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Trends and Outcomes for Deliveries with Hypertensive Disorders of Pregnancy from 2000 to 2018: A Repeated Cross-Sectional Study

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Abstract

OBJECTIVE: To analyze trends, risk factors, and outcomes related to hypertensive disorders of pregnancy (HDP).

DESIGN: Repeated cross sectional.

SETTING: US delivery hospitalizations.

POPULATION: Delivery hospitalizations in the 2000–2018 National Inpatient Sample.

METHODS: US hospital delivery hospitalizations with HDP were analyzed. Several trends were analyzed including: (i) the proportion of deliveries by year with HDP, (ii) the proportion of deliveries with HDP risk factors, and (iii) adverse outcomes associated with HDP including

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Details of ethics approval Use of these data was declared exempt from institutional review board approval given that it is de-identified and publicly available.

IRB approvals University of California, San Francisco Institutional Review Board (20–32165) and the Columbia University Institutional Review Board (IRB-AAAE8144).

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maternal stroke, acute renal failure, and acute liver injury. Risk ratios were determined using regression models with HDP as the exposure of interest.

MAIN OUTCOME MEASURE: Prevalence of HDP, risk factors for HDP, and associated adverse outcomes.

RESULTS—Of 73.1 million delivery hospitalizations, 7.7% had an associated diagnosis of HDP. Over the study period, HDP doubled from 6.0% of deliveries in 2000 to 12.0% in 2018. The proportion of deliveries with risk factors for HDP increased from 9.6% in 2000 to 24.6% in 2018. In adjusted models, HDP were associated with increased stroke (aRR (adjusted risk ratio) 15.9, 95% CI 14.8, 17.1), acute renal failure (aRR 13.8, 95% CI 13.5, 14.2), and acute liver injury (aRR 1.2, 95% CI 1.2, 1.3). Among deliveries with HDP acute renal failure and acute liver injury increased. In comparison, stroke decreased.

CONCLUSION—HDP increased in the setting of risk factors for HDP becoming more common while stroke decreased.

Tweetable abstract.—While hypertensive disorders of pregnancy increased from 2000 to 2018, stroke appears to be decreasing.

Keywords

Preeclampsia; hypertensive disorders of pregnancy; maternal safety; severe maternal morbidity

INTRODUCTION

Hypertensive disorders of pregnancy include gestational hypertension, preeclampsia, and eclampsia and contribute significantly to maternal morbidity and mortality. According to the Centers for Disease Control and Prevention, hypertensive disorders of pregnancy accounted for 6.6% of all US pregnancy-related deaths between 2014 and 2017.[1] Hypertensive disorders of pregnancy during delivery hospitalizations increased by 73% from 1993 to 2014 while chronic hypertension increased by 156%.[2,3] Maternal complications resulting from hypertensive disorders of pregnancy involve multiple organ systems and include stroke, acute renal failure, and acute liver injury.[4–7] Conditions associated with the development of hypertensive disorders of pregnancy include obesity, chronic hypertension, advanced maternal age, multiple gestations, and diabetes, all of which are common on a population basis.[8,9] With increasing underlying maternal comorbidity, related complications may be rising.[9–11]

To improve outcomes, the American College of Obstetricians and Gynecologists (ACOG) Task Force on Hypertension in Pregnancy released guidelines in 2013 that included recommendations for delivery timing and prompt administration of antihypertensive medications.[12–14] Data on outcomes following these recommendations are limited. While it is possible that some complications such as stroke may be decreasing with improved care, it is also possible complications may be increasing secondary to underlying comorbidity.

Given these knowledge gaps, the purposes of this study were to analyze (i) temporal trends in the prevalence of hypertensive disorders of pregnancy during delivery hospitalizations, (ii) trends in risk factors for hypertensive disorders of pregnancy, (iii) incidence of maternal

complications such as stroke, acute renal failure, and acute liver injury, and (iv) the association between hypertensive disorders of pregnancy and stroke, acute renal failure, and acute liver injury. We hypothesized that with risk factors for hypertensive disorders of pregnancy becoming increasingly common, hypertensive disorders of pregnancy and related complications were increasing on a population basis.

METHODS

Data Source

We utilized data from the United States National (Nationwide) Inpatient Sample (NIS) to conduct a repeated cross-sectional analysis of delivery hospitalizations from 2000 to 2018.[15] Assembled annually by the Agency for Healthcare Research and Quality's Healthcare Cost and Utilization Project, the NIS comprises a sample of approximately 20% of all hospitalizations and is one of the largest all-payer inpatient databases.[16] Until 2011, the NIS included all hospitalizations from individual hospitals in the sample and starting in 2012 the NIS switched to a systematic sampling design that draws proportionally from individual hospitals.[17–21]

Prior to the fourth quarter of 2015, the NIS utilized International Classification of Diseases, 9th Edition, Clinical Modification (ICD-9-CM) discharge coding. On October 1, 2015, coding transitioned to International Classification of Diseases, Tenth Revision, Clinical Modification (ICD-10-CM).[20] To perform analyses across the study period and coding change, ICD-9-CM codes were translated to ICD-10-CM codes using the publicly available General Equivalence Mappings SAS programming (Cary, NC) provided by the Centers for Medicare and Medicaid Services and the National Center for Health Statistics.[22]

Patient population

Our sample was restricted to delivery hospitalizations of women aged 15 to 54 years using approaches that identify deliveries with ICD-9-CM and ICD-10-CM coding.[23,24] Hospitalizations in the NIS can be weighted to be representative of the entire US population; [21] specific NIS weights for trends compatible with the 2012 sampling change were applied in this study to create estimates for the entire US population.[25]

Patients were classified as having hypertensive disorders of pregnancy based on the presence of diagnoses for preeclampsia, eclampsia, and gestational hypertension (Table S1). Diagnoses were ordered into hierarchical, non-overlapping categories as follows: (i) preeclampsia with severe features (including superimposed preeclampsia with severe features) or eclampsia, (ii) superimposed preeclampsia without severe features, (iii) preeclampsia without severe features, and (iv) gestational hypertension.

Demographic and clinical factors were identified using NIS data fields and diagnosis codes. Demographic factors within the NIS included maternal age (15–19, 20–24, 25–29, 30–34, 35–39, 40–54 years old), payer (Medicare, Medicaid, private, self-pay, no charge, other), median ZIP code income quartile (quartile 1 (lowest) to quartile 4 (highest)), and maternal race (non-Hispanic White, non-Hispanic Black, Hispanic, other, and unknown). Clinical factors included in the analysis were obesity, chronic hypertension, pre-gestational and

gestational diabetes, systemic lupus erythematosus, chronic kidney disease, asthma, and multiple gestation.

Study objectives and outcomes

This study had four main objectives and one ancillary objective. The first objective was to determine temporal trends in the prevalence of hypertensive disorders of pregnancy diagnoses during delivery hospitalizations. Trends in overall prevalence for hypertensive disorders of pregnancy were analyzed. Temporal trends were also analyzed for the following hierarchically-defined, non-overlapping diagnoses: (i) eclampsia/preeclampsia with severe features, (ii) superimposed preeclampsia without severe features, (iii) preeclampsia without severe features, and (iv) gestational hypertension.

The second objective was to analyze trends in the proportion of deliveries that had ≥2 moderate and/or ≥1 high-risk factors for hypertensive disorders of pregnancy as defined by the ACOG Practice Bulletin for Gestational Hypertension and Preeclampsia.[26] High-risk factors include multiple gestation, chronic hypertension, pre-gestational diabetes, chronic kidney disease, and systemic lupus erythmatosus. Moderate risk factors included obesity, non-Hispanic Black race, low socioeconomic status based on ZIP code income quartile or Medicaid receipt, and advanced maternal age (defined as ≥35 years of age). History of preeclampsia and other prior adverse pregnancy outcomes could not be evaluated due to inherent limitations in cross-sectional administrative data coding.

The third objective was to evaluate temporal trends in the incidence of three maternal complications: 1) stroke (including ischemic and hemorrhagic stroke), 2) acute renal failure, and 3) acute liver injury during delivery hospitalizations. These complications were selected from prior studies and converted to ICD-10 in the methods noted above (Table S1).[27–29] For this objective, we calculated the proportion of deliveries by year complicated by maternal stroke, acute renal failure, and acute liver injury, stratified by the presence or absence of hypertensive disorders of pregnancy.

The fourth objective was to create adjusted models for maternal stroke, acute renal failure, and acute liver injury in the presence or absence of hypertensive disorders of pregnancy during delivery hospitalizations accounting for demographic and clinical factors.

As an ancillary analysis, we sought to determine to what degree risk factors accounted for changing incidence of hypertensive disorders of pregnancy. We compared whether estimates for hypertensive disorders of pregnancy over the study period changed after accounting for demographic, clinical, and hospital factors.

Statistical analysis

For the first objective evaluating trends in the prevalence of hypertensive disorders of pregnancy, we determined the proportion of deliveries by year with a preeclampsia, eclampsia, or gestational hypertension diagnosis. Additionally, we determined the proportion of deliveries each year with the following hierarchical, non-overlapping diagnosis categories: (i) preeclampsia with severe features or eclampsia, (ii) superimposed preeclampsia, (iii) preeclampsia without severe features, and (iv) gestational hypertension.

Additionally, we conducted trends analyses using the National Cancer Institute's Joinpoint Regression Program (version 4.8.0.1).[30–33] This program allows identification of when a trend change is produced and calculates the annual percentage change in rates between trend-change points. The program creates estimates for the average annual percentage change (AAPC) with 95% confidence intervals in the whole period studied which may be useful in interpreting trends in outcomes and clinical practice. The AAPC is derived by first estimating the underlying joinpoint model that best fits the data. The AAPC is calculated using a weighted average of the slope coefficients of the underlying joinpoint regression line with the weights equal to the length of each segment.[34,35] Joinpoint trend analysis is commonly used to assess changes in trends that may occur in the setting of policy changes.[33] For the first objective, joinpoint trend analysis was performed using weighted data for overall risk for hypertensive disorders of pregnancy (any preeclampsia, eclampsia, or gestational hypertension diagnosis) and then individually for (i) preeclampsia with severe features or eclampsia, (ii) superimposed preeclampsia, (iii) preeclampsia without severe features, and (iv) gestational hypertension.

For the second objective, we determined the proportion of deliveries by year that had ≥2 moderate and/or ≥1 high-risk factors factors defined by ACOG.[26] We performed joinpoint analyses for deliveries to characterize trends in the presence of risk factors.

For the third objective, we determined the proportion of deliveries by year complicated by (i) maternal stroke, (ii) acute renal failure, and (iii) acute liver injury stratified by the presence or absence of hypertensive disorders of pregnancy. Additionally, we performed joinpoint analysis for each of these outcomes stratified by the presence or absence of hypertensive disorders of pregnancy. We hypothesized *a priori* that there would be a decrease in AAPC in stroke, with a trend change point identified sometime between 2013 and 2015, concurrent with release of ACOG Task Force recommendations regarding management of acute hypertension.

For the fourth objective, we developed unadjusted and adjusted survey weighted log-linear regression models with Poisson distribution and log link with robust error variance[36] to evaluate the association between the presence of hypertensive disorders of pregnancy during delivery hospitalizations and stroke, acute liver injury, and acute renal failure. We calculated unadjusted and adjusted risk ratios (RR and aRR, respectively) with 95% confidence intervals (CIs) as measures of association. Log-Poisson regression models with sandwich estimators under the generalized estimation equation framework, also known as robust Poisson models, correct for over dispersion (inflated variance) compared to standard Poisson models. Robust Poisson may be preferred over a log-binomial approach because robust Poisson is less sensitive to outliers.[37,38] Models were adjusted for demographic and clinical factors including maternal age, payer, median ZIP code income quartile, maternal race obesity, chronic hypertension (without a superimposed preeclampsia diagnosis), pre-gestational and gestational diabetes, systemic lupus erythematosus, chronic kidney disease, asthma, and multiple gestation. We performed two sets of models: (i) the first model included hypertensive disorders as a dichotomous variable and (ii) the second model included individual diagnoses including preeclampsia with severe features

or eclampsia, superimposed preeclampsia, preeclampsia without severe features, and gestational hypertension.

For the ancillary analysis determining how risk for hypertensive disorders in pregnancy changed over the study period accounting for demographic, hospital, and clinical factors, we created unadjusted and adjusted log-linear regression models with Poisson distribution with hypertensive disorders in pregnancy as the outcome accounting for demographic, clinical, and hospital factors; we sought to determine if adjusted likelihood of hypertensive disorders in later study years accounting for risk factors was lower than in unadjusted models not accounting for risk factors.

Demographic and clinical factors in the population were compared based on the presence or absence of hypertensive disorders of pregnancy by calculating the absolute standardized mean difference (SMD)[39] with a value of >10% (>0.1) considered as a meaningful magnitude of difference between each subgroup. All analyses were performed with SAS 9.4 (Cary, NC) and the National Cancer Institute's Joinpoint regression program. We adhered to the Strengthening the Reporting of Observational Studies in Epidemiology guidelines for cross-sectional studies for this analysis.[40] Given the de-identified and publicly available nature of the data, this study obtained exemptions from university institutional review boards.

RESULTS

This analysis included an estimated 73.1 million delivery hospitalizations from 2000 to 2018 of which 5.6 million (7.7%) had an associated hypertensive disorder of pregnancy diagnosis. The proportion of delivery hospitalizations with a hypertensive disorder of pregnancy diagnosis approximately doubled from 603 per 10,000 delivery hospitalizations in 2000 to 1,196 per 10,000 delivery hospitalizations in 2018 (Table 1) representing an average annual percent change of 3.8% (95% CI 3.4%, 4.2%) over the full study period (Figure 1). Of patients with hypertensive disorders of pregnancy, superimposed preeclampsia and preeclampsia with severe features underwent the largest annual increases (287% overall increase from 2000 to 2018 (AAPC 7.6%, 95% CI 7.1%, 8.2%) and 198% overall increase from 2000 to 2018 (AAPC 6.1%, 95% CI 5.6%, 6.6%), respectively). Smaller relative annual increases were present for gestational hypertension (AAPC 4.0%, 95% CI 3.4%, 4.5%) and preeclampsia without severe features (AAPC 1.3%, 95% CI 0.7%, 2.0%) (Table S2).

Hypertensive disorders of pregnancy occurred more frequently among non-Hispanic Black patients compared to non-Hispanic White patients (10.6% versus 8.0%, SMD 18.1% for maternal race) (Table 1). Hypertensive disorders of pregnancy were also significantly more common among patients with chronic hypertension (SMD 17.4%), obesity (SMD 29.7%), pre-gestational (SMD 14.6%) and gestational diabetes (SMD 15.2%), and multiple gestations (SMD 16.1%).

Over the study period, risk factors for hypertensive disorders of pregnancy increased in the study population. The proportion of all deliveries with ≥2 moderate and/or ≥1 high-risk

factors increased from 9.6% in 2000 to 24.6% in 2018 (AAPC 5.7%, 95% CI 5.2%, 6.2%) (Figure S1, Table S2).

Unadjusted risk ratios for stroke (RR 15.1, 95% CI 14.1, 16.2), acute renal failure (RR 17.6, 95% CI 17.3, 18.0), and acute liver injury (RR 1.6, 95% CI 1.6, 1.6) were all increased in the setting of hypertensive disorders of pregnancy (Table 2, Table S3). In models adjusting for demographic and clinical factors, hypertensive disorders of pregnancy retained a significant association with stroke (aRR 15.9, 95% CI 14.8, 17.1), acute renal failure (aRR 13.8, 95% CI 13.5, 14.2), and acute liver injury (aRR 1.2, 95% CI 1.2, 1.3).

Evaluating temporal trends over the study period (Figure 2), incidence of stroke decreased significantly among patients with hypertensive disorders of pregnancy over the study period (AAPC −4.6%, 95% CI −8.8%, −0.3%). However, this decrease was not consistent over the study period. From 2000 until the trend change point in 2013 risk did not change significantly (AAPC 2000–2013 0.9%, 95% CI −2.4%, 4.2%). (Figure 2). From 2013 on, stroke decreased significantly for deliveries with hypertensive disorders of pregnancy (AAPC 2013–2018 −17.6%, 95% CI −29.3%, −3.9%) For deliveries without hypertensive disorders of pregnancy, stroke did not change significantly from 2000–2018 (AAPC 1.5%, 95% CI −3.7%, 7.1%).

In comparison to stroke, acute renal failure increased over the study period. In the presence of hypertensive disorders of pregnancy, acute renal failure increased from 14.8 diagnoses per 10,000 delivery hospitalizations in 2000 to 65.7 diagnoses per 10,000 delivery hospitalizations in 2018 (AAPC 9.9%, 95% CI 8.5%, 11.4%) (Figure 3). In the absence of hypertensive disorders of pregnancy acute renal failure increased from 0.4 diagnoses 10,000 delivery hospitalizations in 2000 to 5.8 diagnoses per 10,000 delivery hospitalizations in 2018 (AAPC 9.9%, 95% CI: 8.5%, 11.4%). Acute liver injury also increased during delivery hospitalizations with and without hypertensive disorders of pregnancy with the AAPC demonstrating significant increases for both groups (AAPC 15.1%, 95% CI 11.6%, 18.7% and AAPC 17.8%, 95% CI 14.5%, respectively) (Figure 4).

In the ancillary analysis evaluating risk for hypertensive disorders in pregnancy accounting for clinical, demographic, and hospital factors, risk ratio estimates were attenauted in the later years of the study in adjusted versus unadjusted models supporting that the changing prevalence of risk factors accounted for some proportion of increasing diagnoses (Table 1). For example comparing hypertensive disorders in pregnancy in 2018 to 2000, adjusted risk ratios demonstrated a lower estimate (RR 1.68, 95% CI 1.67, 1.68) than unadjusted risk ratios (RR 2.00, 95% CI 1.99, 2.01).

DISCUSSION

Key Findings

In this nationally representative sample, hypertensive disorders nearly doubled from 2000 to 2018. Over this study period, preeclampsia with severe features and superimposed preeclampsia demonstrated the largest average annual percent changes. High and moderate-risk factors for hypertensive disorders of pregnancy also increased over the study period.

Both acute renal failure and acute liver injury increased among women with hypertensive disorders of pregnancy. However, stroke decreased over the study period; while the AAPC for stroke was not significant from 2000 to 2013, from 2013 on large decreases in stroke were noted.

Clinical Implications

There are two primary clinical implications from this study's findings. First, this study found that hypertensive disorders of pregnancy increased on a population basis in recent years, with preeclampsia with severe features and superimposed preeclampsia demonstrating the largest increases. These findings coincide with the finding that moderate and high-risk factors for hypertensive disorders of pregnancy have increased over the same time period and were associated with increased risk over the study period.[3,41–47] Accounting for these risk factors, temporal increases in hypertensive disorders were attenuated. These findings underscore the importance of determining the efficacy of preeclampsia prevention with aspirin, researching new means to prevent hypertensive disorders of pregnancy in moderate-to-high risk populations, and reducing the prevalence of risk factors for hypertensive disorders in pregnancy such as obesity. [14,48–53]

Second, this study found that despite increasing proportions of superimposed preeclampsia and preeclampsia with severe features, stroke decreased from 2013 to 2018 among women with hypertensive disorders of pregnancy. This decrease occurred in the setting of increased risk for acute renal failure and liver injury. The decrease in stroke is concurrent with release in 2013 of recommendations from the ACOG Task Force on Hypertension that support urgent administration of anti-hypertensives to treat severe-range blood pressures.[12] These recommendations were followed by the hypertension bundle and recommendations from the National Partnership for Maternal Safety and Alliance for Innovation on Maternal Health.[54,55]There is evidence from other large administrative datasets that during this period use of anti-hypertensive medications during delivery hospitalizations increased substantially.[56] These findings support the possibility that stroke is decreasing secondary to improved clinical management. Hypertension is the leading cause of stroke during pregnancy,[5] and timely identification of severe-range blood pressures and initiation of anti-hypertensive therapy may reduce likelihood of this complication.[12] As there are not well defined clinical interventions to reduce acute renal failure and liver failure, these outcomes increased, an expected finding given the increasing proportion of preeclampsia with severe features.

Strengths and Limitations

There are several important limitations to consider when evaluating this study. First, inherent limitations of administrative data include possible misclassification and under-ascertainment.[57] It is possible that the increase in hypertensive disorders of pregnancy could be secondary to more frequent ascertainment of less severe disease and decreasing stroke risk could be secondary to sampling a lower-risk population. However, if that were the case, the finding of increasing preeclampsia with severe features and rising risk for acute liver injury and acute renal failure would be unexpected.[14,58–60] Additionally, the overall obstetric population analyzed had increasing likelihood of moderate and high-risk

factors for hypertensive disorders of pregnancy. It is likely that secondary diagnoses such as obesity were poorly ascertained as estimates were well below what is noted from clinical data in the general population. A second limitation of this dataset is that the NIS samples hospitalizations cross-sectionally, and we cannot account for multiple delivery hospitalizations for an individual woman. Third, this study period cannot assess for population-level effects of routine use of aspirin for preeclampsia prevention. Fourth, the database used in this survey only includes hospital discharge data, and thus we were unable to assess outpatient management decisions, prescription receipts, prior hospitalizations or clinical visits, and whether complications developed before hospitalization. Fifth, the sampling design change in 2012 and the coding changes in 2015 may have affected trends. After the switch to ICD-10-CM in 2015, the number of codes increased from around 18,000 to more than 140,000.[61] The ICD-10-CM includes five-times more diagnostic codes and 19-times more procedural codes than in ICD-9-CM[61] and translations between ICD-9-CM and ICD-10-CM are not exact. Sixth, while we identified that stroke decreased contemporaneously with the release of ACOG Hypertension Task Force recommendations, we are unable to analyze antihypertensive administration or control for other practice and policy changes that may have occurred simultaneously. Seventh, this study found a significant increase in acute liver injury among diagnoses among women without hypertensive diagnoses of pregnancy. Because of lack of clinical detail we are not able to determine the cause of these trends. The codes for acute liver injury are non-specific and likely include cases of cholecystitis, cholelithiasis, and cholestasis of pregnancy as well as liver and biliary conditions unrelated to hypertensive disorders of pregnancy. It is possible that the trends we observed may be increasing secondary to other diagnoses such as obesity which are associated with hepatic and biliary conditions such as non-alcoholic steatohepatitis and cholecystitis. Eighth, we were not able to query for all risk factors for hypertensive disorders of pregnancy; specifically, we were unable to ascertain history of preeclampsia and other adverse pregnancy outcomes. Ninth, a significant proportion of stroke occurs postpartum after discharge; we did not analyze these outcomes in this analysis. Tenth, ACOG Hypertension Task Force recommendations released during the study period formalized approaches to hypertensive disorders in pregnancy diagnoses that may have affected ascertainment and trends. The main strengths of this paper include that we used a large database appropriate for analyzing disease burden and population trends, that we were able to analyze a meaningful number of relatively rare outcomes, and that a relatively long study period was included.

CONCLUSION

In conclusion, this study found increasing hypertensive disorders of pregnancy in general and preeclampsia with severe features and superimposed preeclampsia in particular from 2000 to 2018. Risk factors for hypertensive disorders of pregnancy also increased over time on a population basis. In the context of these trends, acute renal failure and acute liver injury increased, whereas stroke decreased after 2013, concurrent with release of ACOG Hypertension Task Force guidelines.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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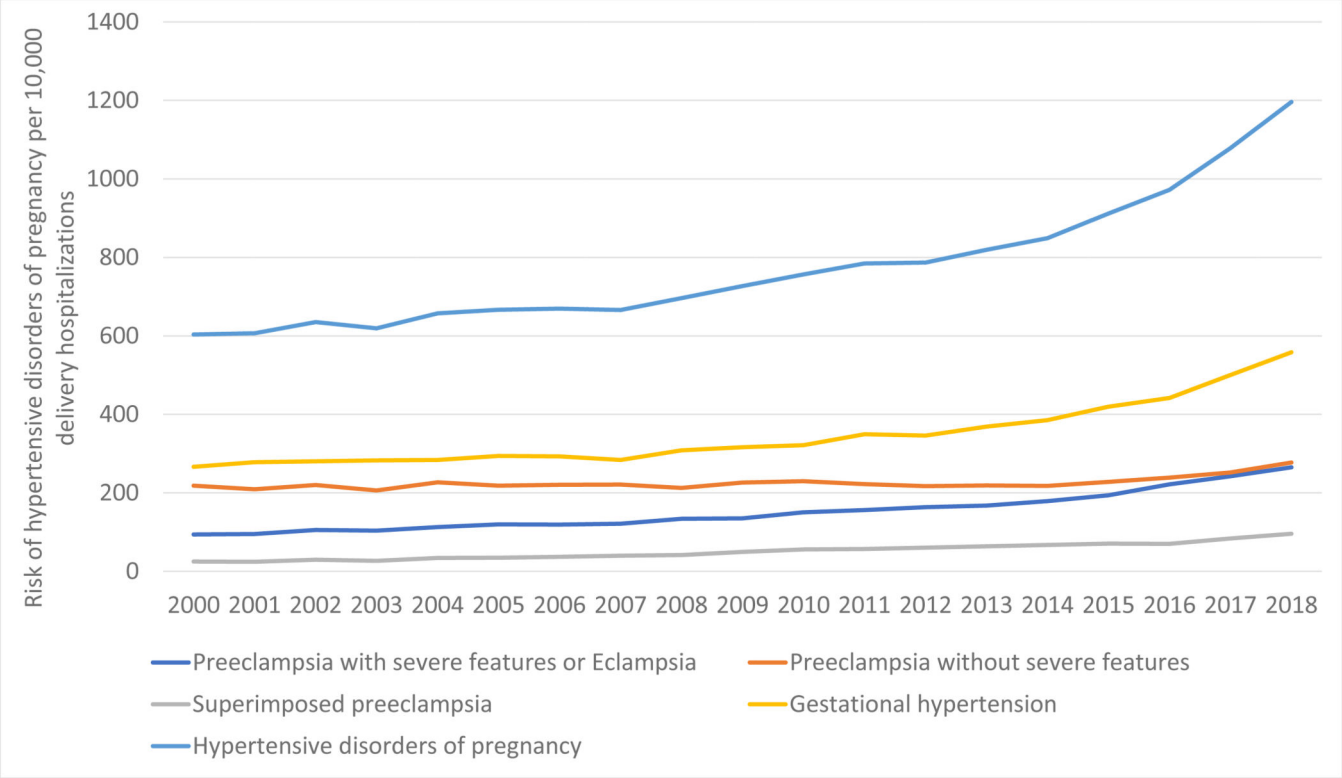

Figure 1. Prevalence of hypertensive disorders of pregnancy diagnosis during delivery hospitalizations by year

The figure demonstrates risk of hypertensive disorders of pregnancy per 10,000 delivery hospitalizations by year.

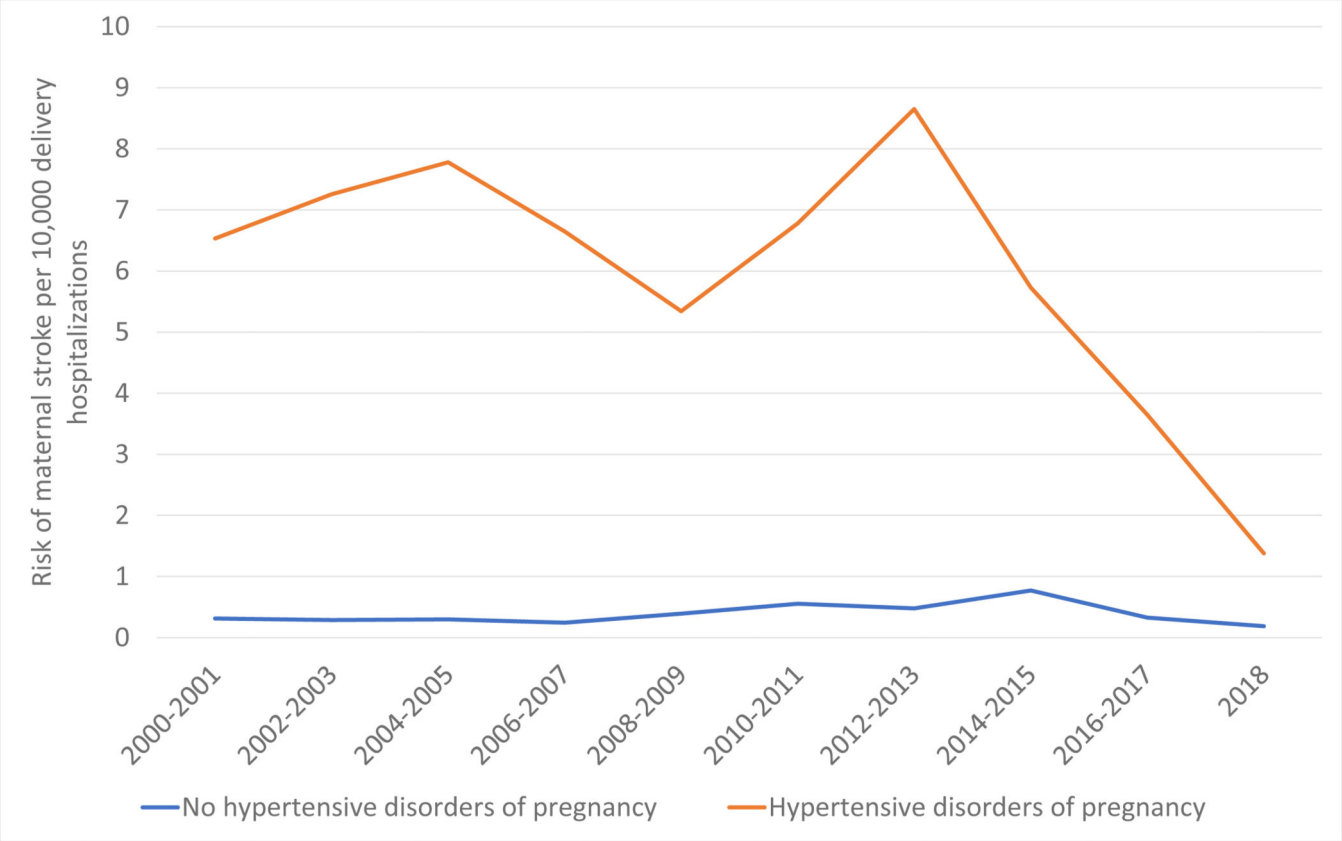

Figure 2. Incidence of stroke diagnosis during delivery hospitalization stratified by presence or absence of hypertensive disorders of pregnancy

The figure demonstrates risk of stroke per 10,000 delivery hospitalizations by year stratified by presence or absence of hypertensive disorders of pregnancy.

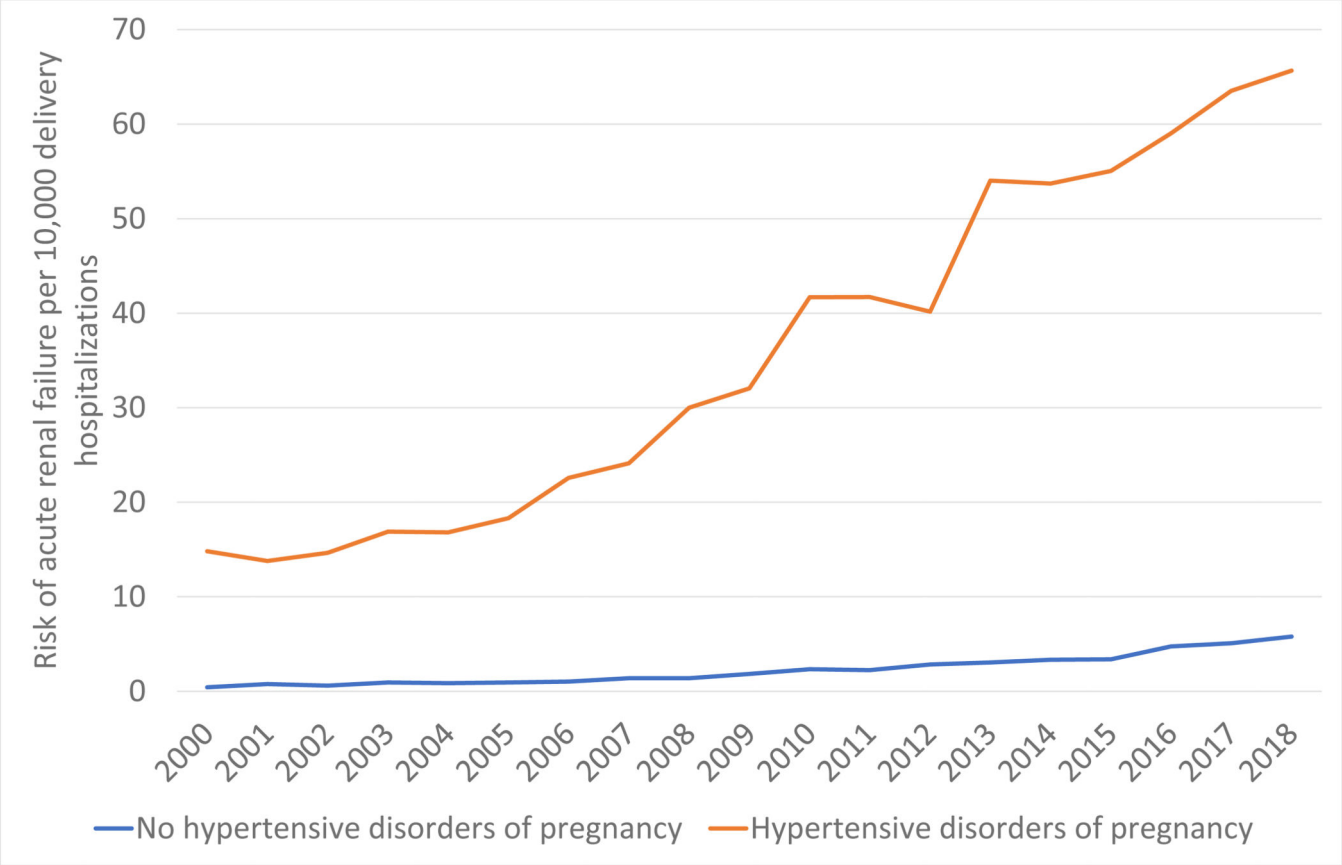

Figure 3. Incidence of acute renal failure diagnosis at delivery hospitalization stratified by presence or absence of hypertensive disorders of pregnancy

The figure demonstrates risk of acute renal failure per 10,000 delivery hospitalizations by year stratified by presence or absence of hypertensive disorders of pregnancy.

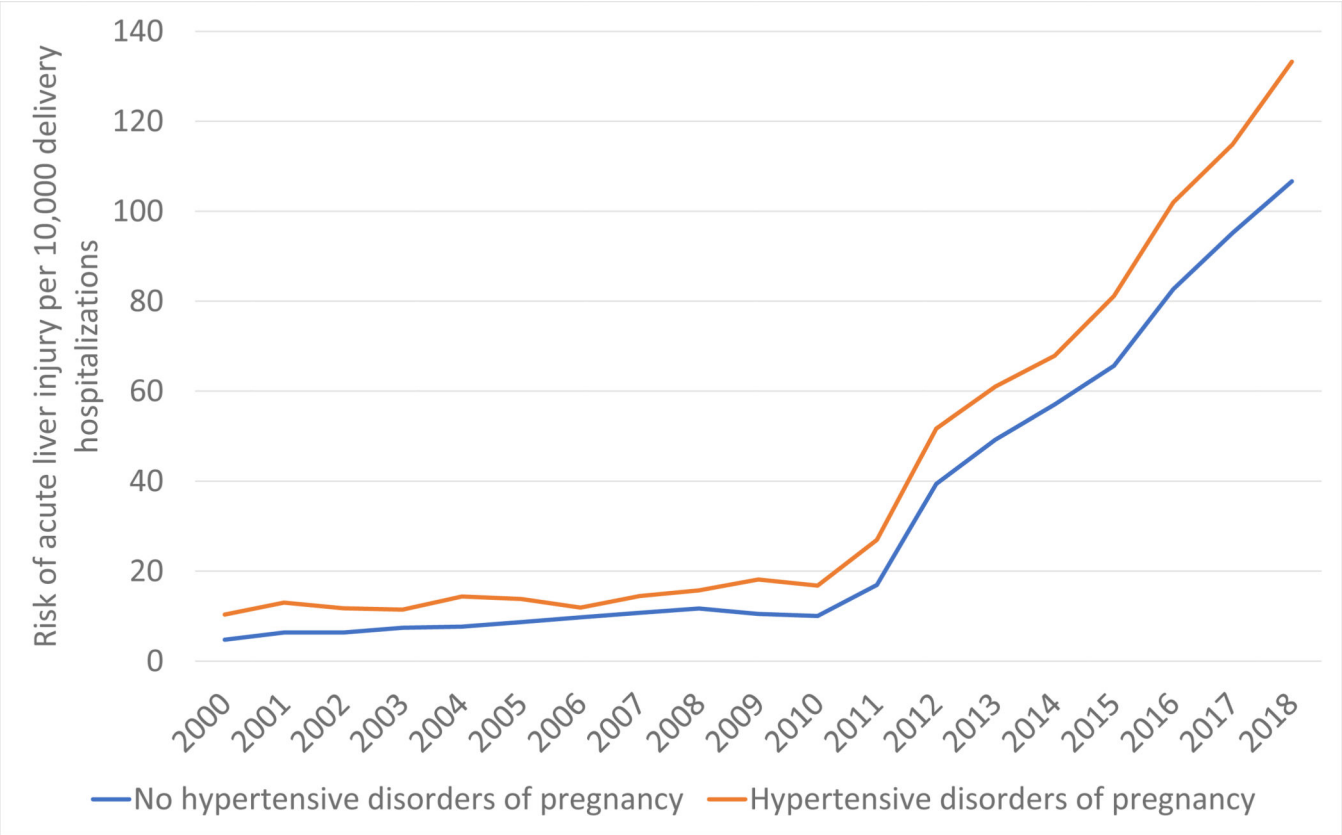

Figure 4. Incidence of acute liver injury diagnosis at delivery hospitalization stratified by presence or absence of hypertensive disorders of pregnancy

The figure demonstrates risk of acute liver injury per 10,000 delivery hospitalizations by year stratified by presence or absence of hypertensive disorders of pregnancy

Table 1.

Characteristics of study population and unadjusted and adjusted models for hypertensive disorders of pregnancy

	HDP Absent		HDP Present		Standardized mean difference	Unadjusted model for HDP		Adjusted model for HDP	
	N	%	N	%					
Year						RR	95% CI	aRR	95% CI
2000	3,584,657	5.3%	230,192	4.1%	22.2%	Reference		Reference	
2001	3,522,301	5.2%	227,492	4.0%		1.01	1.00, 1.01	1.02	1.02, 1.03
2002	3,655,477	5.4%	247,928	4.4%		1.05	1.05, 1.06	1.08	1.07, 1.08
2003	3,623,009	5.4%	239,054	4.3%		1.03	1.02, 1.03	1.00	0.99, 1.00
2004	3,736,127	5.5%	262,872	4.7%		1.09	1.08, 1.10	1.06	1.05, 1.06
2005	3,742,218	5.6%	267,123	4.8%		1.11	1.10, 1.11	1.08	1.07, 1.08
2006	3,788,734	5.6%	271,770	4.8%		1.11	1.11, 1.12	1.08	1.07, 1.08
2007	4,040,276	6.0%	288,264	5.1%		1.11	1.10, 1.11	1.05	1.04, 1.05
2008	3,732,689	5.5%	279,350	5.0%		1.16	1.15, 1.16	1.09	1.08, 1.09
2009	3,632,423	5.4%	284,643	5.1%		1.21	1.20, 1.21	1.14	1.13, 1.14
2010	3,406,362	5.1%	278,789	5.0%		1.26	1.25, 1.27	1.16	1.15, 1.16
2011	3,361,162	5.0%	286,030	5.1%		1.31	1.30, 1.31	1.19	1.18, 1.20
2012	3,454,661	5.1%	295,015	5.2%		1.31	1.30, 1.32	1.18	1.18, 1.19
2013	3,422,533	5.1%	305,490	5.4%		1.37	1.36, 1.37	1.22	1.21, 1.23
2014	3,463,180	5.1%	321,245	5.7%		1.42	1.41, 1.42	1.25	1.24, 1.26
2015	3,397,370	5.0%	340,695	6.1%		1.51	1.50, 1.52	1.32	1.31, 1.33
2016	3,414,826	5.1%	367,660	6.5%		1.59	1.58, 1.60	1.39	1.38, 1.40
2017	3,303,661	4.9%	399,170	7.1%		1.80	1.79, 1.81	1.53	1.52, 1.54
2018	3,200,494	4.7%	434,850	7.7%		2.00	1.99, 2.01	1.68	1.67, 1.68
Age Category									
15–19 years old	5,796,862	8.6%	562,469	10.0%	5.1%	1.19	1.18, 1.19	1.32	1.32, 1.33
20–24 years old	15,769,153	23.4%	1,296,384	23.0%		1.03	1.03, 1.03	1.07	1.07, 1.07
25–29 years old	18,898,822	28.0%	1,502,206	26.7%		Reference		Reference	
30–34 years old	16,947,746	25.1%	1,325,350	23.6%		0.99	0.98, 0.99	0.97	0.97, 0.97
35–39 years old	8,241,534	12.2%	725,773	12.9%		1.10	1.10, 1.10	1.06	1.06, 1.06

	HDP Absent		HDP Present		Standardized mean difference	Unadjusted model for HDP		Adjusted model for HDP	
	N	%	N	%					
Year						RR	95% CI	aRR	95% CI
40–54 years old	1,828,044	2.7%	215,447	3.8%		1.43	1.43, 1.44	1.35	1.34, 1.35
Payer Status									
Medicare	380,797	0.6%	42,477	0.8%	6.5%	1.28	1.27, 1.29	1.02	1.01, 1.03
Medicaid	27,865,068	41.3%	2,311,254	41.1%		0.98	0.98, 0.98	0.88	0.88, 0.88
Private Insurance	35,125,766	52.1%	2,972,867	52.8%		Reference		Reference	
Self-pay	2,106,052	3.1%	133,502	2.4%		0.76	0.75, 0.76	0.80	0.79, 0.80
No Charge	124,605	0.2%	9,691	0.2%		0.91	0.9, 0.93	0.98	0.96, 1.00
Other	1,767,495	2.6%	148,757	2.6%		0.99	0.99, 1.00	0.95	0.95, 0.96
Missing	112,378	0.2%	9,081	0.2%					
Median Income Quartile by ZIP Code									
Income Quartile 1	15,856,524	23.5%	1,505,895	26.8%	17.5%	1.30	1.30, 1.30	1.20	1.20, 1.21
Income Quartile 2	16,289,517	24.1%	1,394,993	24.8%		1.18	1.18, 1.19	1.14	1.13, 1.14
Income Quartile 3	16,438,223	24.4%	1,363,297	24.2%		1.15	1.15, 1.15	1.11	1.10, 1.11
Income Quartile 4	17,836,958	26.4%	1,271,148	22.6%		Reference		Reference	
Missing	1,060,939	1.6%	92,297	1.6%					
Maternal Race									
Non-Hispanic White	29,587,603	43.9%	2,568,942	45.7%	18.1%	Reference		Reference	
Non-Hispanic Black	7,509,640	11.1%	888,232	15.8%		1.32	1.32, 1.32	1.23	1.23, 1.24
Hispanic	12,878,120	19.1%	943,917	16.8%		0.85	0.85, 0.85	0.85	0.85, 0.85
Other	6,199,394	9.2%	392,684	7.0%		0.74	0.74, 0.75	0.75	0.75, 0.75
Unknown	11,307,403	16.8%	833,854	14.8%		0.86	0.86, 0.86	0.97	0.97, 0.97
Clinical Factors									
Chronic hypertension	1,006,790	1.5%	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Obesity	2,393,832	3.6%	614,165	10.9%	28.7%	2.87	2.86, 2.87	2.34	2.34, 2.35

	HDP Absent		HDP Present		Standardized mean difference	Unadjusted model for HDP		Adjusted model for HDP	
	N	%	N	%					
Year						**RR**	**95% CI**	**aRR**	**95% CI**
Pregestational diabetes	515,448	0.8%	148,914	2.7%	14.6%	3.10	3.08, 3.11	2.71	2.69, 2.72
Gestational diabetes	3,679,054	5.5%	529,905	9.4%	15.2%	1.74	1.74, 1.75	1.61	1.60, 1.61
Lupus	62,028	0.1%	12,111	0.2%	3.2%	2.11	2.07, 2.15	1.83	1.8, 1.86
Chronic kidney disease	119,316	0.2%	26,766	0.5%	5.2%	2.38	2.35, 2.41	2.05	2.02, 2.07
Asthma	1,963,773	2.9%	257,870	4.6%	8.8%	1.53	1.53, 1.54	1.23	1.23, 1.24
Multiple gestation	1,072,155	1.6%	241,873	4.3%	16.1%	2.45	2.44, 2.46	2.33	2.32, 2.34

HDP, hypertensive disorders of pregnancy. *n/a,* not applicable.

Table 2.

Adverse outcome diagnoses during delivery hospitalizations by presence or absence of hypertensive disorders of pregnancy

	HDP Absent		HDP Present	
Outcome	**N**	**Risk per 10,000 delivery hospitalizations**	**N**	**Risk per 10,000 delivery hospitalizations**
Stroke	1,359	0.2	1,712	3.0
Acute renal failure	14,806	2.2	21,761	38.7
Acute liver injury	206,782	30.6	27,249	48.4

HDP, hypertensive disorders of pregnancy.

Table 3.

Unadjusted and adjusted analyses for adverse outcomes in setting of hypertensive disorders of pregnancy

	Unadjusted model		Adjusted model	
Outcome	**Risk ratio**	**95% CI**	**Adjusted risk ratio**	**95% CI**
Stroke	15.10	14.06, 16.22	15.91	14.76, 17.14
Acute renal failure	17.62	17.26, 18.00	13.84	13.52, 14.16
Acute liver injury	1.58	1.56, 1.60	1.23	1.22, 1.25

Models include adjustment by maternal demographic (race, age, payer, income quartile) and clinical (obesity, pre-gestational/gestational diabetes, lupus, chronic kidney disease, asthma, multiple gestation) factors in addition to year of delivery.