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Prevalence, Trends, and Outcomes of Chronic Hypertension: a Nationwide Sample of Delivery Admissions

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Abstract

Objective—To define the prevalence, trends, and outcomes of primary and secondary chronic hypertension in a population-based sample of deliveries.

Methods—An estimated 56,494,634 deliveries were identified from the 1995-2008 Nationwide Inpatient Sample. The association of primary and secondary chronic hypertension with adverse fetal and maternal outcomes was evaluated using regression modeling and adjusted population attributable fractions were calculated.

Results—During the study period, the prevalence of primary and secondary hypertension increased from 0.90% in 1995/1996 to 1.52% in 2007/2008 (p for trend <0.001) and from 0.07% to 0.24% (p for trend <0.001), respectively. The population attributable fraction for chronic hypertension was considerable for many maternal adverse outcomes, including acute renal failure (21%), pulmonary edema (14%), preeclampsia (11%), and in-hospital mortality (10%).

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Conclusion—Primary and secondary hypertension were both strongly associated with adverse pregnancy outcomes and accounted for a substantial fraction of maternal morbidity. Prioritizing research efforts in this area is needed.

Introduction

Chronic hypertension is a relatively common comorbidity in pregnancy¹⁻³ and a well established risk factor for a number of adverse perinatal outcomes, including preterm birth^{4, 5}, perinatal death⁵⁻⁸, and intrauterine growth restriction^{4, 5}, as well as adverse maternal outcomes, including preeclampsia^{4, 5, 9, 10}, stroke^{8, 11, 12}, acute renal failure^{8, 11}, pulmonary edema^{8, 11}, and maternal death^{8, 11}. Although the majority of chronic hypertension among pregnant women is due to primary hypertension, about 10% of cases occur secondary to other medical conditions, such as diabetes mellitus, chronic renal disease, thyroid disease, and collagen vascular disease¹³.

There are few population-based studies examining the impact of chronic hypertension on obstetric outcomes in the US^{8, 11}; this is particularly true for chronic hypertension that is secondary to or associated with other conditions. As the prevalence of advanced maternal age¹⁴ and obesity¹⁵ increase among childbearing women in the US, both primary and secondary chronic hypertension are likely to become an increasingly common obstetric conditions.

The purpose of this study is threefold: (1) to examine nationwide trends in the prevalence of primary and secondary chronic hypertension during delivery hospitalizations in the US (2) to assess the effect of primary and secondary chronic hypertension on fetal and maternal obstetric complications, and (3) during the most recent years in the study period, to estimate the contribution of primary and secondary chronic hypertension to the burden of select fetal and maternal complications in the US.

Materials and Methods

Hospital discharge data were obtained from the Nationwide Inpatient Sample (NIS), part of the Healthcare Cost and Utilization Project (HCUP), a federal-state-industry partnership sponsored by the Agency for Healthcare Research and Quality (AHRQ). The NIS is a 20% stratified sample of all US community hospitals as defined by the American Hospital Association –nonfederal, short-term, general and specialty hospitals whose facilities are open to the public. To create a sample that is maximally representative of all US community hospital admissions, hospital are selected for inclusion in the NIS based on five characteristics: rural/urban location, number of beds, region of the country, teaching status, and ownership. The NIS includes all discharges from the sampled hospitals and includes between 5 to 8 million discharges from an average of 1,000 hospitals each year¹⁶. Further information about the methodology used to create the dataset is available at <http://www.hcup-us.ahrq.gov/nisoverview.jsp>

Our analysis included all delivery hospitalizations of women 15 years and older between 1995 and 2008; those who had abortions, ectopic and molar pregnancies were excluded from the analyses. Delivery hospitalizations were identified using a validated approach that

selects admissions with relevant diagnosis-related groups and International Classification of Diseases, 9th revision, Clinical Modification (ICD-9-CM) diagnosis/procedure codes, as previously described.¹⁷ In addition, ICD-9-CM codes were used to classify hospitalizations with chronic hypertension, associated comorbidities, and maternal and fetal outcomes (See Appendix I).

Data management and statistical analyses were conducted using SAS and SAS-callable SUDAAN software (version 9.2, RTI International, Research Triangle, NC) to account for the stratified sampling design used to collect the hospital discharge data. Chi-square tests with a significance level of 0.05 were used to compare the distribution of deliveries with and without chronic hypertension by socio-demographic and hospital characteristics and maternal comorbidities. For purposes of analysis, secondary hypertension was defined as chronic hypertension in association with conditions that can cause hypertension through either vascular or endocrinologic mechanisms including pre-gestational diabetes, chronic renal disease, collagen vascular disease (including systemic lupus erythematosus, scleroderma, and other diffuse diseases of connective tissue), thyroid disorders, pheochromocytoma, hyperplasia of the renal artery, Cushing's syndrome, hyperaldosteronism, and maternal coarctation of the aorta. Primary hypertension was defined as chronic hypertension without any of these associated comorbidities. To examine trends, the age standardized prevalence of overall, primary, and secondary chronic hypertension, as well as chronic hypertension with selected individual comorbidities, were computed for two year intervals. Estimates were standardized by the age distribution of delivery hospitalizations for the last two years (2007-2008) and applying it to the former two year intervals.

Given the increasing prevalence of chronic hypertension, we restricted our analyses of the effect of overall chronic hypertension, primary hypertension, and secondary hypertension on fetal and maternal outcomes to the last two years of the study period (2007-2008). Frequencies per 1,000 deliveries were calculated for fetal outcomes (stillbirth, poor fetal growth, spontaneous delivery < 37 weeks of gestation) and maternal outcomes (preeclampsia, stroke/cerebrovascular complications, acute renal failure, pulmonary edema, mechanical ventilation, cesarean delivery, length of hospital stay > 6 days (corresponding to approximately the 98th percentile for length of stay) and in hospital mortality), stratified by all cause, primary and secondary chronic hypertension status. Logistic regression was used to estimate odds ratios (OR) and respective 95% confidence intervals (CI) of maternal and fetal delivery outcomes by maternal chronic hypertension status, while adjusting for multiple births, year of study, insurance status, region, and age; the models for cesarean delivery were additionally adjusted for previous cesarean delivery and the models for length of stay included adjustment for admission and disposition status. In order to estimate the burden of disease at the population level, population attributable fractions for chronic hypertension (overall), primary hypertension, and secondary hypertension for each of the fetal and maternal outcomes of interest were calculated using adjusted odds ratios as estimates of relative risk, as described elsewhere¹⁸. The population attributable fraction estimates the proportion of disease that would be eliminated if the exposure, in this case chronic hypertension, could be eliminated.

A similar analysis was conducted examining the association of chronic hypertension with the comorbidities most commonly associated with chronic hypertension--pre-gestational diabetes, chronic renal disease, collagen vascular disease, and thyroid disorders--and selected fetal/maternal outcomes. Because the relatively small numbers of patients with chronic hypertension and the comorbidities considered, the NIS sample for the entire study period (1995-2008) was used for this analysis to ensure adequate power to make reliable estimates of risk.

Results

Between 1995 and 2008, an estimated 56,494,634 delivery hospitalizations were identified, of which 731,694 were classified as deliveries with chronic hypertension. Of the patients with chronic hypertension, 649,899 (88.8%) had primary hypertension and 81,795 (11.2%) had secondary hypertension; in the final 2 years of the study period (2007/2008), of the 153,570 patients with chronic hypertension, 132,808 (86.5%) had primary hypertension and 20,762 (13.5%) had secondary hypertension. Compared to women with delivery hospitalizations without chronic hypertension, those with chronic hypertension were older, and had higher rates of multiple birth, previous cesarean delivery, pre-gestational diabetes, chronic renal disease, collagen vascular disease, hyperaldosteronism, Cushing's disease, thyroid disease, and maternal coarctation of the aorta (all $P < 0.001$) (Table 1). The most common comorbidities associated with chronic hypertension included pre-gestational diabetes (present in 6.6% of chronic hypertension admissions), thyroid disorders (present in 4.1%), chronic renal disease (present in 0.9%), and collagen vascular disease (present in 0.6%).

The age-adjusted prevalence of all cause chronic hypertension increased significantly throughout the seven 2-year intervals, from 1.01% in 1995-1996 to 1.76% in 2007-2008 (P for trend < 0.001) (Fig. 1). The prevalence of primary hypertension increased from 0.90% to 1.52% ($P < 0.001$) and of secondary hypertension from 0.07% to 0.24% ($P < 0.001$). Significant increasing trends were also observed for chronic hypertension with pre-gestational diabetes, chronic renal disease, collagen vascular disease and thyroid disorders (all $P < 0.001$) (Fig. 2).

The frequency of considered adverse fetal and maternal outcomes were uniformly higher for delivery hospitalizations with overall, primary, and secondary hypertension (Table 2). As compared to delivery hospitalizations without chronic hypertension, those with primary hypertension had an odds ratio of 2.2 for stillbirth, 3.0 for poor fetal growth, and 2.9 for spontaneous delivery < 37 weeks gestation (Table 3). For adverse maternal outcomes, the odds ratios associated with primary hypertension were in excess of 5 in all categories with the exception of Cesarean delivery. For secondary hypertension, the effects on outcomes were even more profound, particularly adverse maternal outcomes; the odd ratios for most adverse maternal outcome were in excess of 10—including maternal mortality which was 13.2 (Table 3). The population attributable fractions for overall chronic hypertension were substantial for many maternal adverse outcomes; principal among these were acute renal failure (21%), pulmonary edema (14%), preeclampsia (11%), and in-hospital mortality (10%) (Table 3).

In table 4, an analysis of the interaction of chronic hypertension and selected associated comorbidities is presented (compared to a reference group which included delivery hospitalizations without chronic hypertension and without the comorbidity of interest). The combinations of chronic hypertension with chronic renal disease, collagen vascular disease, or pre-gestational diabetes were particularly detrimental. The combination of thyroid disease and chronic hypertension generally did not result in greatly elevated risk above what was observed for hypertension alone.

Comment

Chronic hypertension is a well-recognized risk factor for many adverse pregnancy outcomes and has been previously reported to be increasing in the prevalence among delivery hospitalizations in the US¹¹. Our 14 year study using the largest discharge dataset available in the US, the Nationwide Inpatient Sample, finds that the overall prevalence of chronic hypertension among delivery hospitalizations shows sustained increase (approximately 80% across the study period) such that 1.8% of delivery hospitalizations were complicated by chronic hypertension in 2007-2008, and confirms and quantifies the role of chronic hypertension in mediating a range of adverse fetal and maternal outcomes. Our study also demonstrates that secondary hypertension has increased in prevalence from 0.07% in 1995-1996 to 0.24% in 2007-2008 (approximately 300% increase) and has a particularly strong, detrimental effect on pregnancy outcomes.

Consistent with previously published studies¹⁹⁻²², we found that chronic hypertension increased the risk of stillbirth by approximately 2.3-fold. In our study, the odds ratio for stillbirth increased dramatically when chronic hypertension occurred in the setting of certain comorbid conditions – it was more than 4 for chronic hypertension with diabetes and more than 7 for chronic renal disease and collagen vascular disease. Similar patterns of associations that were observed for poor fetal growth, also in a line with previously published research^{4,5,20}. The synergistic effects of chronic hypertension and these comorbid conditions may be explained by vasculopathy leading to a poorly perfused placenta and/or accelerated placenta aging. Alternatively, it may be an iatrogenic effect of treatment of the hypertension; a metaanalysis of treatment of mild to moderate hypertension suggests that treatment-associated decrease in mean arterial pressure is associated with compromised fetal growth²³. Interestingly, pre-gestational diabetes mitigated the effect of hypertension on poor fetal growth; it is well known that diabetes increases fetal size and predisposes to macrosomia²⁴ and this may be the mechanism.

Consistent with its shared etiology of poor placentation, the risk of preeclampsia follows a similar pattern with what is observed in stillbirth and poor fetal growth—chronic hypertension, by itself is significantly associated with preeclampsia, but markedly more so when concurrent with chronic renal disease or collagen vascular disease. At the most severe end of the spectrum of adverse maternal outcomes, stroke/cerebrovascular complication, acute renal failure, pulmonary edema, mechanical ventilation, and death, the synergistic detrimental effect of the combination of chronic hypertension and associated conditions becomes even more profound. This marked increase in risk of adverse maternal outcomes for patients with chronic hypertension and these associated illnesses should factor both into

preconceptional counseling regarding the risks of pregnancy and the approach to the management of pregnancy and delivery. In many circumstances, patients with these conditions should be cared for by a high-risk obstetric specialist and delivered in hospital settings where intensity of care can be rapidly escalated if need be.

We used standard methodology to calculate population attributable fractions of chronic hypertension for a range of adverse pregnancy outcomes¹⁸. Assuming that the associations are causal and chronic hypertension removable, population attributable fractions estimate the proportion of the adverse outcomes in the population that would be prevented if chronic hypertension or its effects could be negated. Although causality cannot be established in our cross-sectional study, the calculated population attributable fraction estimates suggest that chronic hypertension may be responsible for over ten percent of the population burden of preeclampsia, acute renal failure, pulmonary edema, mechanical ventilation, prolonged hospitalization, and maternal death.

Our study has certain limitations inherent in its methodology. The identification of comorbidities and fetal and maternal outcomes is largely dependent on ICD-9 CM codes collected for billing purposes and thus is susceptible to underascertainment or misclassification bias. Similarly, because we are only able to examine hospital admissions, our analysis of the role of chronic hypertension is confined to outcomes associated with delivery. If a patient had mild hypertension prior to pregnancy and it was no longer an active clinical issue at the time of delivery, it is likely that the patient would not be coded as having chronic hypertension, which would cause us to underestimate the incidence and overestimate the effect of hypertension. Further, we define secondary hypertension as chronic hypertension in the presence of comorbidities that can cause hypertension through vascular or endocrinologic mechanisms. However, we cannot definitively determine whether the hypertension is secondary to the comorbid condition or essential hypertension with associated comorbidity; in either case, the point remains that chronic hypertension associated with certain conditions identifies a group at remarkably high risk of adverse pregnancy outcomes. There are also certain potential confounders, including race and body mass index, associated with both chronic hypertension and adverse maternal and fetal outcomes, that we are unable to adjust for in our analysis because they are not well captured in our dataset. Last, we do not have information on the severity of patients' chronic hypertension and what medications, if any, were used to control it—both of which are likely to have an important role in the risk of adverse outcomes. Despite these limitations, there are few population-based studies examining the role of chronic hypertension in pregnancy outcome and our findings help address this deficit. Further, the size of our cohort allows us to carefully examine the interaction of chronic hypertension and relatively rare associated comorbidities with a range of outcomes, including some which are infrequent and severe.

In conclusion, our nationwide data show a rise in the prevalence of chronic hypertension (from 1.01% to 1.76%) and secondary hypertension (from 0.07% to 0.24%), in delivery hospitalizations in the US from 1995 to 2008, suggesting that the clinical management of this problem will increasingly confront obstetricians and their colleagues. Although primary and secondary chronic hypertension account for a substantial fraction of maternal morbidity and mortality, current recommendations for the clinical management of pregnant women

with chronic hypertension are based on a few small studies, with the benefits and risks of the available treatment strategies remaining uncertain. As the delivering population in the US becomes older and more obese, chronic hypertension rates are likely to rise even further and this will therefore need to become a priority research area for obstetrics.

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Condensation

The article demonstrates that chronic hypertension, particularly when co-existing with certain comorbid conditions, is associated with an increased risk for serious, adverse maternal and fetal complications.

Figure 1.

Trends in age-adjusted prevalence of chronic, primary, and secondary hypertension, 1995-1996 through 2007-2008, Nationwide Inpatient Sample

Figure 2.

Trends in age-adjusted prevalence of chronic hypertension with associated co-morbid conditions, 1995-1996 through 2007-2008, Nationwide Inpatient Sample

Table 1

Patient Characteristics, Comparing Delivering Patients With and Without Chronic Hypertension (all cause), National Inpatient Sample, 1995-2008.

	With Chronic Hypertension (N = 731,694) N (%)	Without Chronic Hypertension (N= 55,762,940) N (%)	P † Value
Age, years			
<20	23,094 (3.2)	6,236,678 (11.2)	<0.001
20-34	478,006(65.3)	41,889,300 (75.1)	
35	230,594 (31.5)	7,637,061 (13.7)	
Primary payer			
Public *	258,620 (35.4)	21,254,523 (38.2)	<0.001
Private (including HMO)	432,453 (59.3)	30,752,962 (55.3)	
Other (including self-pay)	38,693 (5.3)	3,596,175(6.5)	
Multiple birth			
Yes	18,384 (2.5)	919,225 (1.7)	<0.001
No	713,304 (97.5)	54,843,715 (98.3)	
Previous Cesarean delivery			
Yes	156,303 (21.4)	7,374,516 (13.2)	<0.001
No	575,391 (78.6)	48,388,423 (86.8)	
Pre-gestational diabetes			
Yes	48,263 (6.6)	364,907 (0.7)	<0.001
No	683,431 (93.4)	55,398,031 (99.3)	
Chronic renal disease			
Yes	6,614 (0.9)	84,866 (0.2)	<0.001
No	725,080 (99.1)	55,678,074 +(99.8)	
Collagen vascular disease			
Yes	4,482 (0.6)	49,520 (0.1)	<0.001
No	727,212 (99.4)	55,713,420 (99.9)	
Pheochromocytoma			
Yes	-	-	0.32
No	-	55,762,940 (100.0)	

	With Chronic Hypertension (N = 731,694) N (%)	Without Chronic Hypertension (N= 55,762,940) N (%)	<i>P</i> [†] Value
Hyperplasia of the renal artery			
Yes	-	-	0.05
No	-	-	
Hyperaldosteronism			
Yes	158 (0.02)	558 (0.001)	<0.001
No	731,537 (99.9)	55,762,382 (100.0)	
Cushing's syndrome			
Yes	-	412 (0.001)	<0.001
No	-	55,762,529 (100.0)	
Thyroid disorders			
Yes	29,810 (4.1)	772,032 (1.4)	<0.001
No	701,885 (95.9)	54,990,908 (98.6)	
Maternal coarctation of the aorta			
Yes	130 (0.02)	684 (0.001)	<0.001
No	731,565 (99.9)	55,762,257 (100.0)	

* including Medicaid and Medicare

[†] Chi-square P value

— Too small numbers to report a stable estimate (N≤10 and/or RSE >.30)

Table 2

Frequency and Standard Errors, per 1,000 Deliveries, of Fetal and Maternal Complications in Delivering Patients, Stratified by Chronic Hypertension Status, Nationwide Inpatient Sample (NIS) 2007-2008.

	Without chronic hypertension	With chronic hypertension (overall)	Primary hypertension	Secondary hypertension
Fetal outcomes				
Stillbirth	6.0 (0.01)	15.1 (0.7)	14.1 (0.7)	21.1 (2.3)
Poor fetal growth	18.8 (0.4)	53.9 (1.9)	54.3 (2.0)	51.5 (3.7)
Spontaneous delivery <37 weeks gestation	74.0 (0.1)	193.1 (5.0)	183.8 (4.6)	252.2 (9.6)
Maternal outcomes				
Preeclampsia	35.4 (0.7)	268.3 (5.0)	264.0 (5.0)	295.8 (8.9)
Stroke/Cerebrovascular complications	0.4 (0.02)	2.7 (0.3)	2.2 (0.3)	2.8 (0.8)
Acute renal failure	0.4 (0.02)	5.9 (0.5)	4.2 (0.4)	16.7 (2.2)
Pulmonary edema	0.2 (0.01)	1.5 (0.3)	1.4 (0.2)	—
Mechanical ventilation	0.5 (0.02)	3.8 (0.4)	3.5 (0.4)	6.3 (1.3)
Cesarean delivery	323.3 (0.3)	561.7 (4.9)	543.1 (5.1)	680.2 (7.7)
Length of stay >6 days	13.6 (0.5)	95.9 (3.8)	86.7 (3.3)	154.6 (9.1)
In-hospital mortality	0.1 (0.01)	0.4 (0.1)	—	—

*Frequency per 1,000 deliveries

— Too small numbers to report a stable estimate (N ≤ 10 and/or RSE > .30)

Table 3

Estimated Odds Ratios (OR), Population Attributable Fraction (PAF) and 95% Confidence Intervals (CI) of Fetal and Maternal Complications in Delivery Hospitalizations, Stratified by Chronic Hypertension Status, Nationwide Inpatient Sample (NIS), 2007-2008.

	With chronic hypertension (overall)		Primary hypertension		Secondary hypertension	
	OR [†] (95% CI)	PAF (95% CI)	OR [‡] (95% CI)	PAF (95% CI)	OR [‡] (95% CI)	PAF (95% CI)
Fetal outcomes						
Stillbirth [§]	2.31 (2.11 - 2.53)	2.44 (1.99 - 2.90)	2.23 (2.02 - 2.48)	1.93 (1.52 - 2.35)	3.23 (2.57 - 4.06)	0.56 (0.36 - 0.78)
Poor fetal growth [§]	3.00 (2.83 - 3.19)	3.26 (2.89 - 3.64)	3.05 (2.87 - 3.25)	2.86 (2.54 - 3.20)	2.92 (2.52 - 3.38)	0.42 (0.31 - 0.53)
Spontaneous delivery <37 weeks gestation [§]	3.01 (2.88 - 3.14)	2.99 (2.72 - 3.25)	2.89 (2.77 - 3.02)	2.41 (2.20 - 2.62)	4.36 (3.98 - 4.79)	0.61 (0.52 - 0.69)
Maternal outcomes						
Preeclampsia [§]	10.07 (9.68 - 10.48)	10.78 (10.15 - 11.41)	10.18 (9.77 - 10.60)	9.19 (8.67 - 9.71)	11.92 (10.98 - 12.95)	1.63 (1.45 - 1.82)
Stroke/cerebrovascular complications [§]	5.41 (4.27 - 6.86)	7.49 (5.30 - 9.77)	5.37 (4.10 - 7.04)	6.24 (4.16 - 8.42)	6.71 (3.88 - 11.61)	1.29 (0.42 - 2.26)
Acute renal failure [§]	14.62 (12.06 - 17.73)	21.02 (17.13 - 24.95)	13.14 (10.57 - 16.33)	12.90 (10.12 - 15.72)	51.07 (37.60 - 69.38)	8.43 (5.80 - 11.08)
Pulmonary edema [§]	9.26 (6.67 - 12.85)	14.12 (9.34 - 19.06)	8.99 (6.40 - 12.64)	10.89 (6.96 - 14.97)	16.20 (8.82 - 29.75)	3.36 (1.09 - 5.73)
Ventilation [§]	6.33 (5.12 - 7.83)	9.76 (7.33 - 12.28)	6.22 (4.90 - 7.88)	7.56 (5.43 - 9.76)	10.67 (7.13 - 15.98)	2.34 (1.21 - 3.53)
Cesarean delivery ^{//}	2.54 (2.46 - 2.64)	1.83 (1.69 - 1.98)	2.39 (2.31 - 2.48)	1.47 (1.36 - 1.59)	4.37 (4.03 - 4.74)	0.38 (0.34 - 0.42)
Length of stay >6 days [¶]	6.73 (6.21 - 7.29)	9.55 (8.78 - 10.33)	6.49 (5.96 - 7.07)	7.42 (6.80 - 8.05)	11.83 (10.28 - 13.62)	2.24 (1.92 - 2.56)
In-hospital mortality [§]	6.20 (3.33 - 11.54)	10.44 (3.43 - 18.23)	5.49 (2.60 - 11.58)	7.23 (1.34 - 14.15)	13.21 (4.92 - 35.43)	3.34 (-0.28 - 7.40)

*Includes: pre-gestational diabetes mellitus, chronic renal disease, collagen vascular disease, pheochromocytoma, thyroid disorders, Cushing's syndrome, hyperaldosteronism, hyperplasia of the renal artery, coarctation of the aorta

[†] Referent group: Without Chronic Hypertension

[‡] Referent group: Without Chronic Hypertension and Select Comorbidities

[§] Adjusted for multiple birth, year of study, insurance status, region, and age

^{//} Adjusted for previous cesarean delivery, multiple birth, year of study, insurance status, region, and age

[¶] Adjusted for disposition status, admission status, multiple birth, year of study, insurance status, region, and age PAF = pd (RR-1/RR), where pd = proportion of cases (hospitalizations with maternal and fetal outcomes) exposed to risk factor (chronic hypertension status) and RR= relative risk for outcome for exposed compared with unexposed

Table 4

Estimated Odds Ratio (OR) and 95% Confidence Intervals (CI) of Fetal and Maternal Complications in Delivering Patients, Stratified by Chronic Hypertension Status and Presence of Select Comorbidities, Nationwide Inpatient Sample (NIS), 1995-2008.

	Pre-Gestational Diabetes		Chronic Renal Disease		Collagen Vascular Disease		Thyroid Disorders		
	With chronic hypertension	With chronic hypertension	With chronic hypertension	With chronic hypertension	With chronic hypertension	With chronic hypertension	With chronic hypertension	With chronic hypertension	
Fetal outcomes									
Stillbirth*	4.30	3.05	7.29	1.74	7.42	2.74	1.86	0.98	
	(3.81 - 4.85)	(2.88 - 3.23)	(5.59 - 9.52)	(1.51 - 2.02)	(5.37 - 10.25)	(2.35 - 3.20)	(1.48 - 2.33)	(0.92 - 1.05)	
Poor fetal growth*	2.66	1.20	7.94	2.29	7.99	3.87	3.59	1.29	
	(2.40 - 2.94)	(1.14 - 1.27)	(6.67 - 9.44)	(2.12 - 2.49)	(6.44 - 9.91)	(3.55 - 4.22)	(3.20 - 4.02)	(1.25 - 1.34)	
Spontaneous delivery <37 weeks gestation*	4.88	2.90	8.60	2.25	7.19	3.15	3.24	1.24	
	(4.63 - 5.15)	(2.83 - 2.98)	(7.64 - 9.67)	(2.15 - 2.35)	(6.22 - 8.30)	(2.98 - 3.33)	(3.02 - 3.48)	(1.21 - 1.27)	
Maternal outcomes									
Preeclampsia*	13.96	3.80	27.87	3.28	17.41	2.96	9.74	1.38	
	(13.29 - 14.66)	(3.69 - 3.91)	(24.85 - 31.25)	(3.10 - 3.47)	(15.09 - 20.09)	(2.76 - 3.18)	(9.15 - 10.35)	(1.35 - 1.42)	
Stroke/cerebrovascular complications*	7.14	1.85	13.73	3.52	23.00	7.60	3.87	1.58	
	(4.90 - 10.40)	(1.41 - 2.44)	(6.63 - 28.44)	(2.34 - 5.31)	(11.47 - 46.14)	(5.26 - 10.97)	(2.07 - 7.23)	(1.29 - 1.94)	
Acute renal failure*	35.41	4.43	253.4	62.40	191.5	12.60	14.17	1.27	
	(28.39 - 44.16)	(3.57 - 5.48)	(199.5 - 321.9)	(54.37 - 71.63)	(141.4 - 259.4)	(8.88 - 17.88)	(9.65 - 20.82)	(0.97 - 1.65)	
Pulmonary edema*	11.97	4.01	23.29	9.06	15.52	6.08	9.85	1.54	
	(7.86 - 18.24)	(3.07 - 5.25)	(10.32 - 52.56)	(5.84 - 14.06)	(4.92 - 48.95)	(3.46 - 10.69)	(5.64 - 17.19)	(1.16 - 2.05)	
Ventilation*	11.87	3.34	19.29	8.25	26.20	11.09	5.71	1.84	
	(9.22 - 15.26)	(2.80 - 4.00)	(11.36 - 32.76)	(6.43 - 10.60)	(15.04 - 45.63)	(8.46 - 14.52)	(3.69 - 8.86)	(1.55 - 2.18)	
Cesarean delivery†	5.75	3.33	5.73	1.74	4.38	1.89	3.16	1.27	
	(5.46 - 6.05)	(3.26 - 3.41)	(5.03 - 6.53)	(1.68 - 1.81)	(3.74 - 5.12)	(1.80 - 1.98)	(2.97 - 3.36)	(1.25 - 1.29)	
Length of stay >6 days‡	14.74	5.34	42.16	6.52	30.29	6.18	8.40	1.77	
	(13.68 - 15.89)	(5.09 - 5.60)	(36.78 - 48.32)	(6.12 - 6.95)	(25.45 - 36.04)	(5.69 - 6.71)	(7.60 - 9.28)	(1.71 - 1.84)	
In-hospital mortality*	6.02	2.58	27.02	6.88	88.81	23.81	1.74	1.72	
	(2.71 - 13.40)	(1.59 - 4.17)	(8.72 - 83.73)	(3.56 - 13.29)	(41.90 - 188.2)	(14.67 - 38.66)	(0.24 - 12.40)	(1.06 - 2.77)	

* Adjusted for multiple birth, year of study, insurance status, region, and age

† Adjusted for previous cesarean delivery, multiple birth, year of study, insurance status, region, and age

‡ Adjusted for disposition status, admission status, multiple birth, year of study, insurance status, region, and age For each analysis, the reference group was delivery admissions without chronic hypertension and without the comorbidity of interest. Admissions with chronic hypertension but without the comorbidity of interest was included as a group in each analysis. Because of the similarity of the estimates of association in these groups to those obtained when analyzing the effect of overall chronic hypertension (Table 3), results are not shown.