ORIGINAL ARTICLE

Maternal Opioid Use Disorder and Neonatal Abstinence Syndrome Among Rural US Residents, 2007–2014

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Disclosures: The authors report no conflicts of interest.

Funding: This study was supported by the Federal Office of Rural Health Policy (FORHP), Health Resources and Services Administration (HRSA), US Department of Health and Human Services (HHS) Cooperative Agreement U1CRH03717. The information, conclusions and opinions expressed are those of the authors and no endorsement by FORHP, HRSA, or HHS is intended or should be inferred.

Acknowledgments: The authors gratefully acknowledge Alex Evenson's contributions to the design of the figures included in this manuscript.

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doi: 10.1111/jrh.12329

Abstract

Purpose: Opioid use disorder (OUD) during pregnancy is associated with poor maternal and infant outcomes, including neonatal abstinence syndrome (NAS), and both maternal OUD and NAS are increasing disproportionately among rural residents. This study describes the trajectory and characteristics associated with diagnosis of maternal OUD or NAS among rural residents who gave birth at different types of hospitals based on rural/urban location and teaching status.

Methods: Hospital discharge data from the all-payer National Inpatient Sample were used to describe maternal OUD and infant NAS among rural residents from 2007–2014. Hospitals were categorized as rural, urban teaching, and urban nonteaching. We estimated incidence trends by hospital categories, followed by multivariable logistic regression analyses to identify correlates of OUD and NAS among rural residents, stratified by hospital category.

Findings: Incidence of maternal OUD increased in all hospital categories, with higher rates (8.9/1,000 deliveries) among rural residents who gave birth at urban teaching hospitals compared with those who gave birth at rural hospitals (4.3/1,000 deliveries) or urban nonteaching hospitals (3.6/1,000 deliveries; $P < .001$). A similar pattern was observed for infant NAS. In multivariable models, the association between maternal OUD and infant NAS diagnoses and hospital category differed by rurality (micropolitan vs. noncore.)

Conclusions: There has been a sustained increase in both maternal OUD and NAS diagnoses among rural residents. Measured sociodemographic and clinical correlates of maternal OUD and NAS differ by hospital category, indicating variability across hospital locations in patient populations and clinical needs for rural residents with these conditions.

Key words hospitals, maternal opioid use, neonatal abstinence syndrome, substance use disorder.

Among reproductive-age women in the United States, opioid-related hospitalizations increased 75% from 2005-2015.[1] Simultaneously, a growing number of infants are being diagnosed with opioid withdrawal after birth, also known as neonatal abstinence syndrome (NAS).[2,3] Fetal, infant, and maternal complications of opioid use disorder (OUD), including NAS, are contributing to a rise in the health care and economic consequences of the opioid epidemic in the United States.[2,4-6]

Maternal OUD and NAS disproportionately affect rural communities,[7] where poverty levels are higher and where health care access is more limited.[8] From

2004-2013, the incidence of both NAS and maternal OUD increased more rapidly in rural counties, where rates rose from 1.2 to 7.5 per 1,000 compared to urban counties, where rates rose from 1.4 to 4.5 per 1,000.[7] Further, compared with their urban peers, rural women and infants with opioid-related diagnoses are more likely to be from lower-income families, and rural infants are more likely to be transferred to another hospital following delivery.[7] Rural infants in the United States are over-represented among those diagnosed with NAS, with the proportion of infants diagnosed with NAS from rural counties increasing from 12.9% in 2003-2004 to 21.2% in 2012-2013.[7] Diagnosis of opioid-related illness in pregnancy has multiple short and long-term consequences for mothers, infants, families, and communities. For example, maternal OUD and NAS are frequently associated with separation of mother and baby, potentially hampering bonding and attachment.[2,9,10]

Recognizing the particular needs of rural residents with opioid-affected births can inform clinical and policy responses within the rural context, where resources, infrastructure, and health care workforce capacity differ substantially from urban areas.[11-13] For instance, access to hospital-based obstetric care is declining in rural United States counties; currently, fewer than half of rural counties have a hospital that provides obstetric services.[14-17] And, approximately 1 in 4 pregnant rural residents give birth in nonlocal hospitals, often owing to the clinical necessity of higher-acuity care, which is frequently not available in rural communities.[18] Clinical recommendations for perinatal regionalization support nonlocal childbirth for rural residents with pregnancy complications and those who require higher-acuity neonatal care.[18-21] Rural residents who live further away from regional perinatal care centers may have difficulty accessing this care, especially when they are low income, raising the possibility that rural hospitals may be faced with managing complex clinical scenarios, including maternal OUD and infant NAS, with limited capacity and resources.[18,22,23]

The care and clinical support rural residents with maternal OUD receive is likely affected by the birth hospital's geographic setting and teaching status.[12,24] Teaching hospitals may have greater resources and capacity to diagnose and treat highly complex or rare conditions.[24-26] Research and clinical initiatives related to maternal OUD and NAS—even those focused on rural communities—are predominantly housed in urban teaching hospitals with expertise in these conditions.[14,27,28] Yet, some rural residents—even those with OUD and other complex clinical conditions—give birth locally, and rural hospitals have to be prepared to either transfer or care for these patients and their infants, including those who develop NAS. While rural/urban differences in the trajectory of maternal OUD and NAS have been described, information regarding the location of childbirth for rural residents with opioid-affected births and the characteristics of these patients in different delivery hospitals is needed to effectively address the opioid epidemic's effects on rural families. The goal of this study was to identify differences in incidence as well as in sociodemographic correlates associated with diagnosis of maternal OUD and NAS among rural residents who gave birth at different types of hospitals based on rural/urban location and teaching status.

Methods

Data and Study Population

We used hospital discharge data from the 2007-2014 National Inpatient Sample (NIS), an all-payer inpatient claims database made available through the Healthcare and Cost Utilization Project (HCUP) of the Agency for Healthcare Research and Quality.[29] The NIS database has undergone several design changes over time, including a redesign from a sample of hospitals to a sample of discharges in 2012, and we used HCUP's recommended procedures for conducting trend analyses using NIS data.

This analysis had 2 study populations: obstetric deliveries by rural residents (using maternal records), and infants of rural residents (using infant hospital records). In the NIS data, it is not possible to link obstetric deliveries with infant records. To identify obstetric deliveries, we used a previously published method of identifying births in claims data to avoid multiple inclusion of pregnant patients with multiple hospitalizations during pregnancy.[30] Pregnant patients with ages outside biological plausibility for childbirth (<10 years old and >60 years old; 2.1%), urban residents (83.6%), and records with missing hospital category (0.2%) were excluded from the sample. We identified rural infants using the neonatal indicator on the hospital discharge form. Infants who were >1 year of age (0.2%), those with an urban address (85.2%), and records with missing hospital category (0.2%) were excluded from the infant sample. The final study population included 942,798 deliveries and 981,090 infants. Owing to higher-order births, there were more infants than deliveries in the analysis.

Variable Measurement

Outcome variables were defined using the *International Classification of Diseases, 9th revision Clinical Modification (ICD-9-CM)* codes. Maternal OUD was identified by diagnosis codes on the discharge record from the childbirth hospitalization. Appendix 1 (available online only) shows detailed information on the ICD-9 diagnosis codes used to

construct the maternal OUD variable as well as codes that were excluded. NAS was identified with ICD-9 diagnosis code 779.5.

In this analysis, hospitals were classified into 3 categories based on rural/urban location and teaching status. Rural/urban residency and hospital geographic location were determined at the county level, based on the Office of Management and Budget (OMB) standard definition of metropolitan and micropolitan statistical areas.[31] Rural counties include those classified by the OMB as micropolitan counties (those with a population center of 10,000-50,000) or noncore counties (those with no population center of 10,000 or larger).

Teaching hospitals differ from nonteaching hospitals in their mission, financing, and some outcomes and quality of care.[24,25] Hospital teaching status was based on American Hospital Association Annual Survey data. A hospital was considered a teaching hospital if it had a residency program, was a member of the Council of Teaching Hospitals (COTH), or had a ratio of full-time equivalent interns and residents to beds of 0.25 or higher.

Patient sociodemographic characteristics, including age, race/ethnicity, and payer, have been associated with OUD and NAS in prior research.[7,32-35] In this analysis, maternal patient age was measured as a categorical variable (<20 years old, 20-24 years old, 25-29 years old, 30-34 years old, ≥35 years old), and race/ethnicity was reported in 6 categories (white, black, Hispanic/Latino, Native American, other or multiple race/ethnicity, or missing). Primary expected payer was categorized as Medicaid, private payer, or other. Using ICD-9 diagnosis codes, we also identified patients' clinical characteristics, including preterm delivery (<37 weeks gestation), substance use disorders (cannabis, cocaine, sedatives, hallucinogens, antidepressants, other drug/substance), mental illness (depression, schizophrenia, episodic mood disorder, anxiety, personality disorder, pregnancy-related mental disorder), diabetes (pre-existing type 1 and 2, gestational), hypertension (pre-existing hypertension, preeclampsia, eclampsia), and chronic pain. For the infants in this analysis, we measured primary expected payer, residence, and sex.

Analysis

Differences in variable distribution across hospital categories were assessed using Pearson chi-square tests. Analysis of trends in NIS data requires the use of weights to account for changes in the sample over time; we used designated trend weights for all analyses conducted over time. Annual incidences of OUD and NAS from 2007–2014 by hospital category were estimated and assessed for trends using generalized linear models. Differences in trends across hospital categories were assessed using interaction terms.

Descriptive analyses to assess differences in sociodemographic and clinical characteristics of rural residents as well as those with maternal OUD diagnosis by hospital category were performed. Stratified multivariate logistic regressions were performed for each hospital category to identify sociodemographic correlates of maternal OUD and NAS. Adjusted odd ratios and 95% confidence intervals (CI) were calculated, with $P < .05$ considered statistically significant. Results of multivariate analyses are presented as forest plots. All data management and analyses were conducted in SAS version 9.4 (SAS Institute, Inc., Cary, NC).

This study protocol was reviewed and designated exempt by the University of Minnesota Institutional Review Board.

Results

Approximately 71% of rural residents in this analysis (70.8%) gave birth at a rural hospital; the remaining rural residents had births distributed almost evenly between urban nonteaching and urban teaching hospitals (14.8% and 14.5%, respectively). Table 1 shows both outcome measures and how births to rural residents are distributed across hospital categories, based on sociodemographic and clinical characteristics. That is, it presents the percentage of rural residents with a given characteristic that gave birth at rural, urban nonteaching, and urban teaching hospitals, respectively. Micropolitan rural residents were more likely than noncore residents to give birth in rural hospitals (76.2% vs. 61.7%). Younger rural residents, rural residents who are not white, those with Medicaid coverage, and those with tobacco use or other substance use disorders were more likely to give birth at rural hospitals (vs. urban nonteaching or urban teaching hospitals). On the other hand, rural residents with preterm deliveries and those with comorbidities were disproportionately more likely to give birth in urban teaching hospitals ($P < .001$ for all comparisons described). Still, more than half of rural residents with these clinical complications (preterm birth and comorbidities) gave birth in rural hospitals.

The aggregated prevalence of maternal OUD was 8.9 per 1,000 deliveries among rural residents who gave birth at urban teaching hospitals (top of Table 1), significantly higher than at both rural and urban nonteaching hospitals (approximately 4 per 1,000 deliveries, $P < .001$). A similar trend of NAS diagnosis was observed across hospital categories. However, the prevalence of NAS was higher than that of OUD across all hospital categories

Table 1 Characteristics of Rural US Residents Who Gave Birth, Opioid Use Disorder (OUD), and Neonatal Abstinence Syndrome (NAS) Diagnosis, by Hospital Category (N = 942,798)

	Rural		Urban Nonteaching		Urban Teaching		*P* value
	N = 667,047 (70.8%)		N = 139,235 (14.8%)		N = 136,516 (14.5%)		
	N	(%)	N	(%)	N	(%)	
Outcomes							
OUD per 1,000 deliveries	4.3		3.6		8.9		<.001
NAS per 1,000 live births[a]	4.7		5		16.7		<.001
Maternal residence							
Micropolitan	448,777	(76.2%)	68,698	(11.7%)	71,751	(12.2%)	<.001
Noncore	218,270	(61.7%)	70,537	(20.0%)	64,765	(18.3%)	
Maternal age							
<20 y	85,130	(76.0%)	13,748	(12.3%)	13,192	(11.8%)	<.001
20-24 y	213,693	(74.0%)	39,743	(13.8%)	35,312	(12.2%)	
25-29 y	192,039	(69.7%)	42,735	(15.5%)	40,827	(14.8%)	
30-34 y	116,399	(67.0%)	27,987	(16.1%)	29,294	(16.9%)	
35 y and older	59,786	(64.5%)	15,022	(16.2%)	17,891	(19.3%)	
Maternal race/ethnicity							
White	386,598	(68.6%)	91,769	(16.3%)	84,874	(15.1%)	<.001
Black	49,311	(71.8%)	8,787	(12.8%)	10,569	(15.4%)	
Hispanic/Latino	54,795	(71.6%)	11,043	(14.4%)	10,658	(13.9%)	
Native American	14,169	(79.9%)	1,499	(8.5%)	2,077	(11.7%)	
Other race/ethnicity	27,117	(75.3%)	5,099	(14.2%)	3,803	(10.6%)	
Missing	135,057	(74.8%)	21,038	(11.7%)	24,535	(13.6%)	
Maternal primary payer							
Medicaid	344,386	(75.2%)	56,610	(12.4%)	56,867	(12.4%)	<.001
Private	264,734	(65.2%)	72,291	(17.8%)	68,937	(17.0%)	
Other	57,927	(73.4%)	10,334	(13.1%)	10,712	(13.6%)	
Preterm delivery (<37 wks gestation)	35,124	(54.0%)	9,869	(15.2%)	20,070	(30.9%)	<.001
Maternal substance use diagnosis							
Tobacco	80,471	(72.8%)	13,122	(11.9%)	16,888	(15.3%)	<.001
Alcohol	658	(68.5%)	104	(10.8%)	199	(20.7%)	<.001
Other substance	8,964	(74.4%)	1,241	(10.3%)	1,846	(15.3%)	<.001
Maternal comorbidity							
Mental illness[b]	35,774	(67.9%)	6,253	(11.9%)	10,696	(20.3%)	<.001
Diabetes[c]	38,357	(63.5%)	8,967	(14.9%)	13,051	(21.6%)	<.001
Hypertension[d]	62,622	(61.9%)	15,758	(15.6%)	22,713	(22.5%)	<.001
Chronic pain	1,642	(58.7%)	367	(13.1%)	787	(28.2%)	<.001

[a]from unlinked infant data (N = 981,090)

[b]includes depression, anxiety, schizophrenia, episodic mood disorder, personality disorder, severe mental illness, and mental conditions complicating pregnancy

[c]includes pre-existing diabetes mellitus and gestational diabetes

[d]includes hypertensive disorder, preeclampsia, and eclampsia

(16.7 per 1,000 live births at urban teaching hospitals; 4.7 per 1,000 at rural hospitals; and 5.0 for urban nonteaching hospitals, $P < .001$).

Figures 1 and 2 show estimated trends of maternal OUD and infant NAS diagnoses, respectively, from 2007-2014 by delivery hospital category. The incidence of maternal OUD was consistently highest among rural residents who gave birth at urban teaching hospitals. Across the 3 hospital categories, the incidence of maternal OUD was estimated to increase at approximately 1 case per 1,000 deliveries per year. The incidence of NAS was also consistently highest among rural infants born at urban teaching hospitals, and the rate of increase (about 3 per 1,000 births per year) was significantly higher at urban teaching hospitals, compared to urban nonteaching and rural hospitals (about 1 per 1,000 births per year for both; $P < .001$).

Among the 4,606 rural residents in this analysis who had a maternal OUD diagnosis, 62.5% gave birth at a rural hospital and 11.0% and 26.5% gave birth at an

Figure 1 Estimated Trend of Annual Incidence of Maternal Opioid Use Disorder (OUD) Among Rural U.S. Residents, by Delivery Hospital Category.

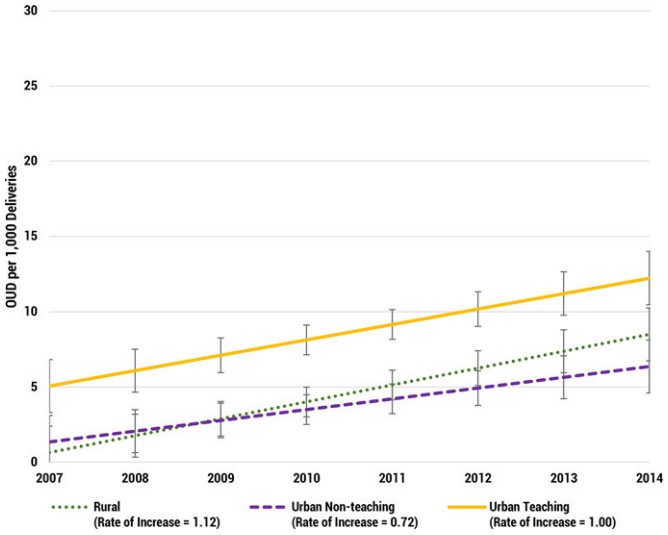
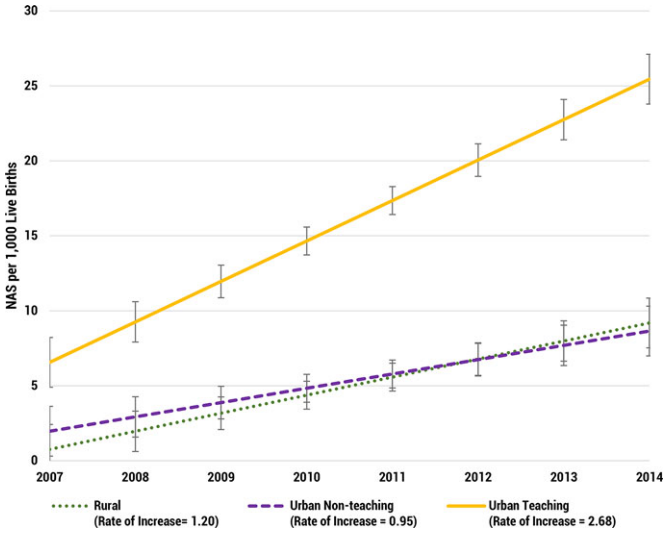


Figure 2 Estimated Trend of Annual Incidence of Neonatal Abstinence Syndrome (NAS) Among Rural U.S. Infants, by Delivery Hospital Category.



urban nonteaching and an urban teaching hospital, respectively (Table 2). Younger rural residents with maternal OUD were more likely than older rural residents with maternal OUD to give birth in rural hospitals vs. urban teaching or nonteaching hospitals ($P = .003$). Also, white, Hispanic/Latino, and Native rural residents with maternal OUD were more likely than black rural residents with OUD to give birth in rural hospitals ($P < .001$). Nearly half (48.3%) of rural residents with maternal OUD and preterm birth delivered their infants at rural hospitals, as did 61.7% of those with tobacco use, 80.0% of those with alcohol use, 69.8% of those with other substance use, 63.8% of those with diagnosed mental illness, and nearly half of those with diabetes, hypertension, and chronic pain diagnoses.

Figure 3 displays a forest plot that shows the results of multivariate logistic models of maternal OUD diagnosis among rural residents, by hospital category. Across all hospital categories, being ≤24 years old (vs. 25-29 years) and black or Hispanic/Latino (vs. white) were negatively associated with maternal OUD, whereas Medicaid enrollment, tobacco use, and diagnosis of mental illness or chronic pain were positive correlates of maternal OUD. Micropolitan rural residents (vs. noncore) had decreased odds of maternal OUD for births in rural hospitals (AOR = 0.8, 95% CI: 0.8-0.9), and elevated odds for births

Table 2 Characteristics of Rural US Residents Who Gave Birth and Had an Opioid Use Disorder (OUD) Diagnosis, by Hospital Category (N = 4,606)

	Rural		Urban Nonteaching		Urban Teaching		*P* value
	N = 2,879 (62.5%)		N = 508 (11.0%)		N = 1,219 (26.5%)		
	N	(%)	N	(%)	N	(%)	
Maternal residence							
Micropolitan	1,804	(64.8%)	290	(10.4%)	692	(24.8%)	<.001
Noncore	1,075	(59.1%)	218	(12.0%)	527	(29.0%)	
Maternal age							
<20 y	115	(67.7%)	22	(12.9%)	33	(19.4%)	.003
20-24 y	978	(65.7%)	155	(10.4%)	356	(23.9%)	
25-29 y	1,049	(61.9%)	168	(9.9%)	477	(28.2%)	
30-34 y	517	(58.8%)	112	(12.7%)	251	(28.5%)	
35 y and older	220	(59.0%)	51	(13.7%)	102	(27.4%)	
Maternal race/ethnicity							
White	2,223	(63.1%)	427	(12.1%)	876	(24.8%)	<.001
Black	50	(54.4%)	7	(7.6%)	35	(38.0%)	
Hispanic/Latino	106	(76.3%)	6	(4.3%)	27	(19.4%)	
Native American	92	(80.0%)	6	(5.2%)	17	(14.8%)	
Other race/ethnicity	38	(61.3%)	9	(14.5%)	15	(24.2%)	
Missing	370	(55.1%)	53	(7.9%)	249	(37.1%)	
Maternal primary payer							
Medicaid	2,349	(63.8%)	374	(10.2%)	958	(26.0%)	<.001
Private	267	(54.6%)	80	(16.4%)	142	(29.0%)	
Other	263	(60.3%)	54	(12.4%)	119	(27.3%)	
Preterm delivery (<37 wks gestation)	310	(48.3%)	77	(12.0%)	255	(39.7%)	<.001
Maternal substance use diagnosis							
Tobacco	1,699	(61.7%)	281	(10.2%)	776	(28.2%)	.002
Alcohol	40	(80.0%)	4	(8.0%)	6	(12.0%)	.032
Other substance	667	(69.8%)	99	(10.4%)	189	(19.8%)	<.001
Maternal comorbidity							
Mental illness[a]	1,671	(63.8%)	273	(10.4%)	674	(25.7%)	.087
Diabetes[b]	88	(49.4%)	29	(16.3%)	61	(34.3%)	<.001
Hypertension[c]	218	(49.9%)	53	(12.1%)	166	(38.0%)	<.001
Chronic pain	115	(49.8%)	30	(13.0%)	86	(37.2%)	<.001

[a]includes depression, anxiety, schizophrenia, episodic mood disorder, personality disorder, severe mental illness, and mental conditions complicating pregnancy

[b]includes pre-existing diabetes mellitus and gestational diabetes

[c]includes hypertensive disorder, preeclampsia, and eclampsia

in urban nonteaching hospitals (AOR = 1.5; 95% CI: 1.2-1.8) and urban teaching hospitals (AOR = 1.2; 95% CI: 1.1-1.4).

Tobacco use was positively associated with maternal OUD across all hospital categories. Having at least one mental health disorder was positively associated with OUD diagnosis; however, the magnitude of association for deliveries in rural teaching hospitals (AOR = 10.6; 95% CI: 9.7-11.6) and in urban nonteaching hospitals (AOR = 10.0; 95% CI: 8.1-12.3) was higher than for deliveries in urban teaching hospitals (AOR: 6.6; 95% CI: 5.8-7.5). Rural residents with a chronic pain diagnosis had increased odds of maternal OUD compared to those without one, regardless of the hospital category.

Both payer type and rural residence were associated with NAS among rural infants (Figure 4). Compared to privately insured infants, the odds of NAS were significantly higher among those with Medicaid as primary payer, particularly those who were born in urban hospitals. Micropolitan infants born in rural hospitals were less likely to be diagnosed with NAS (AOR = 0.8; 95% CI = 0.7-0.9), whereas the opposite was the true among those born in urban teaching (AOR = 1.3; 95% CI: 1.1-1.5) and urban nonteaching hospitals (AOR = 1.1; 95% CI: 1.0-1.2).

Figure 3 Correlates of Maternal Opioid Use Disorder (OUD) Diagnosis Among US Rural Residents Who Gave Birth, by Hospital Category.

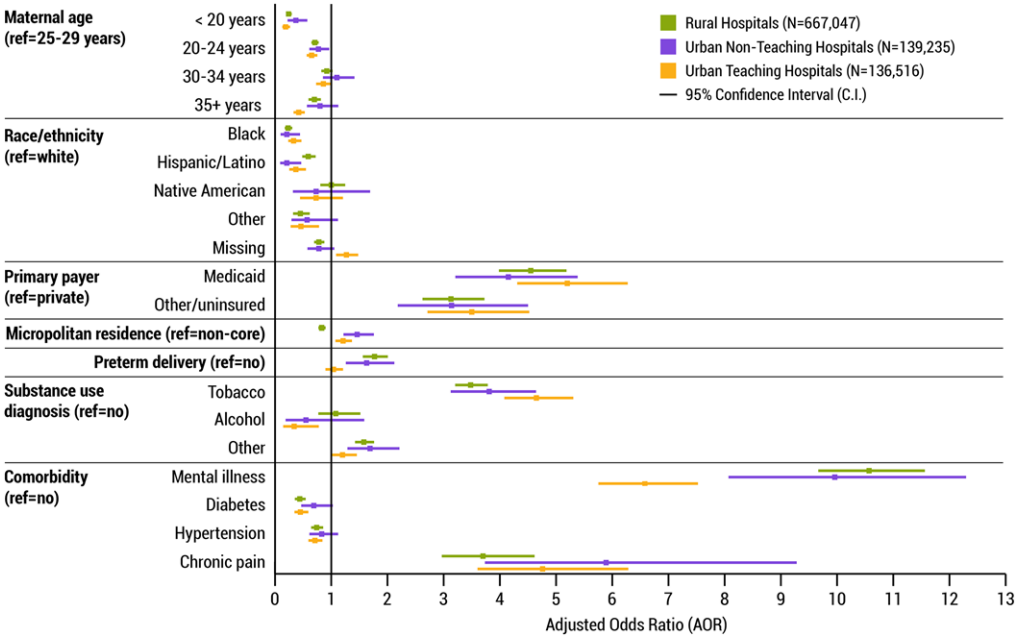
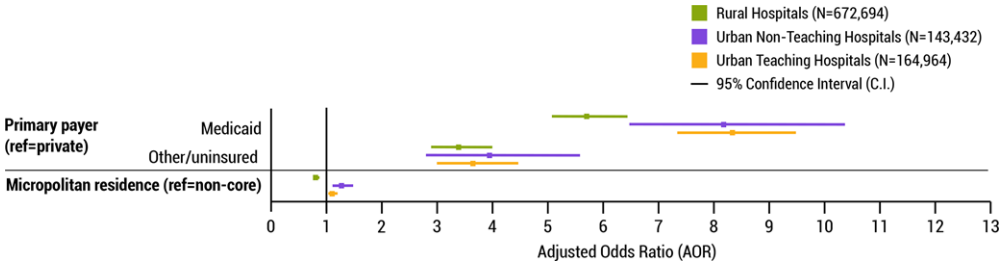


Figure 4 Correlates of Neonatal Abstinence Syndrome (NAS) Among Rural US Infants, by Hospital Category.



Discussion

Diagnosis of maternal OUD and NAS is steadily increasing among rural residents, and opioid-affected births are occurring in all hospital settings: rural and urban, teaching and nonteaching. The characteristics of rural residents with opioid-affected births differ across delivery hospital categories, highlighting the varied clinical and programmatic needs required in each hospital setting to appropriately manage OUD and NAS. Notably, more than half of rural residents with maternal OUD diagnosis (62.5%) gave birth in rural hospitals.

For both OUD and NAS, the highest rates of diagnosis occur in urban teaching hospitals, possibly indicating appropriate referral of higher risk patients. Disproportionally high rates of diabetes, hypertension, and chronic pain, and preterm birth among rural residents with maternal OUD diagnosis at urban teaching hospitals provide support for this possibility. However, nearly half of all rural residents with both maternal OUD and preterm birth (48.3%) deliver their infants at rural hospitals. These women and infants may require specialized and high acuity services, which are frequently limited in rural hospital settings and at hospitals with lower levels of maternal care.[6-8,12,14] The findings from this analysis show that clinicians in rural hospitals see substantial numbers of patients impacted by opioid-affected births as well as other clinical complications, warranting efforts to support complex patient needs in all hospital settings.

Sociodemographic correlates of maternal OUD and NAS among rural residents largely reinforce patterns uncovered in prior research.[3,7,33,35,36] For example, in this study, we found an elevated risk of OUD diagnosis among rural pregnant patients with mental illness, tobacco use, and/or a chronic pain diagnosis, regardless of delivery hospital location and teaching status. Diagnosis of mental illness (depression, anxiety, or severe mental illness) emerged as the correlate of maternal OUD

with the largest odds ratio, consistent with prior research on co-occurrence of mental illness and substance use disorder during pregnancy.[37,39] However, the magnitude of the association was not consistent across hospital category, with mental illness being associated with 10-fold increased odds of OUD among rural residents giving birth in rural and urban nonteaching hospitals, and nearly 7-fold increased odds for those giving birth in urban teaching hospitals. These findings may indicate under-detection of mental illness for rural residents giving birth in distant tertiary care academic health centers where they may not have established relationships with clinicians[12,35,40]; or, rural patients with mental illness may have greater barriers to travel to receive care at urban teaching hospitals.[38,39] Regardless of the reasons for detected differences across hospital categories, the strong association between mental illness and maternal OUD among rural residents reveals a population with complex clinical and psychosocial needs that is increasingly common in rural hospitals. Also, this analysis shows that more than 60% of rural residents with maternal OUD who also have a diagnosed mental illness give birth at rural hospitals, highlighting the urgency of care capacity for complex patients in rural settings.

Consistent with previous studies, we also identified a greater risk of maternal OUD and NAS among rural Medicaid beneficiaries compared with privately insured rural residents.[33,34] Because Medicaid eligibility depends on income during pregnancy, this correlate indicates both family income and payer type. Both limited economic means and Medicaid coverage may constrain treatment options for rural residents with OUD, who also face workforce and health services shortages for both obstetric care and substance use/mental illness.[40,43]

Implications

While many resources dedicated to combating maternal OUD and NAS are concentrated in urban teaching hospitals,[6-8] we demonstrated increases in OUD and NAS diagnosis in all hospital settings, including more than half of rural residents with maternal OUD who give birth in rural hospitals. Rural hospitals may be less well equipped to handle the complex needs of this patient population.[7,8,12,24,40] Both the policy dialogue and the programmatic responses to OUD during pregnancy ought to account for rural residents who may be referred or transferred to urban settings, while also strengthening the resources in rural communities to ensure successful management of the growing number of opioid-affected pregnancies. Promising strategies include formal collaborations between urban-based systems and smaller rural clinics and hospitals, such as Project ECHO and Vermont's Hub and Spoke model.[41-45] Both of these care models ought to be rigorously assessed for potential expansion in other rural US locations where resources to care for opioid-affected births may be limited.

Disproportionate NAS burden in rural communities has been shown nationally and in states like Kentucky and West Virginia.[7,46,47] Hospitals in both rural and urban settings should be prepared for longer hospital stays for rural infants with NAS, versus healthy full-term infants. Prior research shows a mean length of stay of 23 days for infants with NAS vs. 2.6 days for healthy infants, with a possible 5-fold increase in neonatal care costs associated with NAS.[2,37] Readiness in rural hospitals without neonatal intensive care capacity may require partnerships with urban hospitals that have this capacity to ensure safe care locally and swift transfer when needed. Consideration should be given to the utilization of telemedicine assessment, diagnosis, and early treatment of NAS in more rural communities, allowing for timely treatment even in areas where neonatal resources are scarce.[48,49]

Further, the associations between maternal OUD and mental illness, chronic pain, tobacco use, and other substance use call for clinical attention to the multifaceted nature of OUD.[50] This includes focusing on tobacco cessation and mental health treatment during pregnancy and the postpartum period. The increase in both NAS and OUD indicate the importance of heightened clinical attention to opioid-affected births among all rural residents.

Strengths and Limitations

This study examined characteristics of opioid-affected births to rural residents; it is one of the first to focus explicitly on rural residents, who have been hit hardest by the opioid epidemic.[1,3,7] The use of the largest national, all-payer hospital discharge dataset, over an 8-year period, is a strength of this analysis; however, this study also has limitations. Based on differences between self-reported measures and claims-based data, it is likely that OUD and NAS are underreported in hospital discharge records for childbirth.[51] This analysis relies on diagnosis codes, and coding practices may differ across hospital locations. This may be a particular limitation for our measure of NAS, which relies on only one ICD-9 diagnosis code (779.5). The NIS dataset includes only hospital discharge records and does not include clinical documentation by medical providers. Therefore, no information on specific treatment for OUD, or severity of NAS, can be discerned. Mental health conditions are also underreported in hospital discharge data,[52] and the data do not indicate whether a mental illness was present prior to childbirth or newly diagnosed at the time of delivery. In addition, the records analyzed in this

study were limited to hospital discharges for childbirth, and conditions diagnosed during pregnancy may not be recorded at discharge. Records for mothers and infants could not be linked, and limited clinical and sociodemographic information is available on infants. Lastly, transfer status (in or out) across hospital categories could not be assessed consistently due to changes in reporting of this characteristic in the NIS data across the study period. As a result, the findings from multivariate analyses presented here could not be adjusted for transfer status.

Conclusions

There has been a sustained increase in both maternal OUD and NAS diagnoses among rural residents, with the highest rates occurring among rural patients giving birth in urban teaching hospitals. Measured sociodemographic and clinical correlates of OUD and NAS differ by hospital category, indicating variability across hospital locations in patient populations and clinical need for rural residents with these conditions. Given the increase in OUD and NAS in all hospital settings, interventions should be responsive to the specific needs of rural residents and of the hospitals where they receive care. Rural hospitals, which may have more limited resources, personnel, and capacity to meet the complex clinical needs of rural patients with opioid-affected births, may need particular attention. Clinical and policy efforts to address the effects of the opioid epidemic on rural pregnant residents, infants, and families should focus on capacity building and partnerships for rural and urban health care systems.

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Supporting Information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Appendix: ICD-9 Codes for Outcome Variables