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Timing and Risk Factors of Postpartum Stroke

Gloria Too, MD¹, Timothy Wen, MD MPH¹, Amelia K. Boehme, PhD MSPH^{2,3}, Eliza C. Miller, MD², Lisa R. Leffert, MD⁴, Frank J. Attenello, MD⁵, William J. Mack, MD⁵, Mary E. D'Alton, MD¹, and Alexander M. Friedman, MD MPH¹

¹Department of Obstetrics and Gynecology, College of Physicians and Surgeons, Columbia University, New York, NY

²Department of Neurology, College of Physicians and Surgeons, Columbia University, New York, NY

³Department of Epidemiology, Mailman School of Public Health, Columbia University, New York NY

⁴Department of Anesthesia, Critical Care and Pain Medicine, Massachusetts General Hospital, Boston MA

⁵Department of Neurosurgery, Keck School of Medicine, University of Southern California, Los Angeles CA

Abstract

OBJECTIVE: To characterize risk and timing of postpartum stroke readmission after delivery hospitalization discharge.

METHODS: The Healthcare Cost and Utilization Project's Nationwide Readmissions Database for calendar years 2013 and 2014 was used to perform a retrospective cohort study evaluating risk for readmission for stroke within 60 days of discharge from a delivery hospitalization. Risk was characterized as odds ratios (OR) with 95% confidence intervals (CI) based on whether patients had hypertensive diseases of pregnancy (HDP)-- gestational hypertension, or preeclampsia, or chronic hypertension (CHTN), or neither disorder during the index hospitalization. Adjusted models for stroke readmission risk were created.

RESULTS: From January 1st, 2013, to October 31st 2013, and January 1, 2014, to October 31, 2014, 6,272,136 delivery hospitalizations were included in the analysis. One thousand five-hundred five cases of readmission for postpartum stroke were identified. Two-hundred fourteen (14.2%) cases of stroke occurred among patients with HDP, 66 (4.4%) with CHTN, and 1,225 (81.4%) without hypertension. The majority of stroke readmissions that occurred within 10 days of hospital discharge (58.4%), including 53.2% of cases with HDP during the index hospitalization, 66.7% with CHTN, and 58.9% with no hypertension. Hypertensive diseases of

Corresponding author Alexander Friedman, MD, MPH, Division of Maternal-Fetal Fetal Medicine, Department of Obstetrics and Gynecology, Columbia University College of Physicians and Surgeons, 622 West 168th Street, New York, NY 10032, Work: (212) 761-1570 / Fax: (212) 326-5610, amf2104@cumc.columbia.edu.

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pregnancy and CHTN were associated with increased risk of stroke readmission compared to no hypertension (OR 1.74, 95% CI 1.33–2.27, OR 1.88, 95% CI 1.19–2.96, respectively). Median times to readmission were 8.9 days for HDP, 7.8 days for CHTN, and 8.3 days without either condition.

CONCLUSION: Although patients with chronic hypertension and hypertensive diseases of pregnancy are at higher risk of postpartum stroke, they account for a minority of such strokes. The majority of readmissions for postpartum stroke occur within 10 days of discharge; optimal blood pressure management may be particularly important during this period.

Level of evidence—Level II

Précis

Most readmissions for postpartum stroke after delivery hospitalization occur within 10 days of discharge.

INTRODUCTION

Pregnancy-associated stroke (PAS) is a rare event with an incidence of approximately 34 per 100,000 deliveries.¹ However, incidence may be increasing, particularly during the postpartum period. Analysis of nationally representative administrative data by the Centers for Disease Control and Prevention (CDC) found that in the United States postpartum admissions for PAS increased 83% from 1994–5 to 2006–7.² Increased risk for PAS may be secondary in part to the increasing prevalence of hypertensive disorders.^{2,3} Both chronic hypertension (CHTN) and hypertensive diseases of pregnancy (HDP) including gestational hypertension and preeclampsia have been demonstrated to increase risk of PAS in epidemiological studies.^{1–4}

Severe range blood pressure in pregnant or postpartum patients, and in particular systolic blood pressure of 160 mmHg or higher, may be associated with PAS.⁵ The American College of Obstetricians and Gynecologists Task Force on Hypertension in Pregnancy supports monitoring patients with HDP for at least 72 hours postpartum and then again 7 to 10 days after delivery or earlier if symptoms are present.⁶ For patients with systolic blood pressure 150 mm Hg or diastolic blood pressure 100 mm Hg, initiation of an antihypertensive agent is recommended.⁶

Improved blood pressure management for patients with HDP may reduce maternal risk from stroke.⁷ However, research characterizing time intervals between delivery hospitalization discharge and readmission for acute stroke is limited.^{8–10} Improved knowledge of timing of postpartum stroke may be helpful in optimizing post-discharge surveillance for high-risk patients. We sought to better characterize the time interval from delivery hospitalization discharge to stroke readmission for patients with and without diagnoses of HDP and CHTN, as well as characterize risk factors for these events.

MATERIALS AND METHODS

The Healthcare Cost and Utilization Project's (HCUP) Nationwide Readmissions Database (NRD) from 2013 and 2014 was used to perform this retrospective cohort study. The NRD is an all-payer database collected on a state level that can be used to track patients across hospital admissions within a state, generating national estimates of readmissions for the insured and uninsured. The NRD includes public hospitals, community hospitals, and academic medical centers,¹¹ and has been used across a wide number of medical and surgical subspecialties to evaluate readmission hospitalizations.^{12,13} The NRD is part of HCUP that is sponsored by the Agency for Healthcare Research and Quality (AHRQ). The HCUP State Inpatient Databases from which the NRD is drawn contain reliable, verified patient linkage numbers that can be used to track a person across hospitals within a state while adhering to strict privacy guidelines.¹⁴ Data in the NRD is weighted to provide national estimates; with an estimated 35 million United States discharges. In 2014, 22 geographically dispersed states contributed data to the NRD, accounting for 51% of US residents and 49% of all US hospitalizations. The Columbia University and University of Southern California institutional review boards granted exemptions given that the NRD is de-identified and publically available.

For this analysis, index delivery hospitalizations were captured with International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis codes 650 and V27.x. These criteria ascertain >95% of delivery hospitalizations.¹⁵ Females aged 15–54 years were included. The primary outcome of the analysis was a stroke readmission after a delivery hospitalization. The CDC severe maternal morbidity ICD-9-CM coding algorithm for puerperal cerebrovascular disorders was used to identify patients.¹⁶ We included PAS readmission based on CDC criteria up to 60 days after discharge from a delivery hospitalization; we extended the analysis beyond six weeks postpartum to determine if there was prolonged risk after delivery hospitalization. Women were classified into three groups based on diagnoses during the delivery hospitalization: (i) CHTN without superimposed preeclampsia (ICD-9-CM 401.x, 402.x, 403.x, 404.x, 405.x, 642.0x, 642.1x, 642.2x), (ii) HDP (gestational hypertension, preeclampsia, severe preeclampsia, superimposed preeclampsia; ICD-9-CM 642.3x, 642.4x, 642.5x, and 642.7x respectively) or (iii) neither condition. To avoid misclassification of an historical versus acute diagnosis, patients with a diagnosis of stroke during the delivery index hospitalization were excluded. To create national estimates, population weights from the NRD were applied. Because the NRD datasets are year-based and cannot be linked, only delivery hospitalizations where discharge occurred from January 1 through October 31 for each year were included; delivery hospitalizations during November and December were not included because readmissions for the subsequent 60 days could not be fully ascertained.

Demographic factors included maternal age, payer, and ZIP-code income quartile. Risk factors included tobacco use, migraine headaches, pregestational diabetes, cesarean delivery during the index hospitalization, and maternal cardiovascular disorders including valvular, ischemic, and congenital disease. Hospital stays for delivery hospitalizations were dichotomized into longer and shorter stays; longer hospital stay was defined as >4 days for cesarean delivery and >3 days for vaginal delivery. Hospital factors included hospital bed

size, teaching versus non-teaching status, and location based on the NCHS Urban-Rural Classification Scheme for Counties.¹⁷ To account for the influence of clinical and demographic factors on stroke, we used logistic regression models to estimate odds ratios (OR) of factors associated with stroke readmission with 95% confidence intervals (CI).

In addition to the primary analysis above, we performed two sensitivity analyses. First, as administrative data is used primarily for billing purposes and misclassification is a concern with all analyses, we performed an analysis restricted to ICD-9-CM codes for stroke with high sensitivity ascertained in non-obstetric validation studies (430, 431, 434.x1, and 436) as well as ICD-9-CM code 674.0 which we have found to be highly sensitive in pregnancy related stroke in our institution.^{18–21} Second, because risk factors for hemorrhagic and occlusive stroke may differ we performed analyses individually for these outcomes (intracerebral hemorrhage, ICD-9-CM 431; occlusive stroke ICD-9 433.x, 434.x). For both sensitivity analyses we repeated the univariate and adjusted analyses, as well as reevaluated the temporal distribution of readmission events after delivery hospitalization discharge. Finally in addition to the above analyses we determined: (i) the proportion of patients with stroke readmission diagnosed with HDP on readmission but not during the index hospitalization, and (ii) risk of stroke individually for patients with superimposed preeclampsia, mild preeclampsia, severe preeclampsia, and gestational hypertension. All analyses were performed with SAS 9.4 (SAS Institute, Cary, NC).

RESULTS

From January 1st, 2013 to October 31st, 2013 and January 1st, 2014 to October 31st, 2014, 6,272,136 delivery hospitalizations occurred and were included in the analysis. Based on CDC severe morbidity criteria, there were 1,505 cases of stroke (24.0 per 100,000 deliveries, 95% CI 22.8–25.2) that occurred within 60 days after a delivery hospitalization. Of these, 214 (14.2%, 95% CI 12.5–16.6%) occurred in patients with HDP, 66 (4.4%, 95% CI 3.4–5.5%) occurred in patients with CHTN without superimposed preeclampsia, and 1,225 (81.4%, 95% CI 79.3–83.3%) occurred in patients without hypertension (Table 1).

Risk for postpartum stroke readmission within 60 days was 41.7 (95% CI 36.2–47.3) per 100,000 deliveries for patients with HDP, 59.6 (95% CI 45.1–73.8) per 100,000 for patients with CHTN without superimposed preeclampsia, and 21.7 (95% CI 20.5–22.9) per 100,000 for patients without either condition. The majority of stroke readmissions (58.4%) occurred within 10 days of hospital discharge including 53.2% of cases with HDP during the index hospitalization, 66.7% with CHTN without superimposed preeclampsia, and 58.9% with no hypertension (Figure 1). The next 20-day period (post-discharge days 11–30) accounted for 31.3% of stroke readmissions associated with HDP, 16.7% of readmissions associated with chronic hypertension, and 29.7% of stroke readmissions associated with neither diagnosis. The final 30 days accounted for 15.4% of stroke diagnoses associated with HDP, 16.7% associated with CHTN without superimposed preeclampsia, and 11.3% associated with neither diagnosis. Median times to readmission were 8.9 days for patients with HDP (95% CI 6.4 to 11.4 days), 7.8 days for those with CHTN without superimposed preeclampsia (95% CI 5.9 to 9.7 days), and 8.3 days for patients without either condition (95% CI 7.6 to 9.0 days). When a sensitivity analysis was restricted to ICD-9-CM codes 430, 431, 434.x1,

436, 674.0x (n=1,043) the distribution of time to readmission was similar with the majority of readmissions (63.8%) occurring 1 to 10 days after discharge.

Women with either HDP or CHTN without superimposed preeclampsia were at increased risk of stroke readmission compared to patients without these conditions (OR 1.74, 95% CI 1.33–2.27, OR 1.88, 95% CI 1.19–2.96, respectively). Women age >39 were at increased risk of stroke (OR 2.69, 95% CI 1.79–4.05) and patients aged 15–19 were at decreased risk of stroke (OR 0.50, 95% CI 0.31–0.78) with maternal age 25–29 as a reference. Other risk factors associated with maternal stroke included longer length of stay during the delivery hospitalization (OR 1.47, 95% CI 1.26–1.71), cesarean delivery (OR 1.28, 95% CI 1.07–1.51), pregestational diabetes (OR 1.70, 95% CI 1.04–2.78), tobacco use (OR 1.81, 95% CI 1.37–2.40), and Medicaid insurance (OR 1.65, OR 95% CI 1.35–2.03) with private insurance as a reference. Maternal cardiac disease, hospital teaching status and bed size, and ZIP code income quartile were not significantly associated with stroke readmission risk. When this analysis was restricted to higher sensitivity codes for stroke ICD-9-CM codes 430, 431, 434.x1, 436, 674.0, similar odds ratios were noted (results not shown).

For the sensitivity analyses 927 patients diagnosed with stroke had a high-sensitivity diagnostic code, 342 patients had an occlusive stroke, and 320 patients had an intracerebral hemorrhage. Results from the high-sensitivity adjusted analysis were similar to the primary analysis with chronic hypertension, HDP, older maternal age, migraine headache, and tobacco use associated with increased risk for stroke (Table 3). For hemorrhagic stroke factors associated with increased risk included maternal age >39 and Medicaid insurance. Factors associated with increased risk for ischemic stroke included HDP, maternal age >29 years, tobacco use, pregestational diabetes, and longer hospital stay. For patients readmitted within 60 days of a delivery hospitalization, 70.7% of readmissions for intracerebral hemorrhage occurred within the first 10 days after discharge.

Risk for postpartum stroke differed by specific HDP diagnosis with risk highest for preeclampsia superimposed on chronic hypertension (72.0 per 100,000 deliveries, n=30) compared to severe preeclampsia (67.9 per 100,000 deliveries, n=70), mild preeclampsia (46.0 per 100,000 deliveries, n=63), and gestational hypertension (22.5 per 100,000, n=52). Overall, 27.3% of chronic hypertensive patients (n=18) and 19.6% (n=239) of patients without chronic hypertension who did not have an HDP diagnosis during the index delivery hospitalization had a HDP diagnosis during a readmission for postpartum stroke.

DISCUSSION

PAS is an important cause of severe maternal morbidity and mortality and the postpartum period is associated with increased risk for this outcome with many events occurring after discharge home from a delivery hospitalization.^{1,20,22} While multiple risk factors for postpartum stroke have been identified in the literature, including hypertensive and other medical and obstetric conditions,¹ these data from a nationally representative sample suggest that postpartum strokes often occur soon after delivery.^{5,22} While postpartum stroke is relatively rare and the degree to which these events are preventable is unknown, these findings support prompt optimal blood pressure management and evaluation of patients with

concerning symptoms (such as unremitting headache and focal neurologic abnormalities) in the days immediately after hospital discharge.

Our data demonstrate the challenging nature of reducing risk for postpartum stroke readmission as more than 80% of patients readmitted with PAS did not have a diagnosis of HDP or CHTN during their index hospitalization. In the adjusted analyses, specific factors were associated with increased risk for PAS, but the magnitude of risk did not facilitate identification of a small, particularly high-risk cohort. Further research is required to characterize which patients may be at highest risk for events and determine what, if any, interventions may improve outcomes. Providing routine neurologic precautions at delivery discharge may represent a means of improving early detection of events. The use of mobile health technology strategies including text messaging and wireless device applications may represent a cost-effective means of patient monitoring and is an important focus for future research.^{23–25} Large maternal safety collaboratives such as the California Maternal Quality Care Collaborative and New York State's Safe Motherhood Initiative may be able to further characterize which symptoms are most likely to be associated with PAS events.

The mechanism by which risk for stroke is increased postpartum is unknown, but may be secondary to blood pressure elevation that peaks 3 to 5 days after delivery secondary to fluid shifts along with impaired cerebral autoregulation.^{26,27} Regardless of etiology, stroke risk is likely to continue to rise given that many risk factors such as older maternal age, pregestational diabetes, chronic hypertension, and other stroke-related high-risk conditions continue to increase on a population basis. While further research is indicated to determine what mechanisms predispose PAS, research on clinical interventions to reduce risk are needed now.

Strengths of this study include a large nationally representative sample designed to analyze hospital readmissions, allowing a detailed adjusted analysis for this rare outcome. The validity of our findings on the temporal distribution of readmissions was enhanced by the fact that both the primary and the sensitivity analyses demonstrated similar results, as did analysis of specific HDP diagnoses. While misclassification and under-ascertainment are always concerns with administrative diagnosis codes, the sensitivity analysis restricted to higher sensitivity codes²¹ demonstrated similar results to the primary model in the univariate and adjusted analyses. Other factors that enhance the strength of the analysis include that codes for HDP are relatively sensitive,^{17,28,29} and that to avoid misclassification between historical and acute events we excluded patients with diagnoses of PAS during the index admission. Finally, the approach to identifying stroke in administrative data is the same as that utilized by the CDC, and prevalence of this condition was similar to readmission risk ascertained in their analysis of data from the Nationwide Inpatient Sample.^{2,30}

Limitations of the study include shortcomings inherent to administrative data, which provide a broad overview of population-based risk, but lack many important clinical details. While we were able to stratify patients based on specific preeclampsia diagnosis, we were unable to examine the severity of disease, blood pressure control, and interventions that were performed, such as use of antihypertensive or antithrombotic medications. Additionally, administrative data do not capture important risk factors such as body mass index that may

modify risk, and many secondary diagnoses are likely under-ascertained. Discharge medication administration, including initiation of estrogen-containing birth control, was not available. Another limitation is that from this database we were not able to model interval from date of delivery to stroke readmission and used discharge date instead. Additionally, because some stroke codes including those that are pregnancy-related are not specific with regards to the event being hemorrhagic or ischemic, only a minority of the events in our cohort was able to be evaluated in our sensitivity analysis limiting powering. Finally, while we adjusted for variables such as payer and median income which are related to race, we were not able to account for race directly as this variable is not included in the data set.

In conclusion, while this analysis found that risk for stroke was associated with conditions such as HDP and CHTN, the most important risk factor was time from discharge with most readmissions occurring within the first 10 days home from the hospital. This temporal relationship may be important in designing safety interventions for at-risk patients, and the relatively short period may represent an opportunity to meaningfully improve maternal outcomes.

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Figure 1:

The histogram demonstrates the proportion of stroke readmissions by hypertensive diagnosis over the first 60 days after hospital discharge. *Hypertensive diseases of pregnancy include superimposed, severe, and mild or unspecified preeclampsia and gestational hypertension.

Table 1.

Demographic, medical, and hospital factors associated with postpartum stroke readmission

	Stroke readmission		No stroke readmission		
	n	%	n	%	P-value
<i>All patients</i>	1,505	100%	6,270,631	100%	
<i>Hypertension</i>					<0.01
Hypertensive diseases of pregnancy	214	14.2%	512457	8.2%	
Chronic hypertension	66	4.4%	110955	1.8%	
None	1225	81.4%	5647218	90.1%	
<i>Age</i>					<0.01
15–19	55	3.7%	430442	6.9%	
20–24	246	16.3%	1393780	22.2%	
25–29	407	27.0%	1787708	28.5%	
30–34	426	28.3%	1688886	26.9%	
35–39	260	17.2%	784456	12.5%	
> 39	112	7.5%	185358	3.0%	
<i>ZIP code income quartile</i>					<0.01
Lowest	460	30.6%	1648410	26.3%	
Low	402	26.7%	1623536	25.9%	
High	354	23.5%	1555966	24.8%	
Highest	278	18.4%	1383436	22.1%	
Data missing	12	0.8%	59282	1.0%	
<i>Insurance status</i>					<0.01
Medicare	13	0.9%	40652	0.7%	
Medicaid	783	52.0%	2649276	42.3%	
Private	645	42.8%	3263074	52.2%	
Self-pay	24	1.6%	99962	1.6%	
No charge	0	0.0%	3948	0.1%	
Other	41	2.7%	199831	3.2%	
Missing data	0	0.0%	13887	0.2%	
<i>Migraine</i>	29	1.9%	51275	0.8%	<0.01
<i>Maternal cardiac disease</i>	8	0.5%	18985	0.3%	0.10
<i>Tobacco</i>	156	10.5%	342517	5.5%	<0.01
<i>Pregestational diabetes</i>	43	2.9%	64129	1.0%	<0.01
<i>Cesarean delivery</i>	628	41.7%	2034336	32.4%	<0.01
<i>Longer length of stay</i>	446	29.6%	1415760	22.6%	<0.01
<i>Hospital Teaching</i>					<0.01
Metro non-teaching	465	30.9%	1981594	31.6%	
Metro teaching	913	60.7%	3634728	58.0%	
Non-metro	127	8.5%	654307	10.4%	

	Stroke readmission		No stroke readmission		
	n	%	n	%	P-value
Hospital Location *					0.02
Large central metro counties	451	30.0%	1830861	29.2%	
Large fringe metro counties	396	26.3%	1598579	25.5%	
Medium metro counties	285	18.9%	1318757	21.1%	
Small metro counties	187	12.4%	609081	9.7%	
Micropolitan (<50,000 population)	115	7.6%	538255	8.6%	
Not metro/micropolitan	72	4.8%	366991	5.9%	
Missing data	0	0.0%	8,106	0.1%	
Hospital bed size #					0.02
Small	170	11.3%	836292	13.3%	
Medium	435	28.9%	1752213	27.9%	
Large	901	59.8%	3682125	58.7%	

HDP, hypertensive diseases of pregnancy. *Longer length of stay*, >4 days for cesarean delivery and >3 days for vaginal delivery.

* As defined by the NCHS Urban-Rural Classification Scheme for Counties: Large central metro counties are metropolitan statistical areas (MSA) of 1 million or more population that 1) contain the entire population of the largest principal city of the MSA, or 2) are completely contained in the largest principal city of the MSA, or 3) contain at least 250,000 residents of any principal city of the MSA. Large fringe metro counties are counties in MSAs of 1 million or more population that do not qualify as large central. Medium metro counties are counties in MSAs of 250,000 to 999,999 population. Small metro counties are counties in MSAs of less than 250,000 population. From: https://www.cdc.gov/nchs/data_access/urban_rural.htm.

Bed size classification is defined using number of beds, region of the U.S., the urban-rural designation of the hospital, in addition to the teaching status.

Table 2.

Adjusted and unadjusted odds of factors associated with postpartum stroke readmission

	Unadjusted analysis		Adjusted analysis	
	OR	95% CI	aOR	95% CI
<i>Hypertension</i>				
HDP	1.86	(1.61, 2.15)	1.74	(1.33, 2.27)
Chronic hypertension	2.55	(1.99, 3.26)	1.88	(1.19, 2.96)
None	0.48	(0.42, 0.55)	1.00	(Reference)
<i>Age (years)</i>				
15–19	0.52	(0.39, 0.67)	0.50	(0.31, 0.78)
20–24	0.68	(0.60, 0.78)	0.70	(0.54, 0.89)
25–29	0.93	(0.83, 1.04)	1.00	(Reference)
30–34	1.07	(0.96, 1.20)	1.22	(0.96, 1.55)
35–39	1.46	(1.28, 1.67)	1.57	(1.22, 2.02)
> 39	2.64	(2.18, 3.20)	2.69	(1.79, 4.05)
<i>ZIP code income quartile</i>				
Lowest	1.23	(1.11, 1.38)	1.36	(1.00, 1.86)
Low	1.04	(0.93, 1.17)	1.25	(0.91, 1.70)
High	0.93	(0.83, 1.05)	1.15	(0.84, 1.57)
Highest	0.80	(0.70, 0.91)	1.00	(Reference)
<i>Insurance status</i>				
Medicare	1.34	(0.77, 2.31)	1.22	(0.53, 2.84)
Medicaid	1.48	(1.34, 1.64)	1.65	(1.35, 2.03)
Private	0.69	(0.62, 0.77)	1.00	(Reference)
Self-pay	1.00	(0.67, 1.50)	1.28	(0.69, 2.37)
Other	0.85	(0.62, 1.16)	1.14	(0.70, 1.84)
<i>Migraine</i>	2.38	(1.65, 3.44)	2.08	(1.00, 4.32)
<i>Maternal cardiac disease</i>	1.76	(0.88, 3.53)	1.31	(0.48, 3.57)
<i>Pregestational diabetes</i>	2.85	(2.10–3.86)	1.70	(1.04, 2.78)
<i>Cesarean delivery</i>	1.49	(1.35, 1.65)	1.28	(1.07, 1.51)
<i>Tobacco</i>	2.00	(1.70, 2.36)	1.81	(1.37, 2.40)
<i>Longer length of stay</i>	1.44	(1.29, 1.61)	1.47	(1.26, 1.71)
<i>Hospital Teaching</i>				
Metro non-teaching	0.97	(0.87, 1.08)	1.00	(Reference)
Metro teaching	1.12	(1.01, 1.24)	1.05	(0.86, 1.27)
Non-metro	0.79	(0.66, 0.95)	0.86	(0.51, 1.48)
<i>Hospital Location *</i>				
Large central metro counties	1.04	(0.93, 1.16)	1.00	(Reference)
Large fringe metro counties	1.04	(0.93, 1.17)	1.11	(0.88, 1.40)

	Unadjusted analysis		Adjusted analysis	
	OR	95% CI	aOR	95% CI
Medium metro counties	0.88	(0.77, 0.99)	0.93	(0.74, 1.18)
Small metro counties	1.32	(1.13, 1.54)	1.33	(0.99, 1.80)
Micropolitan (<50,000 population)	0.88	(0.73, 1.07)	0.99	(0.58, 1.69)
Not metro/micropolitan	0.81	(0.64, 1.03)	0.88	(0.51, 1.52)
Hospital bed size[#]				
Small	0.83	(0.71, 0.97)	1.00	(Reference)
Medium	1.05	(0.94, 1.17)	1.21	(0.87, 1.67)
Large	1.05	(0.95, 1.16)	1.17	(0.87, 1.56)

aOR, adjusted odds ratio. The adjusted model included all the covariates listed in the table *CI*, confidence interval. *HDP*, hypertensive diseases of pregnancy. *Longer length of stay*, >4 days for cesarean delivery and >3 days for vaginal delivery.

* As defined by the NCHS Urban-Rural Classification Scheme for Counties: Large central metro counties are metropolitan statistical areas (MSA) of 1 million or more population that 1) contain the entire population of the largest principal city of the MSA, or 2) are completely contained in the largest principal city of the MSA, or 3) contain at least 250,000 residents of any principal city of the MSA. Large fringe metro counties are counties in MSAs of 1 million or more population that do not qualify as large central. Medium metro counties are counties in MSAs of 250,000 to 999,999 population. Small metro counties are counties in MSAs of less than 250,000 population. From: https://www.cdc.gov/nchs/data_access/urban_rural.htm.

[#] Bed size classification is defined using number of beds, region of the U.S., the urban-rural designation of the hospital, in addition to the teaching status.

Table 3.

Sensitivity analyses

	High-sensitivity codes	Hemorrhagic stroke	Ischemic stroke
	aOR (95% CI)	aOR (95% CI)	aOR (95% CI)
<i>Hypertension</i>			
HDP	1.53 (1.06–2.21)	1.02 (0.56–1.86)	2.36 (1.40–3.97)
Chronic hypertension	1.88 (1.07–3.30)	1.54 (0.64–3.68)	1.56 (0.47–5.14)
None	1.00 (reference)	1.00 (reference)	1.00 (reference)
<i>Age (years)</i>			
15–19	0.23 (0.10–0.51)	0.16 (0.04–0.64)	0.41 (0.11–1.49)
20–24	0.64 (0.46–0.89)	0.73 (0.45–1.19)	0.90 (0.49–1.63)
25–29	1.00 (reference)	1.00 (reference)	1.00 (reference)
30–34	1.36 (1.01–1.82)	1.05 (0.65–1.68)	2.18 (1.33–3.58)
35–39	1.90 (1.39–2.60)	1.16 (0.68–1.99)	2.49 (1.48–4.17)
> 39	3.56 (2.14–5.91)	3.81 (1.86–7.80)	3.97 (1.75–9.02)
<i>ZIP code income quartile</i>			
Lowest	1.62 (1.15–2.28)	1.28 (0.78–2.12)	1.45 (0.82–2.57)
Low	1.29 (0.91–1.83)	1.41 (0.81–2.46)	1.26 (0.73–2.19)
High	1.06 (0.75–1.50)	0.78 (0.45–1.33)	1.27 (0.66–2.05)
Highest	1.00 (reference)	1.00 (reference)	1.00 (reference)
<i>Insurance status</i>			
Medicare	0.53 (1.13–2.17)	NA	1.26 (0.30–5.24)
Medicaid	1.42 (1.12–1.80)	1.50 (1.01–2.23)	1.27 (0.88–1.82)
Private	1.00 (reference)	1.00 (reference)	1.00 (reference)
Self-pay	1.10 (0.52–2.32)	1.93 (0.72–5.16)	0.33 (0.05–2.37)
Other	0.86 (0.43–1.73)	1.62 (0.69–3.81)	0.63 (0.15–2.67)
<i>Migraine</i>	2.50 (1.01–6.20)	1.23 (0.29–5.13)	2.34 (0.49–11.22)
<i>Maternal cardiac disease</i>	0.99 (0.24–4.14)	1.46 (0.21–10.22)	2.47 (0.59–10.35)
<i>Tobacco</i>	2.30 (1.63–3.26)	1.75 (0.92–3.34)	2.24 (1.26–3.98)
<i>Pregestational diabetes</i>	1.40 (0.72–2.71)	0.34 (0.05–2.49)	2.46 (1.09–5.54)
<i>Cesarean delivery</i>	1.11 (0.88–1.41)	1.13 (0.76–1.68)	1.42 (0.95–2.12)
<i>Longer length of stay</i>	1.27 (0.98–1.65)	1.31 (0.89–1.92)	1.55 (1.02–2.36)
<i>Hospital Teaching</i>			
Metro non-teaching	1.00 (reference)	1.00 (reference)	1.00 (reference)
Metro teaching	0.93 (0.73–1.19)	0.99 (0.67–1.44)	1.06 (0.71–1.57)
Non-metro	0.70 (0.36–1.37)	0.71 (0.16–3.14)	1.55 (0.49–4.84)
<i>Hospital Location*</i>			
Large central metro counties	1.00 (reference)	1.00 (reference)	1.00 (reference)
Large fringe metro counties	1.18 (0.89–1.56)	0.95 (0.61–1.49)	1.17 (0.73–1.86)

	High-sensitivity codes	Hemorrhagic stroke	Ischemic stroke
	aOR (95% CI)	aOR (95% CI)	aOR (95% CI)
Medium metro counties	0.99 (0.73–1.51)	0.96 (0.58–1.57)	1.00 (0.62–1.61)
Small metro counties	1.01 (0.67–1.51)	0.78 (0.40–1.51)	1.03 (0.57–1.87)
Micropolitan (<50,000 population)	1.00 (0.53–1.89)	0.50 (0.13–1.88)	0.46 (0.12–70)
Not metro/micropolitan	0.77 (0.38–1.54)	0.09 (0.01–0.89)	0.67 (0.25–1.79)
Hospital bed size[#]			
Small	1.00 (reference)	1.00 (reference)	1.00 (reference)
Medium	0.96 (0.65–1.42)	0.85 (0.46–1.56)	1.09 (0.55–2.14)
Large	0.96 (0.67–1.39)	1.07 (0.60–1.89)	0.93 (0.51–1.69)

aOR, adjusted odds ratio. CI, confidence interval. HDP, hypertensive diseases of pregnancy. Longer length of stay, >4 days for cesarean delivery and >3 days for vaginal delivery.

[#] Bed size classification is defined using number of beds, region of the U.S., the urban-rural designation of the hospital, in addition to the teaching status.

^{*} As defined by the NCHS Urban-Rural Classification Scheme for Counties: Large central metro counties are metropolitan statistical areas (MSA) of 1 million or more population that 1) contain the entire population of the largest principal city of the MSA, or 2) are completely contained in the largest principal city of the MSA, or 3) contain at least 250,000 residents of any principal city of the MSA. Large fringe metro counties are counties in MSAs of 1 million or more population that do not qualify as large central. Medium metro counties are counties in MSAs of 250,000 to 999,999 population. Small metro counties are counties in MSAs of less than 250,000 population. From: https://www.cdc.gov/nchs/data_access/urban_rural.htm.