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ORIGINAL ARTICLE

Insomnia during pregnancy and severe maternal morbidity in the united states: nationally representative data from 2006 to 2017

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Abstract

Study Objectives: Using a large, nationally representative database, we aimed to estimate the prevalence and trends of insomnia among pregnant women over a 12-year period. In addition, we aimed to examine the interplay among insomnia, maternal comorbidities, and severe maternal morbidity (SMM).

Methods: We conducted a serial cross-sectional analysis of pregnancy-related hospitalizations in the United States from the 2006 to 2017 National Inpatient Sample (NIS). ICD-9 and ICD-10 codes were used to capture diagnoses of insomnia and obstetric comorbidities during delivery and non-delivery hospitalizations. The primary outcome was the diagnosis of SMM at delivery. We used logistic regression to assess the association between insomnia and SMM. Joinpoint regression was used to estimate trends in insomnia and SMM.

Results: Of nearly 47 million delivery hospitalizations, 24 625 women had a diagnosis of insomnia, or 5.2 per 10 000 deliveries. The annual incidence increased from 1.8 to 8.6 per 10 000 over the study period. The crude rate of insomnia was 6.3 times higher for non-delivery hospitalizations. Patients with insomnia had more comorbidities, particularly neuromuscular disease, mental health disorders, asthma, and substance use disorder. Prevalence of non-blood transfusion SMM was 3.6 times higher for patients with insomnia (2.4% vs. 0.7%). SMM increased annually by 11% (95% CI = 3.0% to 19.7%) in patients with insomnia. After adjusting for comorbidities, there remained a 24% increased likelihood of SMM for patients with insomnia.

Conclusions: Coded diagnosis of insomnia during pregnancy has increased over time, and this burden disparately affects women of low socioeconomic status. Diagnosis of insomnia is an independent predictor of SMM.

Statement of Significance

Insomnia is the most common sleep disorder worldwide, and its symptoms are reported in at least one-third of all pregnancies. To our knowledge, this is the largest study examining the effects of clinically diagnosed insomnia on pregnancy to date. In addition, this study examines how a diagnosis of insomnia during pregnancy is associated with unexpected adverse maternal events delivery using severe maternal morbidity as an indicator for these outcomes.

Key words: insomnia; pregnancy; severe maternal morbidity

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Introduction

Insomnia is the most common sleep disorder worldwide, with prevalence ranging from 6% to 50% of the adult population depending on the definition [1–3]. Characterized by delayed sleep initiation, short sleep duration, and poor sleep quality that result in daytime dysfunction, insomnia is a substantial public health problem [1, 3, 4]. The societal effects of poor sleep quality include decreased work productivity and maladapted socio-emotional interactions. Moreover, the substantial burden on health systems emerges from insomnia's association with increased rates of hospitalization, derangement in cardiometabolic and immunologic function, higher rates of medication and substance use, and increased prevalence of mood disorder and suicide [5–7]. This is underscored by the observation of sleep disparities where risk varies across populations including social identity groups [8–11].

Because of its strong female predilection [12] along with the unique physiological and social–emotional changes associated with the gravid state, insomnia's impact on pregnancy must be considered. Symptoms of insomnia are reported in at least one-third of pregnancies with the predominance in the second and third trimesters [13, 14]. This phenomenon may be explained by frequent nighttime awakenings due to decreased sleep depth, progesterone-mediated nasal congestion, frequent nocturia, restless leg syndrome, and physical discomfort [14–17]. Several studies have described poor neonatal and maternal outcomes in pregnancies affected by sleep disorders, including fetal growth restriction, preterm birth, still birth, maternal morbidity (e.g. preeclampsia and cardiomyopathy), and maternal mortality [18–20]. Insomnia, in particular, has been linked to poor maternal mental health, particularly postpartum depression, anxiety, and suicidal ideation [21–23]. Such adverse outcomes are magnified by data from non-pregnant populations that strongly implicate discrimination as a cause of racial sleep inequity [24]. While large meta-analyses and population-based observational studies have examined insomnia during pregnancy, these are limited to data describing the cumulative prevalence and neonatal outcomes. There is a paucity of data in this area examining temporal trends and association with maternal morbidity.

Using a large, nationally representative database we aimed to estimate the prevalence and annual trends of insomnia among pregnant patients over a 12-year period from 2006 to 2017. In addition, we aimed to examine the interplay among insomnia, maternal comorbid conditions, and severe maternal morbidity (SMM) in the overall population and across race/ethnicity as well as community-level socioeconomic status. We hypothesized that the proportion of pregnancies that receive a coded diagnosis of insomnia has increased overtime and that racial/ethnic minorities and people of low community-level socioeconomic status would not only carry the largest burden of insomnia but would also experience higher cumulative incidence of associated morbidity.

Methods

Design, data source, and study sample

Using 2006–2017 annual data from the National Inpatient Sample (NIS), we conducted a 12-year serial cross-sectional analysis of pregnancy-related hospitalizations in the United States among birthing persons 15–49 years of age. The NIS is a product of the Agency for Healthcare Research and Quality's Healthcare Cost and Utilization Project (HCUP), a federal-state-industry partnership that constitutes the largest publicly available, all-payer inpatient database in the United States. As of 2017, over 4500 hospitals in 48 states contribute state-level hospital discharge (i.e. hospitalization) data that are compiled annually to create the NIS [25]. Each year, the NIS contains detailed information from 7 to 8 million hospitalizations (35 million when weighted) that approximates a 20% sample of all hospitalizations in the United States in non-federal, non-rehabilitation, and short-term community hospitals.

Prior to 2012, participating hospitals were stratified by five factors, namely, bed size, ownership, teaching status, urban or rural location, and US census region. Then a 2-stage cluster sampling design first selected hospitals as the primary sampling units (stage 1), and subsequently included all inpatient hospitalizations from the selected hospitals (stage 2) in the final annually compiled NIS database [26]. Beginning in 2012, the NIS sampling strategy was modified to select 20% of hospitalizations from all participating hospitals. Since sampling weights are used to generate national estimates, our analysis includes HCUP-supplied NIS-Trends files to account for changes in the sampling design, ensure consistency of sampling weights over time, and standardize covariate definitions across the study period [25, 26].

To identify diagnoses and procedures performed during each hospitalization, the NIS contains International Classification of Diseases, Ninth Edition, Clinical Modification (ICD-9-CM) codes capturing the principal diagnosis, up to 39 secondary diagnoses, and 15 data elements capturing therapeutic procedures performed. As of October 1, 2015, International Classification of Diseases, Tenth Edition, Clinical Modification (ICD-10-CM) codes were used. The study sample consisted of pregnancy-related hospitalizations of birthing persons aged 15–49 years, and we further differentiated between delivery and non-delivery hospitalizations during pregnancy using published algorithms based separately on a combination diagnosis-related group (DRG) classifiers and ICD-9-CM [27] and ICD-10-CM [28] codes. No data element in the study had more than 2% missingness in the study sample, except race/ethnicity for which we present the "missing/unknown" stratum as its own level.

Insomnia, severe maternal morbidity, and obstetric comorbidities

The primary exposure in the study was a binary indicator for a coded diagnosis of insomnia. For each pregnancy-related hospitalization, we scanned all diagnosis codes for any indication of insomnia (ICD-9: 307.40-307.42, 327.00-327.09, 780.51-780.52, V69.4-V69.5; ICD-10: F51.01-F51.09, F51.12, F51.9, G47.00-G47.09, and Z72.82, Z73.81), with code selection guided by the International Classification of Sleep Disorders [29] and the *Handbook of Sleep Medicine* [30].

The primary outcome of the study was a binary indicator for any severe maternal morbidity (SMM), using codes based on the CDC's classification rubric for identifying 18 conditions constituting SMM (Supplementary Table S1). Due to rare occurrences of certain SMM subtypes, and as we have done previously [31], we combined acute myocardial infarction and aneurysm into a

single indicator, and we combined cardiac arrest, ventricular fibrillation and conversion of cardiac rhythm into a single SMM subtype, also following the CDC rubric [32].

To assess and take into account each birthing person's comorbidity burden, we used an obstetric scoring system developed by Leonard et al [33] that was specifically designed for use with large administrative databases and was validated as a predictor of SMM. Obstetric-focused indices have shown improved ability to predict SMM relative to other comorbidity indices commonly used to assess comorbidity burden in non-pregnant patients (e.g. Elixhauser or Charlson index) [33, 34]. Twenty-seven individual comorbidities were used to assign an overall score representing obstetric comorbidity burden; similar to validation studies, score assignment was slightly different depending on the outcome: "any SMM" or a "non-blood transfusion (BT) SMM". The specific codes (ICD-9-CM and ICD-10-CM) used for insomnia, SMM subtypes, and each obstetric comorbidity are provided in Supplementary Table S1.

Other sociodemographic, clinical, and hospital covariates

In addition to clinical factors, the NIS databases also contain information on various patient sociodemographic and hospital of care characteristics. Each birthing person's age was classified in years as 15–19, 20–24, 25–29, 30–34, 35–39, and 40–49. Race/ethnicity was first grouped by ethnicity as Hispanic or non-Hispanic, with the non-Hispanic group further classified based on their race, namely, White, African American or Black, Asian/Pacific Islander, Native American, and other. The primary payer for the hospitalization (i.e. insurance status) was grouped into three categories: government (i.e. Medicare/Medicaid), private, and other (e.g. self-pay and charity). To serve as a proxy for community-level socioeconomic status, ZIP-code level estimates of median household income based on the patient's residence were grouped into quartiles. Hospital characteristics included US Census region (Northeast, Midwest, South, or West), bed size (small, medium, or large), and type (rural, urban non-teaching, or urban teaching).

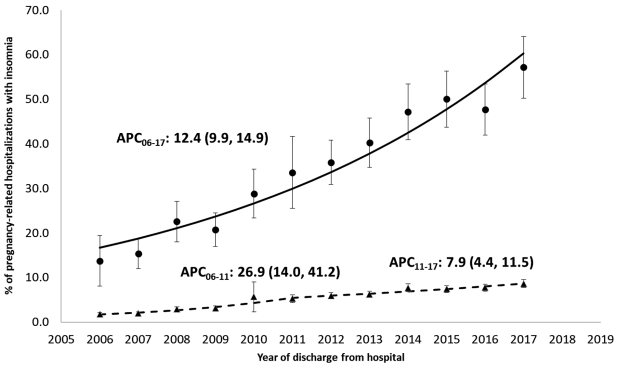

Figure 1. Temporal trends in the rate of a coded diagnosis of insomnia, per 10 000 hospitalizations, stratified by delivery versus other pregnancy-related hospitalizations, NIS 2006–2017. This figure describes the temporal trends in insomnia during the 12-year study period. The Y-axis refers to the insomnia rate per 10 000 hospitalizations. The X-axis refers to the year of discharge from the delivery hospitalization. Circular markers depict observed annual rates among non-delivery pregnancy-related hospitalizations; error bars represent the 95% CIs; the solid line represents the joinpoint regression-estimated trend. Triangular markers depict observed annual rates among delivery hospitalizations; error bars represent the 95% CIs; the dashed line represents the joinpoint regression-estimated trend. APC, annual percent change, expressed as the point estimate (95% CI).

Statistical analysis

Because no personal identifiers are included with the NIS, hospitalizations for the same person cannot be linked over time; therefore, the unit of analysis in NIS-based studies is the hospitalization, not the person. Descriptive statistics including frequencies and percentages were used to describe the distribution of patient and hospital characteristics across levels of the primary study exposure and outcome. The prevalence of insomnia was calculated as hospitalizations with a coded diagnosis of insomnia per 10 000 pregnancy-related hospitalizations, and we compared prevalence between delivery and non-delivery hospitalizations. To assess differences in comorbidity burden in birthing persons with and without insomnia, we compared the prevalence of each obstetric comorbidity between the two exposure groups. Since the SMM coding rubric is designed to be applied to delivery hospitalizations, we then compared the prevalence of SMM in delivery hospitalizations with and without a coded diagnosis of insomnia, overall and across other patient and hospital characteristics. In addition to the 18 individual SMM subtypes, we also calculated the prevalence of three summary indicators: "any SMM," "any non-BT SMM," and "only BT SMM."

We then used survey-weighted logistic regression to calculate odds ratios and 95% CI that estimate the association between insomnia and SMM. The outcome in all models was any indication of SMM. In addition to an unadjusted model, three multivariable models were run. The first multivariable model was adjusted for the following sociodemographic patient characteristics: age, race/ethnicity, payer, zip-code level income, and year of hospitalization. The second model included additional adjustments for hospital region and type. The third fully adjusted model included adjustment for the obstetric comorbidity index. Due to the relative rarity of both insomnia and individual SMM subtypes, we did not run separate models for each subtype.

Nearly half of all delivery hospitalizations with SMM had a BT as the only SMM subtype. Therefore, to assess whether BTs were driving the observed associations with insomnia, we performed a sensitivity analysis that re-ran all analyses after defining the outcome as at least one non-BT SMM subtype.

We also used joinpoint regression to estimate temporal trends in insomnia and SMM across the 12-year study period. Joinpoint regression is an analytic technique specifically designed to identify and characterize changes in the rate of events over time [35]. The algorithm first assumes the observed annual prevalence of the event follows a straight line, reflecting a model with no changes in the rate and having zero joinpoints. Then, joinpoints are added to the model iteratively, each joinpoint reflecting a change in the rate, and a Monte Carlo permutation test is used to assess whether the added joinpoint improves model fit [35]. Once a best-fitting model is selected, each joinpoint represents a statistically significant change in the trend and is characterized using an annual percent change (APC) metric.

Statistical analyses were performed with SAS, version 9.4 (SAS Institute, Inc., Cary, NC) and the Joinpoint Regression Program, version 4.8.0.1 [36]. All statistical tests were two-sided with a 5% type I error rate. In accordance with data suppression rules established by the Healthcare Cost and Utilization Project, counts based on 10 or fewer events are suppressed in tables and

figures. As our study utilized publicly available, de-identified hospital discharge data within the NIS database, it was deemed exempt by the University of South Florida Institutional Review Board. Data is available through the Healthcare Cost and Utilization Project at https://www.hcup-us.ahrq.gov.

Results

Prevalence and temporal trends of insomnia

Out of the nearly 47 million delivery hospitalizations during the 12-year study period, 24 625 patients had a coded diagnosis of insomnia, which corresponds to 1 case of insomnia in every 1923 deliveries, or a prevalence of 5.2 per 10 000 delivery hospitalizations. There were an additional 4.5 million non-delivery pregnancy-related hospitalizations during this same study period. Insomnia was more common among these non-delivery hospitalizations, with 14 991 patients receiving the diagnosis, corresponding to a prevalence of 32.9 per 10 000. Figure 1 displays the temporal trends in the prevalence of insomnia stratified by delivery and non-delivery hospitalizations. For delivery hospitalizations, the prevalence increased from 1.8 per 10 000 (95% CI: 1.3% to 2.2%) to 8.6 per 10 000 (95% CI: 7.7% to 9.5%) between 2006 and 2017. Joinpoint regression analyses estimated a statistically significant annual percent increase in the prevalence of insomnia of 26.9% (95% CI: 14.0% to 41.2%) for the period 2006–2011 and an increase of 7.9% (95% CI: 4.4% to 11.5%) for the period 2011–2017 for delivery-associated insomnia. Prevalence of insomnia in non-delivery hospitalizations increased from 13.7 per 10 000 (95% CI: 8.0% to 19.5%) to 57.2 per 10 000 (95%

Table 1. Frequency and prevalence of a coded diagnosis of insomnia among delivery and other pregnancy-related hospitalizations, stratified by patient and hospital characteristics, NIS, 2006–2017

	Delivery Hospitalizations				Other pregnancy-related hospitalizations			
Characteristic	N[a]	Insomnia	%[b]	Rate per 10 000	N[a]	Insomnia	%[b]	Rate per 10 000
Overall	46 975 745	24 625	100.0	5.2	4 555 956	14 991	100.0	32.9
Age								
15–19	3 806 115	1152	4.7	3.0	458 039	768	5.1	16.8
20–24	10 820 372	4244	17.2	3.9	1 170 718	2964	19.8	25.3
25–29	13 340 666	6766	27.5	5.1	1 229 878	4142	27.6	33.7
30–34	11 836 121	7094	28.8	6.0	988 094	4118	27.5	41.7
35–39	5 823 364	4174	17.0	7.2	543 074	2118	14.1	39.0
40–49	1 349 107	1196	4.9	8.9	166 153	879	5.9	52.9
Race/ethnicity								
NH-White	21 454 808	15 004	60.9	7.0	1 816 262	7802	52.0	43.0
NH-Black	5 847 931	2684	10.9	4.6	954 854	2729	18.2	28.6
Hispanic	9 164 464	2891	11.7	3.2	861 814	1708	11.4	19.8
Asian/PI	2 221 624	732	3.0	3.3	134 204	374	2.5	27.9
Native American	335 605	138	0.6	4.1	41 106	110	0.7	26.8
Other	1 969 711	698	2.8	3.5	174 760	472	3.1	27.0
Missing/not reported	5 981 602	2478	10.1	4.1	572 957	1797	12.0	31.4
Payer								
Government	20 542 096	10 576	42.9	5.1	2 339 101	8383	55.9	35.8
Private	23 575 681	12 787	51.9	5.4	1 788 959	5234	34.9	29.3
Other	2 857 968	1263	5.1	4.4	427 896	1374	9.2	32.1
Zip code-level income								
Lowest quartile	12 821 606	6020	24.4	4.7	1 540 224	4659	31.1	30.3
2nd quartile	11 641 662	6143	24.9	5.3	1 140 125	3702	24.7	32.5
3rd quartile	11 367 588	6554	26.6	5.8	999 517	3535	23.6	35.4
Highest quartile	10 350 571	5626	22.8	5.4	784 093	2811	18.8	35.8
Hospital census region								
Northeast	7 574 027	2634	10.7	3.5	753 561	2324	15.5	30.8
Midwest	10 027 131	5580	22.7	5.6	878 657	3453	23.0	39.3
South	17 890 675	9001	36.6	5.0	1 887 270	5974	39.8	31.7
West	11 483 911	7410	30.1	6.5	1 036 468	3241	21.6	31.3
Hospital bed size								
Small	6 142 592	3855	15.7	6.3	486 058	1762	11.8	36.3
Medium	13 147 431	6172	25.1	4.7	1 190 875	3436	22.9	28.9
Large	27 466 810	14 494	58.9	5.3	2 856 766	9731	64.9	34.1
Hospital type								
Rural	4 939 908	2495	10.1	5.1	420 844	1071	7.1	25.5
Urban, non-teaching	16 766 202	6502	26.4	3.9	1 450 762	3679	24.5	25.4
Urban, teaching	25 050 723	15 523	63.0	6.2	2 662 094	10 179	67.9	38.2

[a]Weighted to estimate national frequency; sum of all groups may not add up to the total because of missing data.
[b]Percentages are column percentages to show the distribution of that characteristic in the delivery and non-delivery groups

Table 2. Prevalence of obstetric comorbidities among pregnancy-related hospitalizations with and without a coded diagnosis of insomnia, NIS, 2006–2017

	Insomnia		No insomnia	
Obstetric comorbidity	N[a]	%[b]	N[a]	%[b]
Anemia, preexisting	6302	15.9	4 350 763	8.4
Asthma, acute or moderate-severe	1799	4.5	500 677	1.0
Connective tissue or autoimmune disease	298	0.8	108 275	0.2
Bariatric surgery	366	0.9	80 398	0.2
Bleeding disorder, pre-existing	721	1.8	404 517	0.8
Cardiac disease, pre-existing	1830	4.6	698 823	1.4
Chronic renal disease	730	1.8	437 327	0.8
Chronic hypertension	2779	7.0	1 333 840	2.6
Substance use disorder	9744	24.6	3 382 447	6.6
Gastrointestinal disease	9026	22.8	2 394 878	4.7
Gestational diabetes mellitus	2550	6.4	3 158 475	6.1
Human immunodeficiency virus	88	0.2	63 262	0.1
Major mental health disorder	21 186	53.5	2 825 558	5.5
Pre-eclampsia without severe features or gestational hypertension	3272	8.3	3 280 470	6.4
BMI 40+ at delivery	2024	5.1	1 233 718	2.4
Multiple gestation	1398	3.5	1 060 212	2.1
Neuromuscular disease	4221	10.7	318 742	0.6
Placenta accreta spectrum	93	0.2	146 026	0.3
Placenta previa complete or partial	426	1.1	334 585	0.6
Placental abruption	597	1.5	547 610	1.1
Pre-existing diabetes mellitus	1304	3.3	710 165	1.4
Previous cesarean delivery	5200	13.1	8 044 077	15.6
Preterm birth	2720	6.9	1 156 989	2.2
Pulmonary hypertension	124	0.3	24 282	0.0
Pre-eclampsia with severe features	1369	3.5	866 115	1.7
Thyrotoxicosis	229	0.6	120 443	0.2
Maternal age 35 years or older	8368	21.1	7 873 330	15.3

[a]Weighted to estimate national frequency.
[b]Percentages are the proportion of all pregnancy-related hospitalizations with a coded diagnosis of obstetric comorbidity.

CI: 50.3% to 64.1%) between 2006 and 2017, an average annual increase of 12.4% (95% CI: 9.9% to 14.9%).

Socio-demographic and clinical characteristics associated with insomnia

Table 1 displays socio-demographic and clinical characteristics of patients diagnosed with insomnia stratified by delivery and other pregnancy-related hospitalizations. Overall, the crude rate of insomnia was 6.3 times higher for non-delivery hospitalizations compared to delivery hospitalizations. In all pregnancy-related hospitalizations, there was an increasing prevalence of insomnia with increasing maternal age, with a 3-fold higher prevalence for patients 40–49 as compared to teenage mothers. NH-White patients tended to have the highest rates of insomnia, with the lowest rates observed in Hispanic patients. Compared to patients with private insurance, patients with government insurance had higher rates of insomnia when hospitalized prior to delivery (35.8 vs. 29.3 per 10 000); however, there was less of a difference in a coded diagnosis of insomnia among delivery hospitalizations (5.1 vs. 5.4 per 10 000). Insomnia diagnosis rates were consistently higher in patients receiving care at an urban teaching hospital compared to an urban non-teaching or rural hospital.

The prevalence of obstetric comorbidities among all pregnancy-related hospitalizations is presented in Table 2. Patients with insomnia had a higher prevalence of all except 2 of the 27 conditions assessed (placenta accreta spectrum, and previous cesarean delivery). Compared to those without an insomnia diagnosis, patients with insomnia had a substantially higher prevalence of neuromuscular disease (10.7% vs. 0.6%), major mental health disorders (53.5% vs. 5.5%), asthma (4.5% vs. 1.0%), and substance use disorder (24.6% vs. 6.6%).

Insomnia and severe maternal morbidity

Table 3 displays the cumulative incidence of 18 SMM conditions at delivery. Overall, patients with a diagnosis of insomnia experienced SMM at 2.6 times the prevalence of those without insomnia (4.3% vs. 1.6%). Over 58% of all SMM cases had blood transfusion as their only SMM subtype; therefore, we also modified the SMM definition to exclude those with a blood transfusion as their only SMM subtype. In that case, the SMM rates for patients with insomnia (2.4%) were 3.6 times higher than for patients without insomnia (0.7%). The increased risk conferred by insomnia varied across SMM subtypes; however, the most pronounced increases were observed for sepsis, respiratory distress syndrome, and thromboembolic disease, all of which had a 5-fold or higher increased risk in patients with insomnia. The increased rates of SMM for patients with insomnia were observed across all patient and hospital characteristics, except for patients delivered at a rural hospital among whom there was no difference in rates (Table 4).

Multivariable models

The adjusted odds ratios generated by survey-weighted logistic regression models and estimating the association between insomnia and SMM at delivery are presented in Table 5. The outcome in all models was any indication of SMM excluding those in which the only morbidity was a blood transfusion. After adjusting for sociodemographic and hospital characteristics, a coded diagnosis of insomnia at delivery was associated with 3.24 (95% CI = 2.72% to 3.87%) increased odds of SMM. Following further adjustment for the obstetric comorbidity index score, which was strongly associated with SMM, there remained a 24% increased likelihood of experiencing SMM for patients with insomnia at delivery: 1.24 (95% CI = 1.01% to 1.53%).

Temporal trends in severe maternal morbidity among patients with and without insomnia

Figure 2 displays the temporal trends in the rate of SMM (excluding those in which blood transfusion was the only morbidity) stratified by whether the patient received a coded diagnosis of insomnia at delivery. Among women without a diagnosis of insomnia, we observed a statistically significant

Table 3. Incidence of severe maternal morbidity among delivery hospitalizations with and without a coded diagnosis of insomnia, NIS, 2006–2017

	Insomnia		No insomnia	
Severe maternal morbidity subtype	N[a]	Rate per 10 000[b]	N[a]	Rate per 10 000[b]
Any SMM	1049	426.0 (366.2, 485.7)	756 726	161.2 (158.0, 164.3)
Any SMM (no BT)	594	241.3 (197.5, 285.1)	316 032	67.3 (66.0, 68.7)
Blood transfusion	638	259.1 (212.5, 305.6)	512 697	109.2 (106.4, 111.9)
Disseminated intravascular coagulation	117	47.6 (28.5, 66.7)	116 887	24.9 (23.9, 25.8)
Sepsis	88	35.6 (18.5, 52.6)	27 310	5.8 (5.6, 6.0)
Pulmonary oedema/acute heart failure	60	24.2 (10.5, 37.8)	23 858	5.1 (4.9, 5.3)
Respiratory distress syndrome	111	45.2 (26.2, 64.3)	35 072	7.5 (7.2, 7.7)
Acute renal failure	114	46.1 (27.2, 65.1)	32 939	7.0 (6.8, 7.3)
Hysterectomy	60	24.2 (10.5, 37.8)	46 389	9.9 (9.6, 10.2)
Eclampsia	59	24.0 (10.4, 37.6)	35 569	7.6 (7.3, 7.8)
Air and thrombotic embolism	44	17.9 (6.2, 29.5)	10 757	2.3 (2.2, 2.4)
Shock	32	13.0 (2.5, 23.5)	21 211	4.5 (4.4, 4.7)
Puerperal cerebrovascular disorders	34	13.8 (3.6, 24.0)	14 138	3.0 (2.9, 3.1)
Sickle cell with crisis	55	22.2 (9.0, 35.3)	6733	1.4 (1.3, 1.6)
Temporary tracheostomy/ventilation	45	18.3 (6.3, 30.2)	9015	1.9 (1.8, 2.0)
Cardiac arrest/ventricular fibrillation/conversion of cardiac rhythm	[c]	[c]	5451	1.2 (1.1, 1.2)
Acute myocardial infarction/aneurysm	[c]	[c]	2189	0.5 (0.4, 0.5)
Severe anesthesia complications	[c]	[c]	6217	1.3 (1.2, 1.4)
Heart failure/arrest during surgery or procedure	[c]	[c]	4541	1.0 (0.9, 1.1)
Amniotic fluid embolism	[c]	[c]	2081	0.4 (0.4, 0.5)
Only SMM was BT	455	184.7 (145.9, 223.4)	440 694	93.9 (91.5, 96.2)

[a]Weighted to estimate national frequency.
[b]Rates are the number of hospitalizations with a coded diagnosis of the severe maternal morbidity subtype per 10 000 delivery hospitalizations.
[c]In accordance with data suppression rules established by the healthcare cost and utilization project, counts and rates based on 10 or fewer events are suppressed.

4.1% (95% CI = 3.0% to 5.2%) annual increase in the rate of SMM between 2006 and 2014, followed by a 4.5 annual decrease (95% CI = −7.9 to −1.0) from 2014 to 2017. However, among women with insomnia, despite some variability in observed annual rates of SMM, joinpoint regressions estimated a statistically significant 11.0% annual increase in SMM prevalence (95% CI = 3.0% to 19.7%) during the 12-year study period.

Discussion

The results of this study define temporal trends of insomnia diagnosed during pregnancy-related hospitalizations in the United States from 2006 to 2017. Overall, we found that rates of a coded diagnosis of insomnia increased throughout the study period in both delivery and non-delivery hospitalizations. Rates of insomnia also increased with maternal age. We observed a strong association between insomnia and nearly all of the obstetric comorbidities identified in the study, and even after controlling for the overall obstetric comorbidity burden, found that the diagnosis of insomnia is an independent predictor of SMM at delivery.

The cause increase in insomnia diagnoses during the study period is likely multifactorial. It is reasonable to suspect that to some degree this is due to a true increased prevalence reflective of an obstetric population that is generally older with more prevalent obesity and comorbid conditions. Alternative effects must be considered. The transition from ICD-9 to ICD-10 may have influenced this phenomenon, however, this has not been studied in the literature. There has also been increased public education about the importance of sleep and the health impacts of sleep disorders as it relates to pregnancy. This increased awareness may have contributed to increased screening and recognition by prenatal providers resulting in higher capture through diagnosis codes.

Many of our findings are supported by existing literature regarding insomnia during pregnancy. The effect of insomnia on mental health outcomes during pregnancy and the postpartum period has on were all been well established [21, 23, 37, 38], and our investigation found insomnia increased the likelihood of co-existing major mental health disorders more than it did for other physical comorbidities. The increased association of sleep disturbances with maternal conditions such as preeclampsia and gestational hypertension were also supported by our findings [18, 39]. Additional demographic characteristics of women in our study offer important insight into the burden of insomnia on pregnancy. The rates of insomnia during pregnancy were substantially higher in all demographic subgroups for non-delivery hospitalizations compared with delivery hospitalizations at a greater than 6-fold increased prevalence overall. This difference suggests that exclusive examination of delivery hospitalizations is likely to severely underestimate the prevalence and burden of insomnia during pregnancy. This observation suggests a bias exists in diagnosing pregnant patients with insomnia: during a non-delivery hospitalization when a patient is receiving treatment for an uncontrolled condition or non-obstetric complication, insomnia is much more likely to be captured as a comorbidity. However, during a delivery hospitalization, especially with a routine intrapartum and postpartum course, providers are less likely to code for other conditions such as insomnia.

Table 4. Incidence of severe maternal morbidity among delivery hospitalizations with and without a coded diagnosis of insomnia, stratified by the patient and hospital characteristics, NIS, 2006–2017

	Insomnia			No insomnia		
Characteristic	N[a]	Any SMM	Rate per 10 000[b]	N[a]	Any SMM	Rate per 10 000[b]
Overall	24 625	1s049	4.3	46 951 120	756 726	1.6
Age						
15–19	1152	40	3.5	3 804 963	71 489	1.9
20–24	4244	127	3.0	10 816 129	171 151	1.6
25–29	6766	266	3.9	13 333 900	189 360	1.4
30–34	7094	317	4.5	11 829 027	179 335	1.5
35–39	4174	212	5.1	5 819 189	109 793	1.9
40–49	1196	88	7.3	1 347 911	35 598	2.6
Race/ethnicity						
NH-White	15 004	487	3.2	21 439 804	286 255	1.3
NH-Black	2684	244	9.1	5 845 247	152 831	2.6
Hispanic	2891	155	5.4	9 161 572	159 818	1.7
Asian/PI	732	35	4.8	2,220 892	34 860	1.6
Native American	138	5	3.6	335 467	7261	2.2
Other	698	33	4.8	1 969 013	35 250	1.8
Missing/not reported	2478	90	3.6	5 979 125	80 450	1.3
Payer						
Government	10 576	553	5.2	20 531 520	385 932	1.9
Private	12 787	472	3.7	23 562 894	321 437	1.4
Other	1263	24	1.9	2 856 706	49 357	1.7
Zip code-level income						
Lowest quartile	6020	288	4.8	12 815 587	248 630	1.9
2nd quartile	6143	257	4.2	11 635 519	186 216	1.6
3rd quartile	6554	270	4.1	11 361 033	165 189	1.5
Highest quartile	5626	215	3.8	10 344 946	139 591	1.3
Hospital census region						
Northeast	2634	120	4.6	7 571 393	134 523	1.8
Midwest	5580	228	4.1	10 021 550	141 773	1.4
South	9001	409	4.5	17 881 674	317 329	1.8
West	7410	292	3.9	11 476 502	163 101	1.4
Hospital bed size						
Small	3855	162	4.2	6 138 736	89 904	1.5
Medium	6172	213	3.5	13 141 259	207 779	1.6
Large	14 494	673	4.6	27 452 316	455 513	1.7
Hospital type						
Rural	2495	39	1.6	4 937 412	77 026	1.6
Urban, non-teaching	6502	165	2.5	16 759 699	219 914	1.3
Urban, teaching	15 523	844	5.4	25 035 199	456 256	1.8

[a]Weighted to estimate national frequency.
[b]Rates are the number of hospitalizations with a coded diagnosis of the severe maternal morbidity per 10 000 delivery hospitalizations.

This diagnostic bias allows us to infer the role of healthcare disparities in the diagnosis of insomnia. Rates of insomnia did not differ substantially among income quartiles. However, non-delivery hospitalizations had the highest rates of insomnia in patients without private insurance. As such, patients from these underserved communities during unplanned antepartum admissions may capture the true burden of insomnia during pregnancy. This is further supported by the fact that substantially higher rates of insomnia were coded in both delivery and non-delivery hospitalizations in patients receiving care in urban teaching hospitals, which tend to serve populations skewed toward lower socioeconomic groups. Existing data has supported that residents of densely-populated inner city areas are at higher risk of short sleep duration due to a multitude of factors including shift work, working multiple jobs, crowded living quarters, ambient noise, pollution, and greater levels of psychosocial stress, and these areas are typically inhabited by racial minorities [40, 41].

Beyond sociodemographic characteristics, women with insomnia have a higher cumulative incidence of obstetric comorbid conditions. Many of the conditions identified in this study—neuromuscular disease, asthma, obesity, substance use disorder—have plausible mechanisms by which they may cause or exacerbate insomnia. Alternatively, downstream effects of insomnia itself may play a role in the pathogenesis of certain conditions by altering immune and inflammatory responses [42].

Although treatment for prenatal insomnia is not directly addressed in this study, it is important for clinicians to be familiar with available therapies. Non-pharmacologic treatment—including improving sleep hygiene, night-time fluid restriction, and stimulant avoidance—is often recommended to patients to address mild sleep disturbances. Pharmacotherapy can also be safely considered when conservative measures are ineffective [43]. Cognitive behavioral

Table 5. Odds ratios and 95% CIs representing the association between coded diagnosis of insomnia and severe maternal morbidity, NIS, 2006–2017

Characteristic	Odds ratio (95% CI)		
	Model 1[a]	Model 2[b]	Model 3[c]
Insomnia			
Yes	3.33 (2.79, 3.97)	3.24 (2.72, 3.87)	1.24 (1.01, 1.53)
No	Reference	Reference	Reference
Age			
15–19	0.95 (0.92, 0.98)	0.96 (0.93, 0.99)	1.14 (1.10, 1.18)
20–24	0.88 (0.85, 0.90)	0.89 (0.86, 0.91)	0.97 (0.94, 0.99)
25–29	Reference	Reference	Reference
30–34	1.25 (1.22, 1.28)	1.23 (1.21, 1.26)	1.11 (1.08, 1.13)
35–39	1.69 (1.64, 1.73)	1.66 (1.61, 1.70)	1.19 (1.16, 1.22)
40–49	2.46 (2.37, 2.55)	2.40 (2.32, 2.49)	1.43 (1.38, 1.49)
Race/ethnicity			
NH-White	Reference	Reference	Reference
NH-Black	1.74 (1.68, 1.79)	1.62 (1.57, 1.67)	1.28 (1.24, 1.32)
Hispanic	1.03 (0.99, 1.07)	0.99 (0.95, 1.03)	1.15 (1.11, 1.19)
Asian/PI	1.07 (1.02, 1.12)	1.03 (0.98, 1.08)	1.26 (1.20, 1.32)
Native American	1.36 (1.21, 1.52)	1.38 (1.24, 1.54)	1.20 (1.09, 1.32)
Other	1.12 (1.07, 1.18)	1.08 (1.03, 1.13)	1.21 (1.15, 1.27)
Missing/not reported	1.09 (1.01, 1.18)	1.07 (1.00, 1.15)	1.08 (1.02, 1.16)
Payer			
Government	1.21 (1.18, 1.23)	1.21 (1.18, 1.24)	1.03 (1.00, 1.05)
Private	Reference	Reference	Reference
Other	1.09 (1.04, 1.13)	1.10 (1.05, 1.14)	1.06 (1.02, 1.11)
Zip code-level income			
Lowest quartile	1.19 (1.14, 1.23)	1.21 (1.17, 1.26)	1.06 (1.02, 1.10)
2nd quartile	1.12 (1.08, 1.16)	1.16 (1.12, 1.20)	1.06 (1.02, 1.10)
3rd quartile	1.07 (1.03, 1.11)	1.08 (1.05, 1.12)	1.03 (0.99, 1.06)
Highest quartile	Reference	Reference	Reference
Hospital census region			
Northeast		Reference	Reference
Midwest		1.03 (0.97, 1.09)	0.96 (0.91, 1.01)
South		1.05 (0.99, 1.10)	0.98 (0.94, 1.03)
West		1.04 (0.98, 1.10)	0.97 (0.92, 1.02)
Hospital type			
Rural		0.66 (0.62, 0.71)	0.84 (0.79, 0.89)
Urban, non-teaching		0.71 (0.68, 0.74)	0.87 (0.83, 0.90)
Urban, teaching			
Obstetric comorbidity index			1.05 (1.05, 1.05)

The outcome in all models was any indication of severe maternal morbidity, excluding those in which the only morbidity was a blood transfusion.
[a]Model 1 was run on all delivery-related hospitalizations and was adjusted for age, race/ethnicity, payer, zip-code level income, and year of hospitalization.
[b]Model 2 adjusted for the same variables as model 1 + hospital region and type.
[c]Model 3 adjusted for the same variables as model 2 + the obstetric comorbidity index.

therapy for insomnia (CBT-I) is a first-line, non-pharmacologic intervention for chronic insomnia that significantly decreases the severity and increases remission in pregnancy, however, this treatment is often inaccessible due to the need for subspecialty services

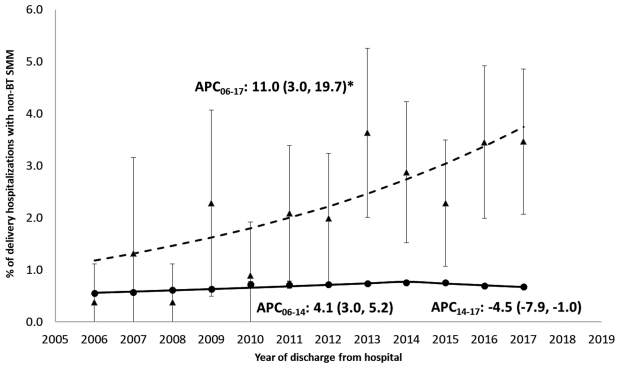

Figure 2. Temporal trends in the rate severe maternal morbidity* as a percentage of all delivery hospitalizations, stratified by coded diagnosis of insomnia, and NIS 2006–2017. This figure describes the temporal trends in SMM during the 12-year study period. The Y-axis refers to the SMM rate per 10 000 hospitalizations. The X-axis refers to the year of discharge from the delivery hospitalization. Circular markers depict observed annual rates among women without a coded diagnosis of insomnia; error bars represent the 95% CIs; the solid line represents the joinpoint regression-estimated trend. Triangular markers depict observed annual rates among women with a coded diagnosis of insomnia; error bars represent the 95% CIs; the dashed line represents the joinpoint regression-estimated trend. APC, annual percent change, expressed as the point estimate (95% CI). BT, blood transfusion; SMM, severe maternal morbidity (excludes women in which the only morbidity was a blood transfusion).

[44]. Two recent randomized trials demonstrated that internet-based digital CBT-I effectively reduced antenatal insomnia severity [45, 46]. Improved access to novel treatment modalities may address adverse outcomes related to severe insomnia in pregnancy as it relates to social determinants of health.

Strengths and limitations

The results of this study must consider limitations attributed to the administrative nature of the dataset being used. First, although the use of a large administrative database provides nationally representative data and statistical power to examine associations between relatively rare exposures and pregnancy outcomes, identification of conditions relies exclusively on ICD-9 and ICD-10 diagnosis codes. As such, data is subject to coding error as well as diagnostic bias in which providers minimize the number of diagnoses coded in patients with routine or non-complicated presentations.

Second, as previously discussed, the prevalence of insomnia estimated during pregnancy-related hospitalizations in this study is a significant underestimation of the true prevalence of insomnia during pregnancy. A population-based study of nearly 3000 women identified clinically significant insomnia by DSM-IV-TR criteria in 61% of pregnancies [47]. Meta-analysis of studies evaluating insomnia in the third trimester of pregnancy reports a prevalence of 42.4%, ranging from 12.3% to 61.9% [48]. As such, one would expect the potential impact of insomnia during maternal health to be substantially greater than our study suggests. Given the comparatively low prevalence of insomnia, our study results are more reflective of the effects of severe insomnia. The objective of this study was to estimate the prevalence of insomnia significant enough to receive a coded diagnosis during prenatal care. Such patients may have had a chronic diagnosis, experienced refractory symptoms, or required pharmacotherapy during pregnancy. In this respect, a third limitation arises in that we are unable to determine the severity of insomnia or the diagnostic criteria used based on coding alone.

Fourth, while the NIS database provides robust information to model obstetric comorbidity index and SMM, the cross-sectional nature of the data precludes us from establishing the temporal relationship between insomnia and the other conditions investigated in this study, which prevents us from making any conclusions regarding a causal relationship between insomnia and comorbid conditions. It also does not provide information about the duration or timing of the insomnia diagnosis.

Fifth, since the HCUP data have no identifiers which would otherwise facilitate the linkage of mothers and infants, neonatal data are unavailable for this analysis. Similarly, we are unable to distinguish whether two non-delivery hospitalizations are among two different people or two hospitalizations of the same person. While this limits the ability to extrapolate an estimate of insomnia prevalence at the level of the person, our aim of estimating coded inpatient prevalence of insomnia is still valid. Any inflation in inpatient prevalence of insomnia is important to consider since it suggests higher resource utilization among non-privately insured patients, which may reflect inadequate resources or treatment in the outpatient setting.

Lastly, race and ethnicity data as reported by the NIS should be interpreted with caution. Approximately 12% of race data was missing or not reported in our investigation. However, when stratified by race, the second highest rate of insomnia was identified in the group of uncategorized race, second only to non-Hispanic whites. The collection of race/ethnicity data is not standardized at a state level, thus variation may exist in reporting to NIS. Similarly, it is not able to be determined if the race is self-identified or assigned.

Despite the limitations, there are several noteworthy strengths. To our knowledge, this is the largest study assessing maternal outcomes among patients diagnosed with insomnia during pregnancy. Additionally, our study leverages coded diagnoses of insomnia to identify patients, whereas other similar large studies rely on symptoms alone to characterize patients with insomnia. This study provides a contemporary and racially and ethnically diverse sample that is expected to be generalizable to the general population of the United States.

Conclusions

Temporal trends in coded diagnoses of insomnia during pregnancy have increased. Priority should be given to further defining the burden of insomnia in pregnancy due to its association with maternal morbidity and its potential to magnify healthcare inequity. Our study is the largest, to date, exploring temporal trends and sociodemographic distribution of insomnia in pregnancy. The incorporation of SMM as it relates to comorbid insomnia at delivery is novel to the literature. Our results underscore the need for further studies and to address and treat insomnia during prenatal care.

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