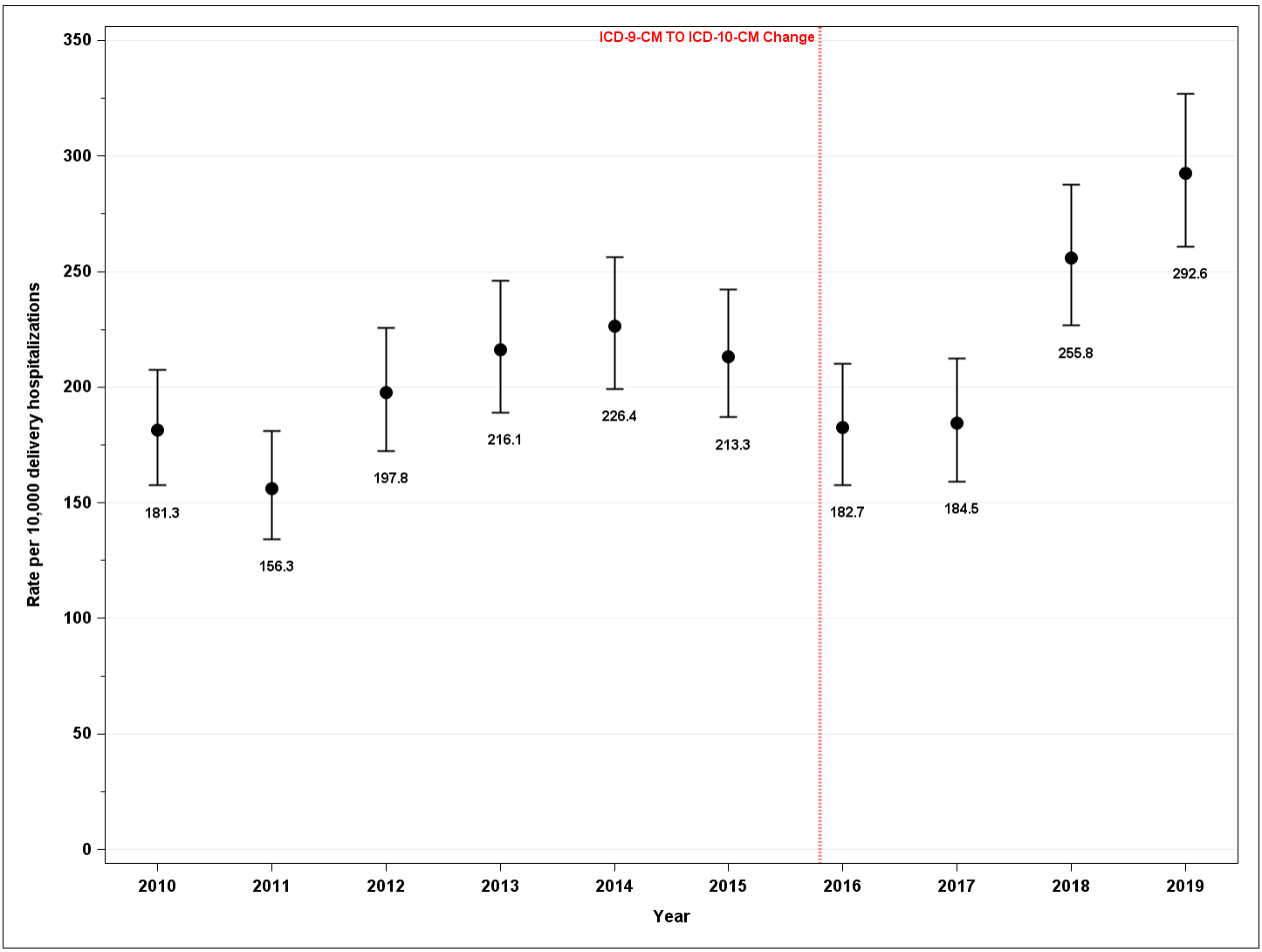
Figure 4. Severe maternal morbidity rates with and without blood transfusion among women age 15-44 years, per 10,000 delivery hospitalizations in Delaware, 2010-2019



Source: Delaware Health and Social Services, Division of Public Health, Delaware Health Statistics Center, Hospital Discharge Data, 2010-2019. Fourth quarter data (i.e., 1st October) in 2015 includes ICD-9-CM and ICD-10-CM codes generalized equivalence mappings.

Hospitals also use revenue codes (i.e., four-digit codes such as '0390' '0391' '030X') for blood transfusion and blood products as part of inpatient claim process.[13] SMM was also estimated using revenue codes '0391' for blood transfusion. Although, the sensitivity for presence of blood transfusion procedure code and presence of revenue code for transfusion was low at 35.3% (95%CI: 33.1%-37.5%), the positive predictive value (PPV) was moderately high at 80.6% (95%CI: 77.9%-83.4%). Figure 5 displays the SMM rates with blood transfusion revenue codes as a proxy for blood transfusion. The estimated rates with blood transfusion revenue codes as a proxy for blood transfusion suggest that the SMM incidence was much higher as compared to the estimated rate using blood transfusion procedure codes. For instance, the SMM rate with blood transfusion revenue codes for 2019 was 292.6 (95%CI: 260.9-32.6) per 10,000 hospitalizations as compared to the SMM rate with blood transfusion procedure codes for 2019 at 59.1 (95%CI: 45.2-75.8).

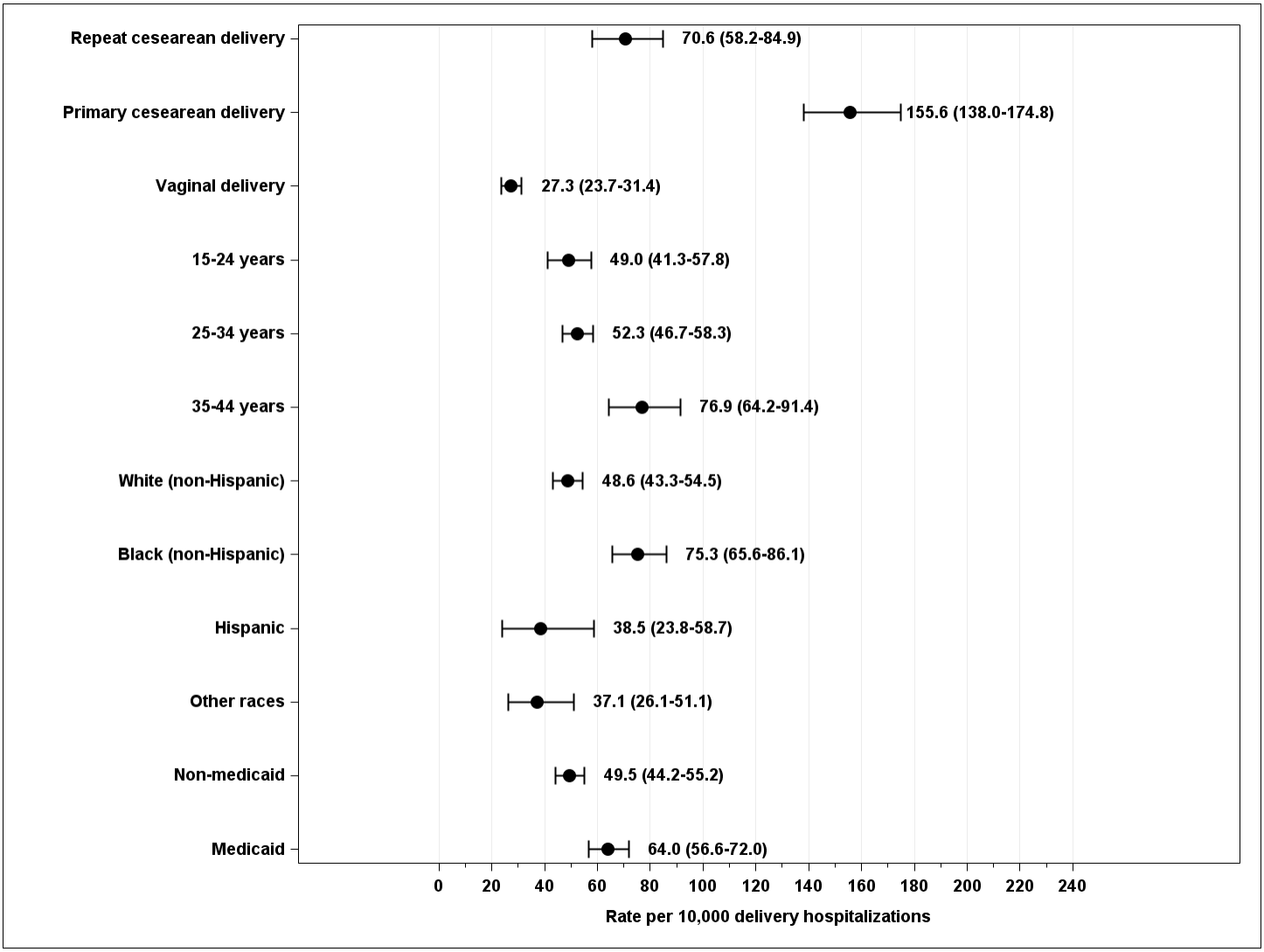
Figure 5. Severe maternal morbidity rates with blood transfusion revenue codes among women age 15-44 years, per 10,000 delivery hospitalizations in Delaware, 2010-2019



Source: Delaware Health and Social Services, Division of Public Health, Delaware Health Statistics Center, Hospital Discharge Data, 2010-2019. Fourth quarter data (i.e., 1st October) in 2015 includes ICD-9-CM and ICD-10-CM codes generalized equivalence mappings.

Due to lack of consensus and variability in coding at national and local levels estimating the true incidence of SMM following transition to ICD-10-CM poses several methodological challenges when using administrative data such as HDD. Figure 6 displays overall SMM rates without blood transfusions stratified by mode of delivery (i.e., vaginal or cesarean), age, race and ethnicity, and Medicaid status (i.e., proxy for socioeconomic status).

Figure 6. Severe maternal morbidity rates without blood transfusion stratified by mode of delivery, age, race and ethnicity, and Medicaid status in Delaware women age 15-44 years, per 10,000 delivery hospitalizations in Delaware, 2010-2019



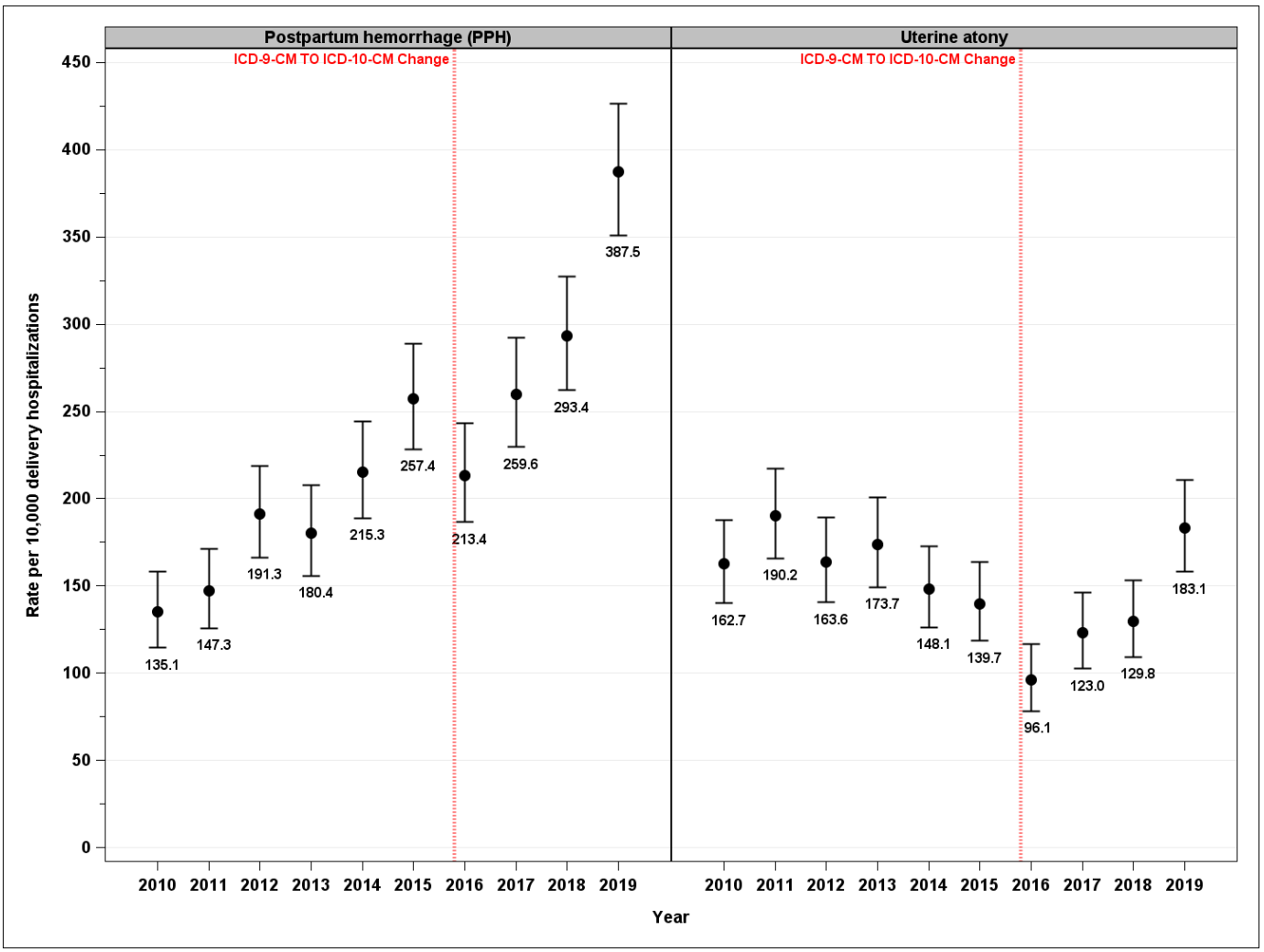
Source: Delaware Health and Social Services, Division of Public Health, Delaware Health Statistics Center, Hospital Discharge Data, 2010-2019. Fourth quarter data (i.e., 1st October) in 2015 includes ICD-9-CM and ICD-10-CM codes generalized equivalence mappings.

SMM rates varied significantly by mode of delivery. For instance, the SMM rate without blood transfusion was significantly higher among women with primary cesarean delivery as compared to repeat cesarean delivery and vaginal delivery. Similarly, the SMM rate without blood transfusion was significantly higher among women 35-44 years of age as compared to 15-24 and 25-34 years of

age. Black (non-Hispanic) women had significantly higher SMM rate without blood transfusion as compared to White (non-Hispanic), Hispanic, and other races. Finally, Medicaid women (i.e., proxy for socioeconomic status) had significantly higher SMM rate without blood transfusion as compared to non-Medicaid women.

Postpartum hemorrhage (PPH), which is one of the leading causes of maternal morbidity and maternal death, was assessed using ICD-9-CM (666.xx) and ICD-10-CM (O72.x) codes that have been previously validated.[14-16] Uterine atony (UTA) is one among the principal causes of PPH[17-18] and ICD-9-CM (661.xx) and ICD-10-CM (O622) codes were used to estimate UTA rates, although, there are no validation studies specific to UTA codes. Figure 7 displays the PPH rates per 10,000 delivery hospitalizations during 2010-2019 in Delaware.

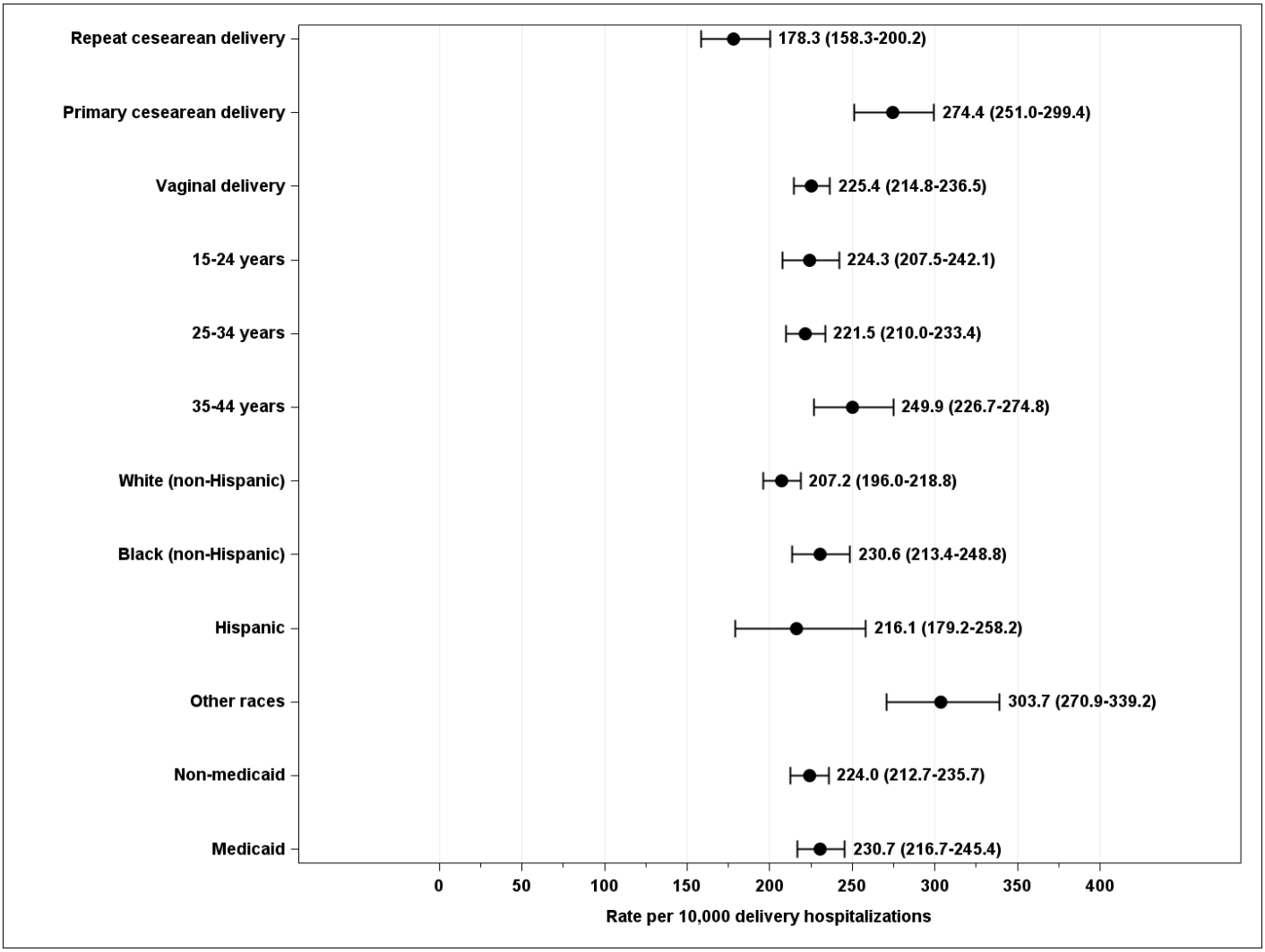
Figure 7. Postpartum hemorrhage and uterine atony rates in women age 15-44 years, per 10,000 delivery hospitalizations in Delaware, 2010-2019



Source: Delaware Health and Social Services, Division of Public Health, Delaware Health Statistics Center, Hospital Discharge Data, 2010-2019. Fourth quarter data (i.e., 1st October) in 2015 includes ICD-9-CM and ICD-10-CM codes generalized equivalence mappings.

Irrespective of the ICD transition, during 2010-2019, PPH and UTA rates increased. For instance, in 2010, the PPH rate increased by 90% from 135.1 (95%CI: 114.6-158.2) to 257.4 (95%CI: 228.5-288.9) per 10,000 hospitalizations in 2015. Similarly, in 2016 the PPH rate increased by 81% from 213.4 (95%CI: 186.5-243.1) to 387.5 (95%CI: 351.1-426.5) per 10,000 hospitalizations in 2019. Unlike PPH, UTA rates increased following ICD transition. For instance, in 2016, the UTA rate increased by 90% from 96.1 (95%CI: 78.3-116.8) to183.1 (95%CI: 158.1-210.8) per 10,000 delivery hospitalizations in 2019. Figure 8 displays overall PPH rates stratified by mode of delivery, age, race and ethnicity, and Medicaid status. It is evident from Figure 8 that the incidence of PPH was higher with primary cesarean deliveries and vaginal deliveries as compared to repeat cesareans. PPH incidence was highest among women 35 and older, other races, and Black (non-Hispanic) women.

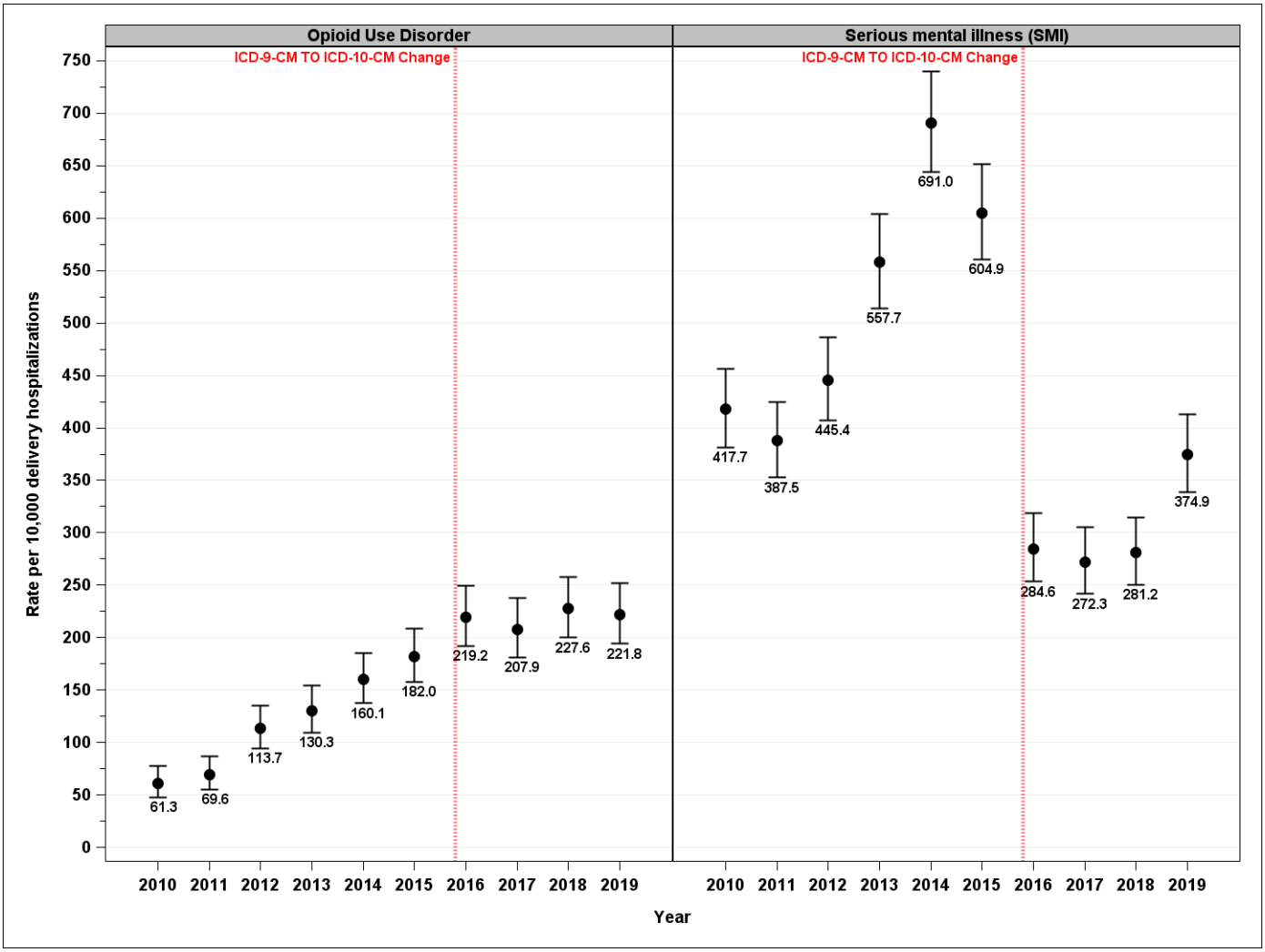
Figure 8. Postpartum hemorrhage rates stratified by mode of delivery, age, race and ethnicity, and Medicaid status in women age 15-44 years, per 10,000 delivery hospitalizations in Delaware, 2010-2019



Source: Delaware Health and Social Services, Division of Public Health, Delaware Health Statistics Center, Hospital Discharge Data, 2010-2019. Fourth quarter data (i.e., 1st October) in 2015 includes ICD-9-CM and ICD-10-CM codes generalized equivalence mappings.

Mental health and drug use have been recognized as contributors to pregnancy-associated mortality and some evidence suggest that pregnancy complicated by mental health conditions or substance use "may create a cascade of events leading to maternal death, suggesting that these deaths could be classified as pregnancy-related."[19] The Delaware Maternal Mortality Review (MMR) committee identified substance use disorder (39%) and mental health (29%) as the leading contributing factors in pregnancy associated mortality.[20] Hence, the incidence of opioid use disorder (OUD)[21] and serious mental illness (SMI) "a diagnosable mental, behavior, or emotional disorder … substantially [that] interferes with or limits one or more major life activities" (e.g. schizophrenia, mood, bipolar, personality, and substance use disorders)[22-23] were examined using ICD-9-CM and ICD-10-CM codes using the Diagnostic and Statistical Manual – Fifth Edition (DSM-V) criteria among all delivery hospitalizations in Delaware during 2010-2019. Figure 9 displays the incidence of OUD and SMI during 2010-2019.

Figure 9. Opioid use disorder and serious mental illness rates in Delaware women age 15-44 years, 2010-2019



Source: Delaware Health and Social Services, Division of Public Health, Delaware Health Statistics Center, Hospital Discharge Data, 2010-2019. Fourth quarter data (i.e., 1st October) in 2015 includes ICD-9-CM and ICD-10-CM codes generalized equivalence mappings.

The incidence of OUD among Delaware delivery hospitalizations increased by 262% or 3.6 times from 61.3 (95%CI: 47.7-77.6) in 2010 to 221.8 (95%CI: 194.3-252.1) per 10,000 delivery hospitalizations in 2019. Similarly, irrespective of ICD transition we find that the incidence of SMI increased by 45% from 417.7 (95%CI: 381.5-456.4) in 2010 to 604.9 (95%CI: 560.8-651.3) in 2015 before ICD-10-CM transition. Further, after ICD-10-CM transition, although the incidence of SMI dropped, the SMI trend continued to increase by 32% from 284.6 (95%CI: 253.5-318.3) in 2016 to 374.9 (95%CI: 339.1-413.3) in 2019.

Table 3 provides estimates of OUD and SMI stratified by age, race and ethnicity, and Medicaid status. It is evident from Table 3 that OUD incidence was highest among women 25-34 years of age (176.0; 95%CI: 165.8-186.7), among White (non-Hispanic) women (233.6; 95%CI: 221.7-246.0), and among Medicaid women (304.3; 95%CI: 288.2-321.1) per 10,000 delivery hospitalizations. However, with regards to SMI there were large differences only in the race and ethnicity category. For instance, as compared to other race and ethnic groups, White (non-Hispanic) women had highest incidence of SMI (539.6; 95%CI: 521.7-557.9) per 10,000 delivery hospitalizations.

Table 3. Opioid use disorder and serious mental illness rates stratified by age, race and ethnicity, and Medicaid status in Delaware women age 15-44 years, 2010-2019

Demographic characteristics	Opioid use disorder (OUD)*		Serious mental illness (SMI)†	
	N	Rate§ (95% CI)	N	Rate§ (95% CI)
Age (in years)				
15-24	414	144.0 (130.5-158.4)	1,220	424.2 (401.2-448.2)
25-34	1,084	176.0 (165.8-186.7)	2,683	435.7 (419.7-452.1)
35-44	191	114.7 (99.1-132.1)	731	439.2 (408.5-471.4)
Race and ethnicity				
White (non-Hispanic)	1,412	233.6 (221.7-246.0)	3,261	539.6 (521.7-557.9)
Black (non-Hispanic)	234	82.8 (72.5-94.0)	1,009	356.9 (335.5-379.1)
Hispanic	13	23.8 (12.7-40.7)	117	214.2 (177.5-256.2)
Other races	19	19.0 (11.5-29.7)	208	208.5 (181.3-238.4)
Medicaid status				
Non-Medicaid	395	61.3 (55.4-67.6)	2,818	437.1 (421.5-453.2)
Medicaid	1,294	304.3 (288.2-321.1)	1,816	427.1 (408.1-446.7)

Source: Delaware Health and Social Services, Division of Public Health, Delaware Health Statistics Center, Hospital Discharge Data, 2010-2019. Fourth quarter data (i.e., 1St October) in 2015 includes ICD-9-CM and ICD-10-CM codes generalized equivalence mappings.
*Any listed diagnoses containing ICD-9-CM 304.xx and ICD-10-CM F11.xx codes for OUD as per DSM-V criteria.
†Any listed diagnoses containing ICD-9-CM 295.xx, 296.xx, 300.xx, 301.xx, and ICD-10-CM F06.xx, F20.xx, F21, F22, F23, F25.xx, F28, F29, F31.xx, F32.xx, F33.xx, F42, F43.xx, F50.xx codes as per DSM-V criteria.
§Rate per 10,000 delivery hospitalizations

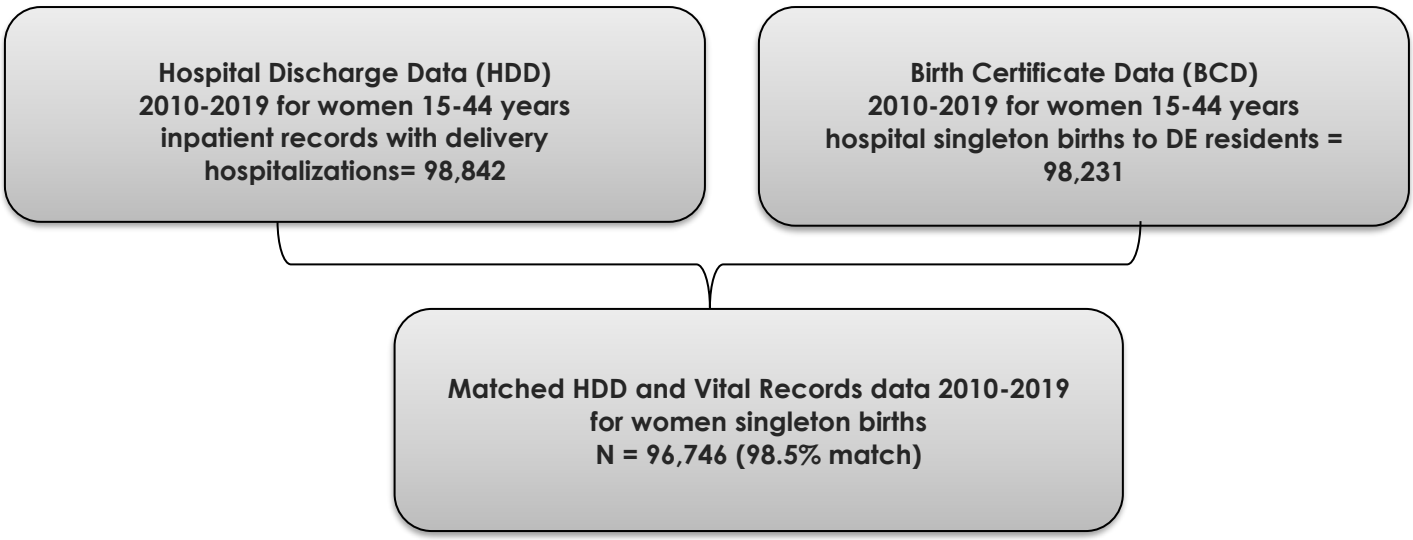
Severe maternal morbidity using linked data

Using linked data from the state of Washington, Lisonkova et al.[24] indicated that maternal age-specific incidence of SMM varied and older women (> 40 years) had elevated rates of life-threatening morbidities. Another study that utilized linked data from New York in a stratified analysis of deliveries found that women who deliver vaginally were less likely to experience severe maternal

morbidity, compared to women with cesarean deliveries; and that non-Hispanic white women had lower odds of SMM.[25] Frederiksen et al.[26] utilized probabilistic linkage data from the state of Iowa and found that payer (i.e., Medicaid vs. non-Medicaid) was differentially associated with SMM across age groups. In a more recent study, Snowden et al.[8] used linked birth certificate data and inpatient maternal hospitalizations for birth cohort files for 2007-2012 from California to assess reliability between seven administrative data-based SMM definitions using ICD-9-CM code. They found low agreement between SMM composite based on birth certificate data and inpatient maternal hospitalizations definition.[8] However, their study did not extend to the post ICD-10-CM transition.

Linked hospital discharge data (HDD), and birth certificate data (BCD) for 2010-2019 were utilized for all singleton deliveries because hospital discharge data are limited with regards to characteristics surrounding care, labor and delivery, perinatal outcomes (Figure 10). The purpose of using the link dataset was multifold: 1) assess agreement, sensitivity, specificity, positive predictive value, and negative predictive value between HDD and BCD SMM indicators before and after ICD-10-CM transition; 2) identify risk factors for SMM; and 3) assess how SMM, OUD, and SMI may impact neonatal outcomes.

Figure 10. Linked Hospital Discharge Data and Vital Records data for Severe Maternal Morbidity sample selection, Delaware, 2010-2019.



Of the 96,746 singleton births among Delaware women 15-44 years of age with matched HDD data, 1,063 (1.1%) were any SMM cases with blood transfusion procedure codes, 369 (0.4%) were any SMM cases without blood transfusion, and 1,968 (2.0%) were any SMM cases with blood transfusion revenue codes. Of the 96,746 singleton births, 53,826 (53.6%) were before ICD-10-CM transition (i.e., before October 1, 2015) and 42,920 (44.4%) included after ICD-10-CM transition (i.e., October 1, 2015 and beyond). As shown previously (see Figures 3 to 5) SMM cases varied before and after ICD transition. For instance, there were 1.5% (794/53,826) cases before transition and 0.6% (269/42,920) any SMM cases with blood transfusion procedure codes after transition. Similarly, there were 0.4%

(230/53,826) before transition and 0.3% (139/42,920) cases of any SMM without blood transfusion after transition. Finally, there were 1.9% (1,032/53,896) before transition and 2.2% (936/42,920) SMM cases with blood transfusion revenue codes after transition.

Tables 4 to 8 display the counts of: a) blood transfusion codes with procedure codes; b) blood transfusion codes with revenue codes; c) eclampsia; d) hysterectomy; e) and cesarean deliveries in HDD and BCD. Assuming HDD as the "gold standard," Cohen's kappa (κ) for agreement (<0–0.20 = poor; 0.20–0.40 = fair; 0.40–0.60 = moderate; 0.61–0.80 = good; and 0.81–1.00 = very good), sensitivity, specificity, positive and negative predictive values were estimated with respective 95% confidence intervals.[27-28]

Table 4. Counts for blood transfusion severe maternal morbidity indicator procedure codes by hospital discharge and birth certificate data, Delaware, 2010-2019

HDD (Blood transfusion procedure codes)	BCD (Blood transfusion)*		
	Yes	No	Total
Yes	215	470	687
No	650	95,409	96,059
Total	865	95,881	96,746

Source: Delaware Health and Social Services, Division of Public Health, Delaware Health Statistics Center, Hospital Discharge Data and Birth Certificate Data, 2010-2019. Fourth quarter data (i.e., 1st October) in 2015 includes ICD-9-CM and ICD-10-CM codes generalized equivalence mappings.
*Check mark on 2003 birth certificate data for maternal morbidity item 47 "maternal transfusion."

From Table 4, it is evident that the κ value for blood transfusion with procedure codes was poor at 0.27 (95%CI: 0.24-0.30) with low sensitivity (i.e., 215/865) at 24.9% (95%CI: 21.2%-27.7%), low positive predictive value (215/687) at 31.3% (95%CI: 27.9%-34.8%) and high specificity (i.e., 95,409/95,881) and high negative predictive (95,409/96,059) value ≥ 99%.

Table 5. Counts for blood transfusion severe maternal morbidity indicator revenue codes by hospital discharge and birth certificate data, Delaware, 2010-2019

HDD (Blood transfusion revenue codes)	BCD (Blood transfusion)*		
	Yes	No	Total
Yes	553	1,123	1,676
No	312	94,758	95,070
Total	865	95,881	96,746

Source: Delaware Health and Social Services, Division of Public Health, Delaware Health Statistics Center, Hospital Discharge Data and Birth Certificate Data, 2010-2019. Fourth quarter data (i.e., 1st October) in 2015 includes ICD-9-CM and ICD-10-CM codes generalized equivalence mappings.
*Check mark on 2003 birth certificate data for maternal morbidity item 47 "maternal transfusion."

From Table 5, the κ value for blood transfusion revenue codes was fair at 0.43 (95%CI: 0.40-0.45), with moderate sensitivity (553/865) 63.9% (95%CI: 60.7%-67.1%), low positive predictive value (553/1,676) at 33.0% (95%CI: 30.8%-35.3%) and high specificity (94,758/95,881) and high negative predictive value (94,758/95,070) ≥ 99%.

Table 6. Counts for eclampsia severe maternal morbidity indicator codes by hospital discharge and birth certificate data, Delaware, 2010-2019

HDD (Eclampsia)	BCD (Eclampsia)		
	Yes	No	Total
Yes	14	69	83
No	122	93,541	96,663
Total	136	96,610	96,746

Source: Delaware Health and Social Services, Division of Public Health, Delaware Health Statistics Center, Hospital Discharge Data and Birth Certificate Data, 2010-2019. Fourth quarter data (i.e., 1st October) in 2015 includes ICD-9-CM and ICD-10-CM codes generalized equivalence mappings.
*Check mark on 2003 birth certificate data for risk factors in this pregnancy item 41 "eclampsia."

With regards to eclampsia (see Table 6) the κ value was poor at 0.13 (95%CI: 0.06-0.19) with low sensitivity (14/136) at 10.3% (95%CI: 5.2%-15.4%), low positive predictive value (14/83) at 16.9% (95%CI: 9.5%-26.7%) and high specificity (93,541/96,610) and high negative predictive value (93,541/96,663) ≥ 99%.

Table 7. Counts for hysterectomy severe maternal morbidity indicator codes by hospital discharge and birth certificate data, Delaware, 2010-2019

HDD (Hysterectomy)	BCD (Hysterectomy)*		
	Yes	No	Total
Yes	28	39	67
No	21	96,658	96,679
Total	49	96,610	96,746

Source: Delaware Health and Social Services, Division of Public Health, Delaware Health Statistics Center, Hospital Discharge Data and Birth Certificate Data, 2010-2019. Fourth quarter data (i.e., 1st October) in 2015 includes ICD-9-CM and ICD-10-CM codes generalized equivalence mappings.
*Check mark on 2003 birth certificate data for maternal morbidity item 47 "unplanned hysterectomy."

From Table 7, it is evident the κ value for unplanned hysterectomy was moderate at 0.48 (95%CI: 0.37-0.59) with moderate sensitivity (28/49) 57.1% (95%CI: 43.3%-71.0%) moderate positive predictive value (28/67) at 41.8% (95%CI: 29.9%-53.6%) and high specificity (96,658/96,610) and high negative predictive value (96,658/96,679) ≥ 99%. In general, specific SMM indicators such as blood transfusions, eclampsia, and hysterectomy had poor to fair agreement in HDD and BCD similar to Snowden et al.[8] These findings were consistent after stratifying the data before and after ICD transition.

The only indicator with high sensitivity and positive predictive value was for cesareans (see Table 8). For instance, the κ value or agreement for cesarean delivery was very good at 0.92 (95%CI: 0.92-0.93) with very high sensitivity (28,469/29,945) was 95.1% (95%CI: 94.8%-95.3%) and very high positive predictive value (28,469/30,137) 94.5% (95%CI: 94.2%-94.7%) and high specificity (65,116/66,784) and high negative predictive value (65,116/66,592) ≥ 97%. This finding is consistent with other national studies.[29]

Table 8. Counts for cesarean delivery codes by hospital discharge and birth certificate data, Delaware, 2010-2019

HDD (Cesarean)*	BCD (Cesarean)†		
	Yes	No	Total§
Yes	28,469	1,668	30,137
No	1,476	65,116	66,592
Total	29,945	66,784	96,729

Source: Delaware Health and Social Services, Division of Public Health, Delaware Health Statistics Center, Hospital Discharge Data and Birth Certificate Data, 2010-2019. Fourth quarter data (i.e., 1st October) in 2015 includes ICD-9-CM and ICD-10-CM codes generalized equivalence mappings.

*Includes primary and repeat cesarean deliveries

†Includes primary and repeat cesarean deliveries. Check mark on 2003 birth certificate data for final route and method of delivery "cesarean."

§Total does not equal 96,746 as 17 cases in BCD were missing.

As 'true' incidence of SMM is 'unknown' and underestimated as noted previously, the linked dataset was used to estimate risk factors associated with any SMM without blood transfusion procedure codes.

Table 9 provides an overview of the characteristics of women with and without SMM (i.e., excluding blood transfusions) for 2010-2019. During 2010-2019, there were 369 (0.4%) cases of SMM without blood transfusion and 96,377 (99.6%) non SMM cases among hospital-based singleton births in Delaware. The percentage of SMM cases was higher pre ICD-10-CM transition (0.4%) as compared to post ICD-10-CM transition (0.3%) and the difference was statistically significant. Delaware has six birthing hospitals (with one affiliate of the same organization i.e., five facilities), and one hospital accounts for over 60% of all births. One of the hospitals (D) in Delaware had the highest (1.1%) SMM cases during this time-period compared to other hospitals in the state. The percentage of SMM cases was lowest in vaginal deliveries (0.2%) compared to cesarean deliveries (0.8%) and the difference was statistically significant. Women with prepregnancy (0.6%) and gestational hypertension (1.0%) had higher incidence of SMM compared to women without prepregnancy (0.4%) and gestational (0.3%) hypertension and the difference was statistically significant. In contrast, although there were small number of cases among women with prepregnancy diabetes (11; 1.2%) the incidence was higher than those without prepregnancy diabetes (0.4%). The percentage of SMM cases was also higher among women with a previous preterm birth (0.9%) compared to those without (0.4%) and the difference was statistically significant. Although there were only 11 cases of SMM among women with OUD, the percentage of SMM cases was higher among women with OUD (0.7%) compared to women without OUD (0.4%). Similarly, the percentage of SMM cases was higher among women who smoked during pregnancy (0.5%) compared to women who did not smoke (0.4%) and the difference was statistically significant.

With regards to demographic characteristics, women with higher educational levels had lower percentage of SMM. Black (non-Hispanic) women and Hispanic women had the highest percentage of SMM cases. Women with highest SMM cases indicated Medicaid as their payer, indicated they live in Sussex County, and had the highest percentage of SMM without blood transfusions.

Table 9. Characteristics of women with and without severe maternal morbidity excluding blood transfusions from linked hospital discharge and birth certificate data, 2010-2019

Delivery and demographic characteristics	Total (n = 96,746)	SMM Status	
		SMM (n = 369)	Non-SMM (n = 96,377)
	N (%)*	N (%)†	N (%)†
Year of Delivery			
Pre ICD-10-CM transition	53,826 (55.6%)	230 (0.4%)	53,596 (99.6%)
Post ICD-10-CM transition	42,920 (44.4%)	139 (0.3%)	42,781 (99.7%)
Delivery Hospital			
Hospital A	20,469 (21.2%)	71 (0.3%)	20,398 (99.7%)
Hospital B	8,929 (9.2%)	19 (0.2%)	8,910 (99.8%)
Hospital C	54,608 (56.4%)	183 (0.3%)	54,425 (99.7%)
Hospital D	7,168 (7.4%)	76 (1.1%)	7,092 (98.9%)
Hospital E	5,572 (5.8%)	20 (0.4%)	5,552 (99.6%)
Mode of Delivery			
Vaginal delivery	66,605 (68.8%)	140 (0.2%)	66,465 (99.8%)
Cesarean sections (C-section)	30,141 (31.2%)	229 (0.8%)	29,912 (99.2%)
Parity			
0	38,585 (39.9%)	144 (0.4%)	38,441 (99.6%)
≥1	58,140 (60.1%)	225 (0.4%)	57,915 (99.6%)
Fetal presentation			
Cephalic	90,374 (93.4%)	336 (0.4%)	90,038 (99.6%)
Non-cephalic	6,379 (1.4%)	33 (0.5%)	6,339 (99.5%)
Hypertension			
Prepregnancy			
Yes	3,396 (3.5%)	21 (0.6%)	3,375 (99.4%)
No	93,350 (96.5%)	348 (0.4%)	93,002 (99.6%)
Gestational			
Yes	7,362 (7.6%)	76 (1.0%)	7,286 (99%)
No	89,384 (92.4%)	293 (0.3%)	89,091 (99.7%)
Diabetes			
Prepregnancy			
Yes	887 (0.9%)	11 (1.2%)	876 (98.8%)
No	95,859 (99.1%)	358 (0.4%)	95,501 (99.6%)
Gestational			
Yes	6,772 (7.0%)	23 (0.3%)	6,749 (99.7%)
No	89,974 (93.0%)	346 (0.4%)	89,628 (99.6%)

Table 9 (continued).

Delivery and demographic characteristics	Total (n = 96,746)	SMM Status	
		SMM (n = 369)	Non-SMM (n = 96,377)
	N (%)*	N (%)†	N (%)†
Prepregnancy Body Mass Index (kg/m²)			
Underweight	3,920 (4.1%)	24 (0.6%)	3,896 (99.4%)
Normal	39,852 (41.9%)	135 (0.3%)	39,717 (99.7%)
Overweight	24,895 (26.2%)	97 (0.4%)	24,798 (99.6%)
Obese	26,432 (27.8%)	108 (0.4%)	26,324 (99.6%)
Previous preterm birth			
Yes	5,327 (5.5%)	46 (0.9%)	5,281 (99.1%)
No	91,419 (94.5%)	323 (0.4%)	91,096 (99.6%)
Serious mental illness (SMI)			
Yes	4,213 (4.4%)	12 (0.3%)	4,201 (99.7%)
No	92,533 (95.6%)	357 (0.4%)	92,176 (99.6%)
Opioid use disorder (OUD)			
Yes	1,672 (1.7%)	11 (0.7%)	1,661 (99.3%)
No	95,074 (98.3%)	358 (0.4%)	94,716 (99.6%)
Smoking during pregnancy			
Yes	10,246 (10.6%)	53 (0.5%)	10,193 (99.5%)
No	86,469 (89.4%)	315 (0.4%)	86,154 (99.6%)
Prenatal Care			
No prenatal care	2,174 (2.3%)	15 (0.7%)	2,159 (99.3%)
First trimester	72,520 (76.4%)	260 (0.4%)	72,260 (99.6%)
Second trimester	16,187 (17%)	59 (0.4%)	16,128 (99.6%)
Third trimester	4,100 (4.3%)	20 (0.5%)	4,080 (99.5%)
Demographics			
Age			
15-19 years	6,251 (6.5%)	20 (0.3%)	6,231 (99.7%)
20-24 years	21,218 (21.9%)	82 (0.4%)	21,136 (99.6%)
25-29 years	29,020 (30.0%)	109 (0.4%)	28,911 (99.6%)
30-34 years	26,183 (27.1%)	100 (0.4%)	26,083 (99.6%)
35-39 years	11,703 (12.1%)	46 (0.4%)	11,657 (99.6%)
40-44 years	2,371 (2.5%)	12 (0.5%)	2,359 (99.5%)

Table 9 (continued).

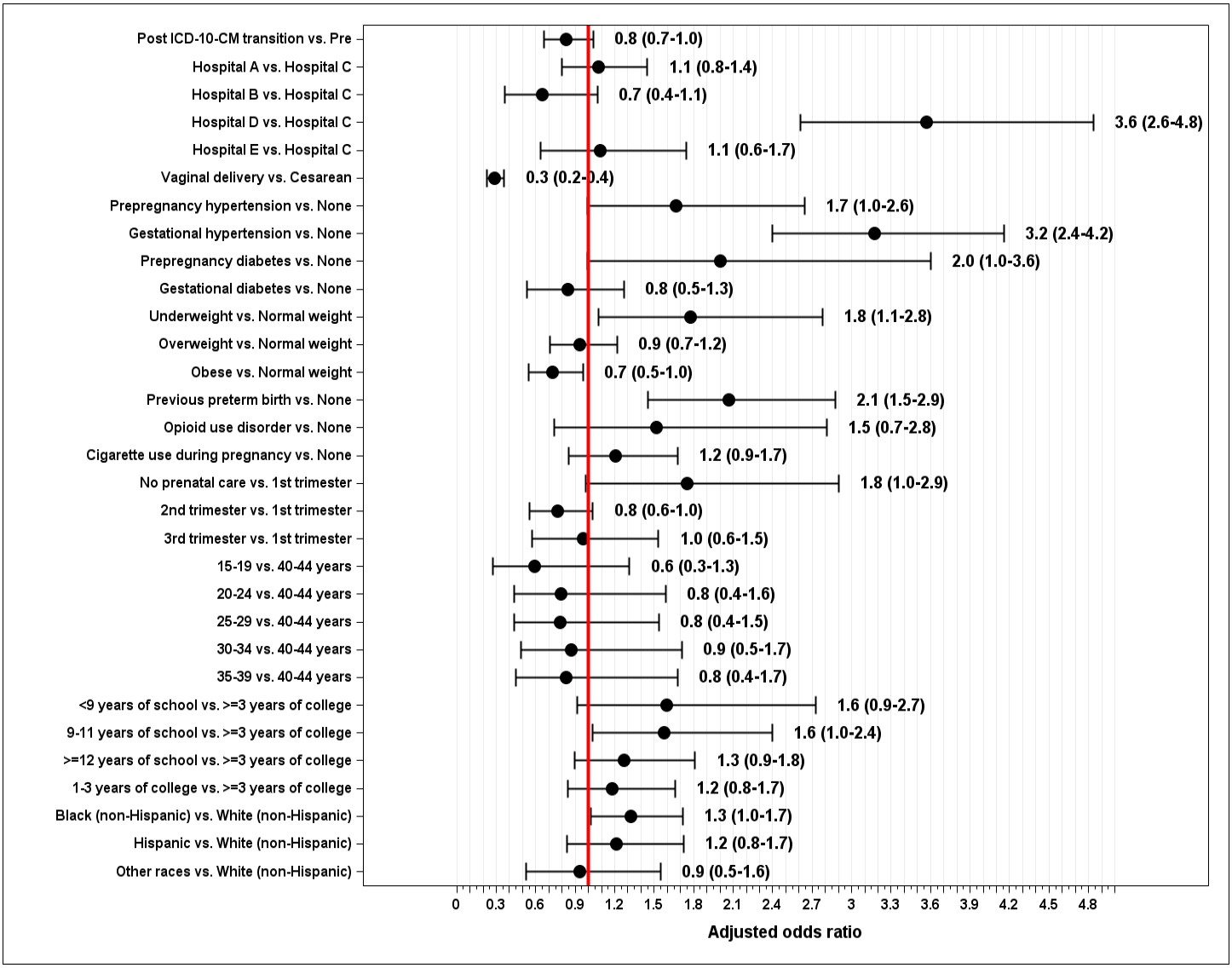
Delivery and demographic characteristics	Total (n = 96,746)	SMM Status	
		SMM (n = 369)	Non-SMM (n = 96,377)
	N (%)*	N (%)†	N (%)†
Education			
< 9 years of schooling	4,659 (4.8%)	29 (0.6%)	4,630 (99.4%)
9-11 years of schooling	11,873 (12.3%)	59 (0.5%)	11,814 (99.5%)
High school graduate	25,820 (26.8%)	106 (0.4%)	25,714 (99.6%)
1-3 years of college	25,569 (26.6%)	93 (0.4%)	25,476 (99.6%)
>= 3 years of college	28,304 (29.4%)	75 (0.3%)	28,229 (99.7%)
Race and Ethnicity			
White (non-Hispanic)	50,297 (52%)	166 (0.3%)	50,131 (99.7%)
Black (non-Hispanic)	26,349 (27.2%)	123 (0.5%)	26,226 (99.5%)
Hispanic	13,723 (14.2%)	63 (0.5%)	13,660 (99.5%)
Other races	6,344 (6.6%)	17 (0.3%)	6,327 (99.7%)
Medicaid status			
Medicaid	47,168 (48.9%)	227 (0.5%)	46,941 (99.5%)
Non-Medicaid	49,371 (51.1%)	141 (0.3%)	49,230 (99.7%)
County of Residence			
Kent	19,425 (20.1%)	68 (0.4%)	19,357 (99.6%)
New Castle	57,456 (59.4%)	179 (0.3%)	57,277 (99.7%)
Sussex	19,865 (20.5%)	122 (0.6%)	19,743 (99.4%)

Source: Delaware Health and Social Services, Division of Public Health, Delaware Health Statistics Center, Hospital Discharge Data and Birth Certificate Data, 2010-2019. Fourth quarter data (i.e., 1St October) in 2015 includes ICD-9-CM and ICD-10-CM codes generalized equivalence mappings.
*Column percentage
†Row percentage

To assess the associations for SMM, multivariable logistic regressions were conducted using *a priori* associations in bivariate analyses and assessing best fitting models using Firth's Penalized Maximum Likelihood Estimates. Figure 11 displays the adjusted odds ratios (AOR) with 95% confidence intervals for any SMM without blood transfusion procedure codes. *Ceteris paribus*, women delivering in hospital D had significantly greater odds of SMM (AOR = 3.6; 95%CI: 2.6-4.8) compared to Hospital C. Women with vaginal deliveries had lower odds of SMM (AOR = 0.3; 95%CI: 0.2-0.4) compared to cesarean deliveries. Women with prepregnancy hypertension had greater odds of SMM (AOR = 1.7; 95%CI: 1.0-2.6) compared to those without prepregnancy hypertension and women with gestational hypertension had greater odds of SMM (AOR = 3.2; 95%CI: 2.4-4.2) compared to those without gestational hypertension. Similarly, women with prepregnancy diabetes had greater odds of SMM (AOR = 2.0; 95%CI: 1.0-3.6) compared to those without prepregnancy diabetes. Being underweight (prepregnancy BMI < 18.5) as opposed to normal weight (prepregnancy BMI >= 18.5 and <=24.5) was associated with greater odds of SMM (AOR = 1.8;

95%CI: 1.1-2.8). Women with a previous preterm birth had greater odds of SMM (AOR = 2.1; 95%CI: 1.5-2.9) compared to women without a previous preterm birth. Women with no prenatal care had higher odds of SMM (AOR = 1.8; 95%CI: 1.0-2.9) as compared to those with first trimester prenatal care. Women with 9 to 11 years of schooling had greater odds of SMM (AOR = 1.6; 95%CI: 1.0-2.4) as compared to women with 3 or more years of college. Lastly, Black (non-Hispanic) women had greater odds of SMM (AOR = 1.3; 95%CI: 1.0-1.7) as compared to White (non-Hispanic) women. Maternal age was not associated with increased SMM in this study.

Figure 11. Adjusted odds ratios with 95% confidence intervals for severe maternal morbidity excluding blood transfusions from linked hospital discharge and birth certificate data, Delaware, 2010-2019



Source: Delaware Health and Social Services, Division of Public Health, Delaware Health Statistics Center, Hospital Discharge Data and Birth Certificate Data, 2010-2019. Fourth quarter data (i.e., 1st October) in 2015 includes ICD-9-CM and ICD-10-CM codes generalized equivalence mappings.

Conclusion

In conclusion, during 2010-2019, the SMM rates in Delaware varied due to ICD transition and coding issues specific to blood transfusions. As of this writing, there is no national estimate and consensus on ascertainment of SMM. However, post ICD-10-CM transition, the most frequently used SMM ascertainment method is the use of SMM without blood transfusion procedure codes. Although not validated through medical chart abstraction, this research brief provided an alternative method of case ascertainment for blood transfusion using revenue codes for purpose of surveillance. OUD and SMI play an important role in SMM vis-à-vis pregnancy related mental health deaths.[30] However, SMI and OUD was not found to be associated in this study perhaps due to changes in DSM-V criteria with transition to ICD-10-CM codes.

Acknowledgements: Delaware Division of Public Health authors would like to acknowledge/thank Dr. Khaleel S. Hussaini and the Maternal and Child Health Epidemiology Program, Field Support Branch, Division of Reproductive Health, National Center for Chronic Disease Prevention and Public Health Promotion, Centers for Disease Control and Prevention, for preparation of this research brief.

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