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The weekend effect on mechanical thrombectomy: A nationwide analysis before and after the pivotal 2015 trials

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Abstract:

OBJECTIVES: As hospitals rapidly implement mechanical thrombectomy (MT) into stroke protocols following the pivotal trials in 2015, access to and outcomes from MT may be poorer for weekend-admitted patients. We sought to investigate whether a "weekend effect" influences MT outcomes nationally.

MATERIALS AND METHODS: We identified stroke patients from 2010–2014 (pre-trials) to 2015–2017 (posttrials) using the Nationwide Readmissions Database. On multivariate analyses, we determined factors independently associated with receiving MT. Among MT patients, we then determined whether weekend admission was independently associated with inpatient mortality and unfavorable discharge.

RESULTS: We identified 2,121,462 patients from 2010 to 2014, of whom 1.11% of weekday-admitted and 1.08% of weekend-admitted patients underwent MT. Of the 1,286,501 patients identified from 2015 to 2017, MT was performed in 2.82% and 2.91%, respectively. In the earlier cohort, weekend admission was independently associated with reduced odds of MT (odds ratio [OR] = 0.92, 95% confidence interval [CI]: 0.89–0.95, $P < 0.0001$), although this was not statistically significant in the later cohort. During both periods, age >80 years was independently associated with a reduced likelihood of receiving MT, and status as a teaching or large bed-size hospital was associated with a greater likelihood. Weekend admission was independently associated with unfavorable discharge only in the 2015–2017 cohort (OR = 1.11, 95% CI: 1.02–1.22, $P = 0.02$).

CONCLUSIONS: While nationwide access to MT has improved for weekend-admitted patients, the elderly and those at smaller, nonteaching hospitals remain underserved. Although we found no effect of weekend admission on inpatient mortality, since the major shift in practice, an emerging "weekend effect" may influence discharge outcomes. Data suggest that some hospitals are being challenged to provide this new standard of care efficiently and equitably.

Keywords:
Acute ischemic stroke, large-vessel occlusion, mechanical thrombectomy, weekend effect

Introduction

The "weekend effect" theory posits that the quality of care, and resulting outcomes, are poorer for patients admitted during the weekend than those admitted during the weekday.[1] Data from multiple specialties have shown that weekend-admitted patients have greater morbidity and mortality.[1-4] Evidence of a weekend effect has been shown in the treatment of acute ischemic stroke (AIS), both in the U. S. and internationally,[5-9] including older data on outcomes after mechanical thrombectomy (MT).[10] However, nationally representative data that reflect the recent, widespread implementation of MT into hospital stroke protocols has been lacking.[11,12]

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In 2015, the American Heart Association/American Stroke Association (AHA/ASA) strongly recommended MT for patients with anterior circulation, large-vessel occlusions (LVOs),[13] after several landmark studies had demonstrated a significant benefit in functional outcomes.[14-18] As MT then became the standard of care, hospitals have assiduously sought to become Thrombectomy-Capable Stroke Centers (TSCs).[11,19] The time-sensitive nature of performing an MT, as well as the potential financial benefit from obtaining TSC certification, have incentivized hospitals to streamline their stroke protocols by eliminating any delays or inequities in quality of care.[11,19,20] However, systems issues of weekend care-staffing shortages, longer time to mobilize teams, lack of in-house providers including stroke neurologists and interventionalists may delay otherwise efficient stroke protocols and limit the ability to provide quality MT, which can in turn lead to greater morbidity.[1-4,10]

Using a national database that captures more than half of all U. S. hospitalizations and discharges,[21] we investigate whether weekend admission affects the likelihood of performing MT for AIS patients and whether outcomes differ from those of weekday-admitted patients. By comparing data from before and after the 2015 update to the AHA/ASA guidelines,[13] we sought to determine whether any deleterious weekend effect has been successfully resolved at a national level.

Methods

Data source

The Nationwide Readmissions Database (NRD), sponsored by the Health Care Utilization Project (HCUP), is the largest all-payer national dataset, capturing 58.2% of U. S. admissions in 2017.[21] The NRD receives data from 28 state inpatient databases, accounts for 35 million weighted discharges (18 million unweighted), and tracks patients longitudinally with unique, de-identified patient linkage numbers (PLNs). Information captured includes age, sex, weekend versus weekday admission, inpatient mortality, type of hospital (e.g., size and teaching), length of stay (LOS), insurance, International Classification of Diseases, 9th Revision Clinical Modification (ICD-9 CM) codes (before January 10, 2015), and International Classification of Diseases, 10th Revision Clinical Modification (ICD-10 CM) codes (January 1, 2015, to present). Further details on the NRD design are available at https://www.hcup-us.ahrq.gov/nrdoverview.jsp. As the NRD is publicly available and data are de-identified, this study was exempt from institutional review board approval. All analyses comply with the HCUP data use agreement.

Patient selection

In this retrospective cohort study, we queried the NRD for all patients aged >18 years from 2010 to 2017 who were admitted with a primary diagnosis of AIS (*n* = 3,615,268, weighted), using ICD-9 codes from January 2010 to September 2015 (436, 433.01, 433.11, 433.21, 433.31, 433.81, 433.91, 434.01, 434.11, and 434.91), and ICD-10 codes from October 2015 to December 2017 (I63.0, I63.1, I63.2, I63.3, I63.4, I63.5, I63.6, I63.8, I63.9). Using PLNs, we excluded duplicate AIS admissions (*n* = 75,325, weighted), as well as those with missing values on LOS, or elective admissions with LOS <1 day. Our final study population (*n* = 3,407,964, weighted) was then divided into two cohorts – before the 2015 AHA/ASA updated guidelines[13] (2010–2014) and after (2015–2017).

Outcomes

Our primary outcome was whether or not MT was performed during the index hospitalization for AIS, in both the 2010–2014 and 2015–2017 cohorts. Similar to previous authors,[9,10] we then further categorized patients into weekday (Monday to Friday) and weekend (Saturday and Sunday) admissions (per HCUP definition), and determined factors independently associated with receiving MT. Our secondary aim was to determine whether the outcomes among MT patients admitted during the weekend differed from those admitted during the weekday, in terms of inpatient mortality and odds of unfavorable discharge (to a skilled nursing facility, intermediate care facility, subacute rehabilitation, or similar).

Variables and definitions

Patient-level variables relevant to AIS, including comorbidities (e.g., atrial fibrillation, hypertension, smoking), procedures (e.g., MT, administration of intravenous thrombolytics (IVT), decompressive hemicraniectomy [DHC]), and complications were identified by searching all primary and secondary diagnostic codes using the HCUP-defined Clinical Classification Software (CCS). CCS is a validated tool which groups related procedural and diagnostic ICD-9 and ICD-10 codes into clinically relevant categories (See detailed coding methodology in Supplementary Materials).[21-23] Patient discharge was categorized as routine (to home), home with home health care, acute rehabilitation facility, or unfavorable. Unfavorable discharge, a validated surrogate for poor functional status after stroke, is nearly universally documented in administrative databases.[24] Functional status on admission was determined using the All Patient Refined-Diagnosis-Related Groups (APR-DRG) severity of illness subclass, a four-point ordinal scale derived from age, diagnoses, and procedures that ranges from minor loss of function (1) to extreme loss of function (4). The APR-DRG algorithm is a validated, reliable indicator of functional status in stroke for studies using large, administrative databases,[25-27] including the NRD.[28]

Statistical analysis

Weekday and weekend-admitted patients were first compared in a univariate analysis (in both 2010–2014 and 2015–2017 cohorts), in which categorical and continuous variables were assessed using the Rao-Scott Chi-square test and the Wilcoxon signed-rank sum test, respectively. We used sampling weights provided in the NRD to generate national estimates. Categorical variables were expressed as a percentage of the group of origin and continuous variables were reported as mean ± standard deviation (SD). Reported probability values were two-tailed and were considered statistically significant if $P \leq 0.05$. To determine variables independently associated with receiving MT, we then built a multivariate, survey-weighted logistic regression model, using strata and cluster design to derive odds ratios (OR) and 95% confidence intervals (95% CI) with corresponding P values. Statistically significant ($P \leq 0.05$) and/or clinically relevant variables from the univariate analysis were included in the multivariate model. In a similar manner, for our secondary aim, we built separate multivariate models to determine OR for inpatient mortality and unfavorable discharge among weekend-admitted patients treated with MT (with weekday as reference). The model for unfavorable discharge was built after exclusion of patients who died in the hospital. SAS 9.4 (SAS Institute Inc., Cary, North Carolina) was used for data analysis.

Results

Acute ischemic stroke cohorts

A total of 2,121,462 patients were admitted with a primary diagnosis of AIS from 2010 to 2014, of whom 549,979 (25.9%) were admitted during the weekend. From 2015 to 2017, 1,286,501 AIS patients were admitted, of whom 332,388 (25.8%) were during the weekend. On univariate analysis, demographics, comorbidities, insurance status, and hospital characteristics of weekday-admitted AIS patients were similar to weekend-admitted patients in both cohorts [Table 1].

Overall mechanical thrombectomy data

The overall frequency of MTs performed per 100,000 AIS cases increased annually from 685 in 2010, to 2,133 in 2015, and 3,493 in 2017 [Figure 1]. This increase was seen among all hospital types (small, medium, and large bed-size, as well as teaching and nonteaching). Within the 2010–2014 cohort, a total of 1.11% of weekday-admitted AIS patients received a MT compared to 1.08% among those who were weekend-admitted, which was not statistically significant on univariate analysis ($P = 0.34$). A greater overall proportion of the

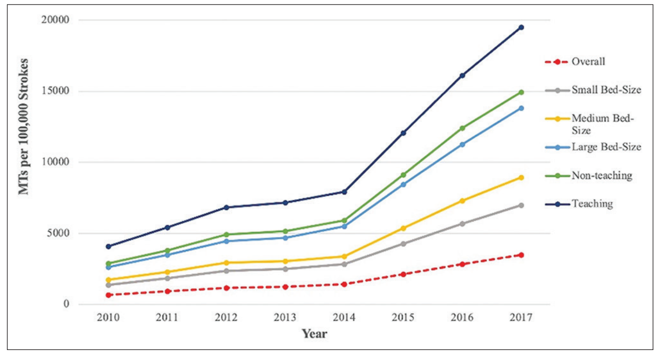

Figure 1: Trend of frequencies of MTs performed per 100,000 strokes in various hospital types, 2010-2017. MT: Mechanical thrombectomies

2015–2017 cohort received MT, although the difference between weekdays and weekends was again not statistically significant (2.82% and 2.91%, respectively, $P = 0.11$).

Factors independently associated with receiving mechanical thrombectomy

In our multivariate model of the 2010–2014 cohort, however, weekend admission was independently associated with a reduced likelihood of receiving MT compared to weekday admission (OR: 0.92, 95% CI: 0.89–0.95, $P < 0.0001$). This effect was not statistically significant in the 2015–2017 cohort [Table 2]. Advanced age >80 years was strongly associated with a reduced odds of receiving MT in the 2010–2014 cohort (OR: 0.43, 95% CI: 0.41–0.46, $P < 0.0001$), and to a lesser, yet still statistically significant extent in the 2015–2017 cohort (OR: 0.65, 95% CI: 0.62-0.68, $P < 0.0001$). In both cohorts, MT was also independently associated with private insurance and admission to large, teaching hospitals [Table 2]. In addition, regarding factors related to the severity of strokes treated with thrombectomy, MT was independently associated with receiving IVT, having intracranial hemorrhage and/or cerebral edema as sequelae, major to extreme loss of function on admission (APR-DRG severity 3–4), and atrial fibrillation [Table 2].

Outcomes of mechanical thrombectomy patients

Our multivariate model in Table 3 describes the effect of weekend admission on inpatient mortality and unfavorable discharge among patients who underwent MT, controlling for clinically and statistically significant variables (including APR-DRG functional status, as done by previous authors).[28] Weekend-admitted patients undergoing MT did not have a statistically significant difference in inpatient mortality compared to those admitted during the weekday (variable of reference), during both periods. From 2010 to 2014, we found no effect of weekend admission on unfavorable discharge. However, during the 2015–2017 time period,

Table 1: Baseline characteristics of patients admitted with acute ischemic stroke, 2010-2014 and 2015-2017

Variables	2010-2014			2015-2017		
	Weekdays (*n*=1,571,483), *n* (%)	Weekends (*n*=549,979), *n* (%)	*P*	Weekdays (*n*=954,113), *n* (%)	Weekends (*n*=332,388), *n* (%)	*P*
Age (years)			<0.0001			<0.0001
18-49	7.92	7.70	Reference	7.83	7.52	Reference
50-79	58.7	58.1	0.18	60.7	60.0	0.02
≥80	33.4	34.2	<0.0001	31.5	32.5	<0.0001
Sex (male reference)						
Female	51.6	52.1	0.0008	50.6	51.1	0.0005
Inpatient treatment						
MT	1.11	1.08	0.34	2.82	2.91	0.11
IVT	8.23	8.78	<0.0001	11.1	11.9	<0.0001
DHC	0.40	0.45	0.018	0.24	0.26	0.28
Complications						
ICH	3.16	3.32	0.001	3.98	4.12	0.034
Hydrocephalus	0.50	0.52	0.33	0.52	0.52	0.99
Cerebral edema	3.38	3.64	<0.0001	4.71	5.05	<0.0001
Comorbidities						
Hypertension	82.4	82.8	0.0048	84.3	84.3	0.904
Smoking	29.0	28.9	0.24	36.8	36.3	0.002
Drug abuse	2.48	2.58	0.018	2.72	2.71	0.86
Alcohol abuse	4.39	4.52	0.017	4.50	4.61	0.10
Obesity	10.3	10.3	0.57	12.8	12.7	0.43
Chronic liver disease	1.20	1.18	0.57	1.58	1.53	0.15
Chronic renal disease	14.6	14.5	0.18	16.4	15.9	<0.0001
Hypothyroidism	13.6	13.7	0.24	14.0	14.1	0.37
DM	36.1	35.6	0.0004	37.5	37.0	0.001
Dyslipidemia	56.0	55.9	0.76	58.1	58.0	0.39
Atrial fibrillation	24.5	25.2	<0.0001	25.6	26.3	<0.0001
CHF	14.4	14.5	0.12	15.5	15.5	0.89
PVD	9.85	9.67	0.035	9.96	9.95	0.93
Valvular disease	10.0	10.1	0.53	10.2	10.2	0.95
Long-term use of Anti-thrombotics	14.1	14.3	0.098	24.1	24.2	0.25
Long-term use of Anticoagulants	6.96	7.07	0.15	8.82	8.74	0.38
Functional status (APR-DRG)			<0.0001			0.0005
1-2 (mild to moderate loss of function)	60.5	59.9	Reference	58.6	58.1	Reference
3-4 (major to extreme loss of function)	39.5	40.1	<0.0001	41.4	41.9	0.0005
Discharge outcomes			<0.0001			<0.0001
Routine to home	40.0	38.4	Reference	40.9	39.2	Reference
HHC	18.7	18.7	<0.0001	16.7	16.6	<0.0001
Acute rehabilitation	1.63	1.71	<0.0001	1.32	1.29	0.41
Adverse discharge (SNF, ICF, subacute rehabilitation, or similar)	33.8	34.9	<0.0001	35.5	37.1	<0.0001
AMA	0.64	0.58	0.11	0.89	0.87	0.36
Death in hospital	5.09	5.43	<0.0001	4.60	4.86	<0.0001
Missing data	0.181	0.1969	0.043	0.09	0.09	0.43
Insurance status			0.0067			<0.0001
Medicare	67.6	67.9	Reference	67.3	68.1	Reference
Medicaid	7.24	7.30	0.22	8.57	8.50	0.062
Private	17.5	17.1	0.015	17.7	17.0	<0.0001
Self-pay	4.48	4.50	0.38	3.54	3.57	0.99
Other	3.20	3.15	0.33	2.89	2.80	0.011
Hospital characteristics			<0.0001			<0.0001
Small bed-size	11.3	10.8	Reference	14.6	13.9	Reference
Medium bed-size	24.3	24.2	0.038	27.9	27.7	0.0004

Contd...

Table 1: Contd...

Variables	2010-2014			2015-2017		
	Weekdays (*n*=1,571,483), *n* (%)	Weekends (*n*=549,979), *n* (%)	*P*	Weekdays (*n*=954,113), *n* (%)	Weekends (*n*=332,388), *n* (%)	*P*
Large bed-size	64.5	65.0	<0.0001	57.5	58.5	<0.0001
Teaching hospital (reference, nonteaching)	50.9	51.9	<0.0001	66.2	67.4	<0.0001
Median household income by patient zip code			0.13			0.0009
0-25th percentile	31.1	30.9	Reference	31.0	30.5	Reference
26th-50th percentile	25.4	25.4	0.42	26.0	26.2	0.0069
51st-75th percentile	22.7	22.8	0.097	23.7	23.6	0.13
76th-100th percentile	19.2	19.4	0.061	17.9	18.3	0.0001
Missing	1.57	1.62	0.049	1.41	1.43	0.17

MT: Mechanical thrombectomy, IVT: Intravenous thrombolysis, DHC: Decompressive hemicraniectomy, ICH: Intracerebral hemorrhage, DM: Diabetes mellitus, CHF: Congestive heart failure, PVD: Peripheral vascular disease, HHC: Home with home health care, SNF: Skilled nursing facility, ICF: Intermediate care facility, AMA: Against medical advice, APR-DRG: All patient refined-diagnosis-related groups

weekend admission was independently associated with unfavorable discharge (OR: 1.11, 95% CI: 1.02–1.22, $P = 0.02$). From the 2010–2014 to 2015–2017 time periods, average LOS among weekend-admitted patients decreased slightly from 3.43 days (±1 SD 2.03–7.53) to 2.83 days (1.70–4.79), $P < 0.0001$, which was similar among weekday-admitted patients, which decreased from 3.46 (1.78–7.02) to 2.78 days (1.50–5.30), $P < 0.0001$.

Discussion

Although AIS remains a leading cause of death and disability,[29] the "weekend effect" among stroke patients is understudied. To the best of our knowledge, this is the first study to use large, population-level datasets to investigate whether the rapidly evolving endovascular management of stroke is subject to a weekend effect, in terms of the likelihood of receiving the treatment and post-treatment outcomes. In this analysis of more recent, nationally representative data, we found that overall, a small weekend effect had initially been present in terms of the likelihood of receiving MT, but then resolved after the 2015 update to the AHA/ASA guidelines.[13] However, certain subgroups of patients, particularly the elderly, remained significantly less likely to receive MT. In terms of outcomes, weekend admission was independently associated with more frequent unfavorable discharges in the postguidelines, 2015–2017 cohort. Our data suggest that, on a national level, non–uniform access to and varying outcomes from endovascular treatment remain. These findings may be related to rapidly changing hospital practices and socioeconomic influences following the guidelines update.

Prior studies have demonstrated a greater overall mortality and morbidity among stroke patients who are admitted during the weekend,[5-8] attributing this to an *off-hours* phenomenon of hospital "systems inadequacies,[4]" also reported during holiday[6] and nighttime admissions.[8,30] For patients undergoing MT, existing data have primarily assessed outcomes from single centers, or reflect patterns of MT usage prior to the updated guidelines.[13] Further, few have used administrative databases to determine factors that affect the likelihood of a patient receiving an MT. Overall, institutional studies have had mixed results in assessing whether weekend admission influences outcomes.[31-33] However, a pre-guidelines study of patients undergoing MT, which used the nationwide inpatient sample (NIS), found that those admitted to nonteaching hospitals during the weekend were 60% more likely to have moderate or severe disability at discharge.[10] In another NIS study that investigated trends of MT by comparing pre- to post-guidelines data, the probability of a good outcome had slightly improved.[12] Similar to our data, the authors found that MT had more than doubled in utilization, and that the proportion of patients receiving concurrent IVT with MT had declined (60.3% in 2010–2014 to 43.4% in 2015–2017 in our data).[12] In addition, a smaller proportion underwent DHC in the later cohort, consistent with prior data,[34] however demographics and comorbidities of the earlier and later cohorts were generally similar.

Although our data showed no overall effect of weekend admission on inpatient mortality, we did find evidence of a weekend effect in the postguidelines cohort, in terms of a modestly increased likelihood of unfavorable discharge (as mentioned earlier, a surrogate for poorer functional outcome among stroke patients[24]) relative to their weekday counterparts. Although seemingly counterintuitive, this finding may in fact be related to the recent, widespread implementation of MTs into a large variety of hospital settings, driven by positive results from clinical trials[14-18] and strong financial incentives to become TSCs.[11,12,19] Indeed, the latter NIS study found that approximately 50% more hospitals had started providing MT after the guidelines update.[12] As a

Table 2: Factors associated with odds of receiving mechanical thrombectomy in 2010-2014 and 2015-2017, multivariate model

Variables	2010-2014		2015-2017	
	OR	*P*	OR	*P*
Weekend admission (weekday reference)	0.92 (0.89-0.95)	<0.0001	0.98 (0.94-1.02)	0.2379
Age groups (years)				
18-49	Reference		Reference	
50-79	0.73 (0.70-0.77)	<0.0001	0.88 (0.84-0.91)	<0.0001
≥80	0.43 (0.41-0.46)	<0.0001	0.65 (0.62-0.68)	<0.0001
Female sex (male reference)	1.04 (1.02-1.07)	0.0033	-	-
Treatments and complications				
IVT	10.8 (10.5-11.1)	<0.0001	4.75 (4.65-4.86)	<0.0001
DHC	0.90 (0.82-0.99)	0.0282	0.92 (0.76-1.12)	0.4121
ICH	2.90 (2.80-3.01)	<0.0001	3.06 (2.96-3.15)	<0.0001
Hydrocephalus	1.14 (1.02-1.27)	0.0181	1.05 (0.90-1.23)	0.5219
Cerebral edema	2.67 (2.57-2.78)	<0.0001	2.79 (2.71-2.88)	<0.0001
Comorbidites				
Hypertension	0.88 (0.85-0.91)	<0.0001	0.86 (0.84-0.89)	<0.0001
Smoking	0.91 (0.88-0.94)	<0.0001	0.84 (0.82-0.86)	<0.0001
Liver disease	-	-	0.83 (0.75-0.91)	0.0001
Obesity	1.16 (1.11-1.21)	<0.0001	-	-
Renal failure	0.68 (0.65-0.71)	<0.0001	0.76 (0.73-0.78)	<0.0001
Hypothyroidism	0.99 (0.90-1.07)	0.7225	0.97 (0.92-1.03)	0.3086
DM	0.82 (0.80-0.85)	<0.0001	0.72 (0.70-0.74)	<0.0001
Dyslipidemia	0.92 (0.90-0.95)	<0.0001	0.87 (0.85-0.89)	<0.0001
Atrial Fibrillation	2.39 (2.32-2.47)	<0.0001	2.50 (2.44-2.57)	<0.0001
CHF	1.20 (1.15-1.24)	<0.0001	1.28 (1.25-1.32)	<0.0001
PVD	1.47 (1.41-1.54)	<0.0001	1.35 (1.31-1.40)	<0.0001
Valvular disease	1.16 (1.12-1.21)	<0.0001	1.12 (1.09-1.16)	<0.0001
Long term use of anti-thrombotics	-	-	0.79 (0.76-0.81)	<0.0001
Long term use of anticoagulants	1.38 (1.32-1.44)	<0.0001	1.20 (1.16-1.25)	<0.0001
Insurance status				
Medicare	Reference		Reference	
Medicaid	1.06 (1.01-1.12)	0.0293	1.07 (1.02-1.12)	0.0026
Private insurance	1.16 (1.11-1.20)	<0.0001	1.22 (1.18-1.26)	<0.0001
Self-pay	1.07 (1.0-1.15)	0.0579	1.18 (1.11-1.26)	<0.0001
No charge/other	0.94 (0.87-1.02)	0.1617	1.16 (1.09-1.24)	<0.0001
Hospital characteristics				
Small bed-size	Reference		Reference	
Medium bed-size	1.40 (1.28-1.53)	<0.0001	2.18 (2.05-2.32)	<0.0001
Large bed-size	3.86 (3.57-4.18)	<0.0001	5.07 (4.78-5.38)	<0.0001
Teaching hospital (reference, nonteaching)	3.32 (3.21-3.44)	<0.0001	3.08 (2.98-3.19)	<0.0001
Median household income by patient zip code				
0-25th percentile	Reference		Reference	
26th-50th percentile	1.10 (1.06-1.14)	<0.0001	1.05 (1.02-1.08)	0.0032
51st-75th percentile	1.24 (1.20-1.29)	<0.0001	1.13 (1.10-1.17)	<0.0001
76th-100th percentile	1.23 (1.18-1.28)	<0.0001	1.12 (1.09-1.15)	<0.0001
Missing	1.10 (0.98-1.23)	0.1193	1.02 (0.92-1.12)	0.7494
Functional status (APR-DRG)				
1-2 (mild to moderate loss of function)	Reference		Reference	
3-4 (major to extreme loss of function)	(42.128-35.724) 49.680	<0.0001	(44.428-38.403) 51.398	<0.0001

IVT: Intravenous thrombolysis, DHC: Decompressive hemicraniectomy, ICH: Intracerebral hemorrhage, DM: Diabetes mellitus, CHF: Congestive heart failure, PVD: Peripheral vascular disease, APR-DRG: All patient refined-diagnosis-related groups, OR: Odds ratio

result, a growing proportion of MTs are being performed at nonteaching, lower-volume centers, and while this has greatly improved access to MT, the likelihood of a good functional outcome is known to be marginally lower in such settings.[10,11] Our findings of modestly poorer weekend outcomes are in contrast to the overall outcomes reported in the NIS data,[12] possibly because the study did not account for the effect of weekend admission. In addition, the NRD captures approximately three times as many unique hospitalizations as the

Table 3: Effect of weekend admission on outcomes in mechanical thrombectomy population, multivariate models

Outcome variable	2010-2014		2015-2017	
	OR	*P*	OR	*P*
Inpatient mortality	0.97 (0.83-1.12)	0.65	1.08 (0.96-1.21)	0.20
Adverse discharge (to SNF/ICF/subacute rehabilitation)[a]	1.04 (0.89-1.22)	0.63	1.11 (1.02-1.22)	0.02

Models were adjusted for admission day (i.e., weekday vs. weekend), age, sex, IVT, DHC, ICH, hydrocephalus, cerebral edema, hypertension, smoking, drug abuse, alcoholism, PVD, valvular disease, atrial fibrillation, long term use of antithrombotics, long-term use of anti-coagulants, insurance status, bed-size of hospital, teaching status of hospital, median income, and baseline functional status (APR-DRG), [a]Model run after excluding inpatient deaths. IVT: Intravenous thrombolysis, DHC: Decompressive hemicraniectomy, ICH: Intracerebral hemorrhage, PVD: Peripheral vascular disease, APR-DRG: All patient refined-diagnosis-related groups, OR: Odds ratio, SNF: Skilled nursing facility, ICF: Intermediate care facility

NIS, and thereby may be considered statistically more representative of the U. S. population.[12,21]

Unlike higher-volume, academic hospital settings (where the functional benefits of MT were initially shown[14-18]), lower-volume centers often lack the resources to have a comparable level of prompt neuroimaging, appropriate patient selection, interventionalist availability, stroke nursing, and rehab capabilities.[11] In effect, although MT has become more widely available (approximately five-fold from 2010 to 2017 in our data), there is evidence of a new weekend effect, likely as hospitals rapidly adapt and optimize their clinical infrastructure to become endovascular-capable. Indeed, some hospitals have implemented and streamlined LVO protocols to mitigate the weekend effect.[35]

Weekend admission no longer affected the odds of receiving MT postguidelines, suggesting that this implementation has by and large been successful. The difference in outcomes, however, suggests that the full course of hospitalization may not yet be optimized, which may be related to in-hospital as well as pre-hospital factors.[36-38] As stroke treatment relies on highly protocolized, time-sensitive workflow algorithms with multidisciplinary coordination, a weekend effect may result from even minor delays or inadequacies in a necessarily well-orchestrated sequence of events from triage to diagnosis, to appropriate treatment and aftercare. System inadequacies on the weekend may include insufficient nursing or interventional staff, longer transport times to computed tomography scan or to the interventional suite, greater door-to-reperfusion or imaging-to-reperfusion times, and unavailable equipment.[1-4,32,33,39]

Further, unlike stroke patients who only receive IVT, the outcomes of LVO patients rely heavily on the availability and technical ability of the subspecialized proceduralist, which may result in a weekend effect similar to that observed among patients undergoing coronary reperfusion[40] and carotid endarterectomies.[4] Weekend coverage by more junior interventionalists or those with commitments to multiple hospitals may affect access to and outcomes of MT, as appropriate patient selection and time to MT strongly influence functional outcomes.[20] A weekend effect may also be due to implicit, unconscious biases on behalf of the physician, in that the clinical context of the stroke (e.g., inconvenient off-hours time) is known to affect judgment, even when assessing objective information.[31]

Such biases and system inadequacies may result in nonuniform access to subspecialty services.[31,35] Although weekend admission did not seem to affect overall access to MT postguidelines, other demographic and socioeconomic factors influenced the likelihood of receiving the treatment. The very elderly (age >80 years), in particular, were significantly less likely to receive MT than younger patients with similar comorbidities and socioeconomic status, despite the fact that, as the population ages, the >80 years of age group now accounts for nearly one third of AIS patients. Although overall outcomes of octogenarians with LVOs are poorer, MT still provides a substantial functional benefit in appropriately selected patients.[41-43] While a proportion of the elderly may have a poorer baseline functional status that could preclude them from MT, it is unclear to which degree other biases are at work, such as a hesitancy to intervene due to perceived futility of care. Indeed, patients >80 years were excluded or under-represented in many of the clinical trials,[41-43] and preconceived notions about the futility of treatment may prompt withdrawal of care, which may in turn influence outcomes.[44] Technical factors, such inadequate vascular access due to tortuous, atherosclerotic vessels, may also play a role. In terms of other subgroups, patients admitted to large bed-size or teaching hospitals, those with private insurance, and those who were wealthier were more likely to receive MT, consistent with prior studies.[10,45]

Our study has several limitations. As is true with any retrospective study that analyzes large, coding-based administrative data, sensitivity and specificity may differ based on codes, granularity may be limited, and small fraction of the data may be missing or misrepresented. In addition, associations are not necessarily proof of causality, and certain findings may reach statistical significance due to large sample sizes. The coding system nationwide changed from ICD-9 to ICD-10 for Q4 2015 (at approximately the same time as the AHA/ASA guidelines update), which may have temporarily introduced coding errors as financial coders became more proficient.[12] To minimize this effect, we calculated month-by-month frequencies of codes to verify that sudden shifts in data did not occur, and we used validated ICD-9 and ICD-10 codes similar to prior authors.[12] Although databases such as the NRD provide nationally representative data, certain details relevant to MT are not included, such as the severity of the stroke (e.g., National Institutes of Health Stroke Scale), the thrombolysis in cerebral infarction grade, imaging details, time to reperfusion, or technical details of the procedure. In addition, the NRD does not include variables for ethnicity, geographical location, whether a center is a TSC, or quality of life metrics.[21]

Future efforts should focus on determining, on a hospital-by-hospital basis, factors that may contribute to unequal access to and outcomes from MT, as the treatment becomes increasingly more common. This may include overcoming substantial social, economic, and logistical hurdles. Indeed, one study found that treatment interval periods decrease with better protocol experience.[35] As national datasets become available with each successive year, future, nationally representative studies should then determine whether our findings have persisted after 2017.

Conclusions

To the best of our knowledge, there has not been a recent, updated study of nationally representative data that assesses the presence of a weekend effect on MT before and after the significant change in the standard of care for stroke in 2015. Our data suggest that weekend admission affected overall access to MT before the 2015 guidelines update, but this effect was no longer present thereafter, likely as the updated guidelines have resulted in an appropriate, national shift in practice. As the trend of performing MT becomes more common and available, however, a new, post-guidelines weekend effect has become evident as poorer-than-expected outcomes, and certain subgroups of patients, such as the elderly, may still be under-treated. This new effect of weekend admission may be due to lower volume centers providing the treatment, which may be more susceptible to systems inadequacies and implicit biases.

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Conflicts of interest

There are no conflicts of interest.

References

1. Bell CM, Redelmeier DA. Mortality among patients admitted to hospitals on weekends as compared with weekdays. N Engl J Med 2001;345:663-8.
2. Glance LG, Osler T, Li Y, Lustik SJ, Eaton MP, Dutton RP, *et al*. Outcomes are worse in US patients undergoing surgery on weekends compared with weekdays. Med Care 2016;54:608-15.
3. Pauls LA, Johnson-Paben R, McGready J, Murphy JD, Pronovost PJ, Wu CL. The weekend effect in hospitalized patients: A meta-analysis. J Hosp Med 2017;12:760-6.
4. O'Donnell TF, Schermerhorn ML, Liang P, Li C, Swerdlow NJ, Wang GJ, *et al*. Weekend effect in carotid endarterectomy. Stroke 2018;49:2945-52.
5. Angerer S, Buttinger K, Stummer H. The weekend effect revisited: Evidence from the Upper Austrian stroke registry. Eur J Health Econ 2019;20:729-37.
6. Huang HK, Chang WC, Hsu JY, Wang JH, Liu PS, Lin SM, *et al*. Holiday season and weekend effects on stroke mortality: A nationwide cohort study controlling for stroke severity. J Am Heart Assoc 2019;8:e011888.
7. Fang J, Saposnik G, Silver FL, Kapral MK; Investigators of the Registry of the Canadian Stroke Network. Association between weekend hospital presentation and stroke fatality. Neurology 2010;75:1589-96.
8. Ogbu UC, Westert GP, Slobbe LC, Stronks K, Arah OA. A multifaceted look at time of admission and its impact on case-fatality among a cohort of ischaemic stroke patients. J Neurol Neurosurg Psychiatry 2011;82:8-13.
9. Adil MM, Vidal G, Beslow LA. Weekend effect in children with stroke in the nationwide inpatient sample. Stroke 2016;47:1436-43.
10. Saad A, Adil MM, Patel V, Owada K, Winningham MJ, Nahab F. Clinical outcomes after thrombectomy for acute ischemic stroke on weekends versus weekdays. J Stroke Cerebrovasc Dis 2014;23:2708-13.
11. Saber H, Navi BB, Grotta JC, Kamel H, Bambhroliya A, Vahidy FS, *et al*. Real-world treatment trends in endovascular stroke therapy. Stroke 2019;50:683-9.
12. Atchaneeyasakul K, Liaw N, Lee RH, Liebeskind DS, Saver JL. Patterns of mechanical thrombectomy for stroke before and after the 2015 pivotal trials and US national guideline update. J Stroke Cerebrovasc Dis 2020;29:105292.
13. Powers WJ, Derdeyn CP, Biller J, Coffey CS, Hoh BL, Jauch EC, *et al*. 2015 American Heart Association/American Stroke Association focused update of the 2013 guidelines for the early management of patients with acute ischemic stroke regarding endovascular treatment: A guideline for healthcare professionals from the American Heart Association/American Stroke Association. Stroke 2015;46:3020-35.
14. Campbell BC, Mitchell PJ, Kleinig TJ, Dewey HM, Churilov L, Yassi N, *et al*. Endovascular therapy for ischemic stroke with perfusion-imaging selection. N Engl J Med 2015;372:1009-18.
15. Goyal M, Demchuk AM, Menon BK, Eesa M, Rempel JL, Thornton J, *et al*. Randomized assessment of rapid endovascular treatment of ischemic stroke. N Engl J Med 2015;372:1019-30.
16. Berkhemer OA, Fransen PS, Beumer D, van den Berg LA, Lingsma HF, Yoo AJ, *et al*. A randomized trial of intraarterial treatment for acute ischemic stroke. N Engl J Med 2015;372:11-20.
17. Saver JL, Goyal M, Bonafe A, Diener HC, Levy EI, Pereira VM, *et al*. Stent-retriever thrombectomy after intravenous t-PA vs. t-PA alone in stroke. N Engl J Med 2015;372:2285-95.
18. Jovin TG, Chamorro A, Cobo E, de Miquel MA, Molina CA, Rovira A, *et al*. Thrombectomy within 8 hours after symptom onset in ischemic stroke. N Engl J Med 2015;372:2296-306.
19. Shen YC, Chen G, Hsia RY. Community and hospital factors associated with stroke center certification in the United States, 2009 to 2017. JAMA Netw Open 2019;2:e197855.
20. Saver JL, Goyal M, van der Lugt A, Menon BK, Majoie CB, Dippel DW, *et al*. Time to treatment with endovascular thrombectomy and outcomes from ischemic stroke: A meta-analysis. JAMA 2016;316:1279-88.
21. NRD Overview. [Healthcare Cost and Utilization Project (HCUP).]; 2017. Available from: http://www.hcup-us.ahrq.gov/

nrdoverview.jsp. [Last accessed on 2021 Jul 15].

22. HCUP CCS. Healthcare Cost and Utilization Project (HCUP). Rockville, MD: Agency for Healthcare Research and Quality; 2017. Available from: https://www.hcup-us.ahrq.gov/toolssoftware/ccs/ccs.jsp. [Last accessed on 2021 Jul 15].
23. Reid LD, Fingar KR. Inpatient stays and emergency department visits involving traumatic brain injury, 2017: Statistical brief #255. In: Healthcare Cost and Utilization Project (HCUP) Statistical Briefs. Rockville (MD): Agency for Healthcare Research and Quality (US); 2006.
24. Qureshi AI, Chaudhry SA, Sapkota BL, Rodriguez GJ, Suri MF. Discharge destination as a surrogate for Modified Rankin Scale defined outcomes at 3- and 12-months poststroke among stroke survivors. Arch Phys Med Rehabil 2012;93:1408-13.e1.
25. Faigle R, Urrutia VC, Cooper LA, Gottesman RF. Individual and system contributions to race and sex disparities in thrombolysis use for stroke patients in the United States. Stroke 2017;48:990-7.
26. Prabhakaran S, McNulty M, O'Neill K, Ouyang B. Intravenous thrombolysis for stroke increases over time at primary stroke centers. Stroke 2012;43:875-7.
27. Chaudhry SA, Afzal MR, Chaudhry BZ, Zafar TT, Safdar A, Kassab MY, *et al*. Rates of adverse events and outcomes among stroke patients admitted to primary stroke centers. J Stroke Cerebrovasc Dis 2016;25:1960-5.
28. Stein LK, Agarwal P, Thaler A, Kwon CS, Jette N, Dhamoon MS. Readmission to a different hospital following acute stroke is associated with worse outcomes. Neurology 2019;93:e1844-51.
29. Sidney S, Sorel ME, Quesenberry CP, Jaffe MG, Solomon MD, Nguyen-Huynh MN, *et al*. Comparative trends in heart disease, stroke, and all-cause mortality in the United States and a large integrated healthcare delivery system. Am J Med 2018;131:829-36.e1.
30. Almallouhi E, Al Kasab S, Harvey JB, Reardon C, Alawieh A, Girotra T, *et al*. Impact of treatment time on the long-term outcome of stroke patients treated with mechanical thrombectomy. J Stroke Cerebrovasc Dis 2019;28:185-90.
31. Nikoubashman O, Probst T, Schürmann K, Othman AE, Matz O, Brockmann MA, *et al*. Weekend effect in endovascular stroke treatment: do treatment decisions, procedural times, and outcome depend on time of admission? J Neurointerv Surg 2017;9:336-9.
32. Mpotsaris A, Kowoll A, Weber W, Kabbasch C, Weber A, Behme D. Endovascular stroke therapy at nighttime and on weekends-as fast and effective as during normal business hours? J Vasc Interv Neurol 2015;8:39-45.
33. Almekhlafi MA, Hockley A, Desai JA, Nambiar V, Mishra S, Volny O, *et al*. Overcoming the evening/weekend effects on time delays and outcomes of endovascular stroke therapy: The Calgary Stroke Program experience. J Neurointerv Surg 2014;6:729-32.
34. Rumalla K, Ottenhausen M, Kan P, Burkhardt JK. Recent nationwide impact of mechanical thrombectomy on decompressive hemicraniectomy for acute ischemic stroke. Stroke 2019;50:2133-9.
35. Raymond SB, Akbik F, Stapleton CJ, Mehta BP, Chandra RV, Gonzalez RG, *et al*. Protocols for endovascular stroke treatment diminish the weekend effect through improvements in off-hours care. Front Neurol 2018;9:1106.
36. Santana Baskar P, Cordato D, Wardman D, Bhaskar S. In-hospital acute stroke workflow in acute stroke – Systems-based approaches. Acta Neurol Scand 2021;143:111-20.
37. Chowdhury SZ, Baskar PS, Bhaskar S. Effect of prehospital workflow optimization on treatment delays and clinical outcomes in acute ischemic stroke: A systematic review and meta-analysis. Acad Emerg Med 2021;28:781-801.
38. Baskar PS, Chowdhury SZ, Bhaskar SM. In-hospital systems interventions in acute stroke reperfusion therapy: A meta-analysis. Acta Neurol Scand 2021;144:418-32.
39. Mehta BP, Leslie-Mazwi TM, Chandra RV, Bell DL, Sun CH, Hirsch JA, *et al*. Reducing door-to-puncture times for intra-arterial stroke therapy: A pilot quality improvement project. J Am Heart Assoc 2014;3:e000963.
40. Sorita A, Ahmed A, Starr SR, Thompson KM, Reed DA, Prokop L, *et al*. Off-hour presentation and outcomes in patients with acute myocardial infarction: Systematic review and meta-analysis. BMJ 2014;348:f7393.
41. Goyal M, Menon BK, van Zwam WH, Dippel DW, Mitchell PJ, Demchuk AM, *et al*. Endovascular thrombectomy after large-vessel ischaemic stroke: A meta-analysis of individual patient data from five randomised trials. Lancet 2016;387:1723-31.
42. Jayaraman MV, McTaggart RA. Endovascular treatment of anterior circulation large vessel occlusion in the elderly. Front Neurol 2017;8:713.
43. Sussman ES, Martin B, Mlynash M, Marks MP, Marcellus D, Albers G, *et al*. Thrombectomy for acute ischemic stroke in nonagenarians compared with octogenarians. J Neurointerv Surg 2020;12:266-70.
44. Becker KJ, Baxter AB, Cohen WA, Bybee HM, Tirschwell DL, Newell DW, *et al*. Withdrawal of support in intracerebral hemorrhage may lead to self-fulfilling prophecies. Neurology 2001;56:766-72.
45. Rinaldo L, Rabinstein AA, Cloft H, Knudsen JM, Castilla LR, Brinjikji W. Racial and ethnic disparities in the utilization of thrombectomy for acute stroke. Stroke 2019;50:2428-32.

Supplementary Table 1: International Classification of Diseases, 9th revision and International Classification of Diseases, 10th revision codes for variables

Variables	ICD-9	ICD-10
AIS	436, 433.01, 433.11, 433.21, 433.31, 433.81,433.91, 434.01, 434.11, 434.91	I63.0, I63.1, I63.2, I63.3, I63.4, I63.5, I63.6, I63.8, I63.9
ICH (including IPH and SAH)	431, 430, 432.9	I60, I61, I62.9
IVT	991.0, V45.88	Z92.82, 3E03317
MT	39.74	03CP3, 03CQ3, 03CL3, 03CK3, 03CG3
Percutaneous endoscopic gastrostomy	43.11-43.19	0DH64UZ, 0DH63UZ
Tracheostomy	31.10, 31.20, 31.21, or 31.29	0B114, 0B113
Decompressive craniectomy	01.24, 01.25, 01.39, 01.53, 01.59, 02.02	0WC1, 0WH1, 0WW1, 0WP1, 0WJ1, 0WH1, 0W91, 0NW0, 0NP0, 0NH0, 0N80, 00W0, 00J0, 0N50, 0NB0, 0090, 00C0, 00H0, 00P0, 00W0, 00B7, 0050, 00B0, 0NS0
Cerebral edema	348.5, 348.4	G93.5, G93.6
Hydrocephalus	331.4	G91.1, G91.4, G91.8, G91.9
Carotid endarterectomy	38.12	03CK, 03CL
Carotid angioplasty/stent placement	00.63, 00.64	037K3, 037K4, 037L3, 037L4
Intracranial angioplasty/stent placement	00.62, 00.65	037G3, 037G4
Postprocedure stroke	997.02	I97.821, I97.811
Anticoagulants	V58.61	Z79.01
Anti-thrombotics	V58.63, V58.66	Z79.02, Z79.82
Smoking	V15.82, 305.1	Z87.891, F17
Atrial fibrillation	427.31, 427.32	I48
Dyslipidemia	CCS 53	CCS 53
Cm_Chf, Cm_Perivasc, Cm_Valve, Cm_Drug, Cm_Alcohol, Cm_Htn_C, Cm_Obese, Cm_Liver, Cm_Renlfail, Cm_Hypothy, Cm_Dmcx, and Cm_Dm	Comorbidity measures are assigned using the AHRQ comorbidity software. The AHRQ comorbidity measures identify coexisting medical conditions that are not directly related to the principal diagnosis, or the main reason for admission, and are likely to have originated prior to the hospital stay. Comorbidities are identified using ICD-9-CM diagnoses and the DRG in effect on the discharge date. Derived from https://www.hcup-us.ahrq.gov/tools_software.jsp	
APR-DRG	APR-DRGs are assigned using software developed by 3m health information systems. This severity measure includes the base APR-DRG, the severity of illness subclass, and the risk of mortality subclass within each base APR-DRG. Derived from https://www.hcup-us.ahrq.gov/db/vars/aprdrg/nisnote.jsp	

The CCS for ICD-9-CM is based on the ICD-9-CM, which is a uniform and standardized coding system. The ICD-9-CM's multitude >14,000 diagnosis codes and >3900 procedure codes are collapsed into a smaller number of clinically meaningful categories. These are generally more useful for presenting descriptive statistics. Derived from https://www.hcup-us.ahrq.gov/toolssoftware/ccs/ccs.jsp. AIS: Acute ischemic stroke, DRG: Diagnosis-related group, CCS: Clinical Classifications Software, ICD: International Classification of Diseases, ICD-9-CM: ICD, 9th Revision, clinical modification, ICH: Intracerebral hemorrhage, IPH: Intraparenchymal hemorrhage, SAH: Subarachnoid hemorrhage, IVT: Intravenous thrombolysis, MT: Mechanical thrombectomy, APR-DRG: All patient refined-DRG, AHRQ: Agency for healthcare research and quality

Supplementary File 2: Tables of Covariates used in Table 3

Table A: Covariates for mortality outcome, 2010-2014

Covariate	OR	95% CI	*P*
Weekend admission (weekday reference)	0.966	0.83-1.124	0.6533
Age groups (years)			
18-49	Reference		
50-79	2.158	1.685-2.763	<0.0001
≥80	3.773	2.857-4.983	<0.0001
Female sex (male reference)	0.904	0.788-1.036	0.1464
Treatments and complications			
IVT	0.878	0.756-1.019	0.0864
DHC	0.882	0.614-1.269	0.4987
ICH	1.546	1.328-1.8	<0.0001
Hydrocephalus	4.34	2.908-6.48	<0.0001
Cerebral edema	3.498	2.929-4.177	<0.0001
Comorbidites			
Hypertension	1.139	0.958-1.353	0.1396
Smoking	0.916	0.789-1.064	0.2518
Drug abuse	0.52	0.334-0.81	0.0038
Alcohol abuse	0.939	0.692-1.274	0.6841
Obesity	0.831	0.646-1.069	0.1499
Liver failure	0.739	0.39-1.402	0.3546
Renal failure	1.094	0.886-1.352	0.4039
Hypothyroidism	0.808	0.667-0.98	0.0303
DM	1.09	0.906-1.312	0.3593
Hyperlipidemia	0.682	0.598-0.776	<0.0001
Atrial fibrillation	0.827	0.712-0.959	0.0123
CHF	1.325	1.137-1.544	0.0003
PVD	1.262	1.056-1.509	0.0106
Valvular disorders	0.66	0.528-0.826	0.0003
Long-term use of anti-thrombotics	1.094	0.932-1.285	0.2732
Long-term use of anticoagulants	0.947	0.743-1.206	0.6581
Insurance status			
Medicare	Reference		
Medicaid	0.869	0.649-1.163	0.3435
Private insurance	0.853	0.729-0.999	0.0483
Self-pay	1.14	0.766-1.699	0.5177
Other	1.143	0.819-1.596	0.432
Hospital characteristics			
Small bed-size	Reference		
Medium bed-size	1.62	1.086-2.416	0.0182
Large bed-size	1.441	1.009-2.058	0.0442
Teaching hospital versus nonteaching hospital	0.818	0.666-1.004	0.0547
Median household income by patient zip code			
0-25th percentile	Reference		
26th-50th percentile	1.085	0.899-1.31	0.395
51st-75th percentile	1.222	0.989-1.509	0.063
76th-100th percentile	1.252	1.029-1.523	0.0247

IVT: Intravenous thrombolysis, DHC: Decompressive hemicraniectomy, ICH: Intracerebral hemorrhage, DM: Diabetes mellitus, CHF: Congestive heart failure, PVD: Peripheral vascular disease, OR: Odds ratio, CI: Confidence interval

Table B: Covariates for mortality outcome, 2015-2017

Covariate	OR	95% CI	*P*
Weekend admission (weekday reference)	1.079	0.964-1.208	0.1848
Age groups (years)			
18-49	Reference		
50-79	1.718	1.416-2.083	<0.0001
≥80	2.771	2.22-3.458	<0.0001
Female sex (male reference)	0.812	0.739-0.892	<0.0001
Treatments and complications			
IVT	0.834	0.764-0.912	<0.0001
DHC	1.227	0.869-1.733	0.244
ICH	1.617	1.445-1.808	<0.0001
Hydrocephalus	4.222	3.173-5.616	<0.0001
Cerebral edema	3.704	3.308-4.148	<0.0001
Comorbidities			
Hypertension	0.959	0.836-1.101	0.554
Smoking	0.954	0.84-1.083	0.4622
Drug abuse	0.769	0.564-1.048	0.0963
Alcohol abuse	0.789	0.618-1.006	0.0562
Obesity	1.041	0.906-1.196	0.5705
Liver failure	1.063	0.705-1.602	0.7707
Renal failure	1.336	1.168-1.528	<0.0001
Hypothyroidism	0.843	0.731-0.974	0.0202
DM	1.324	1.196-1.465	<0.0001
Hyperlipidemia	0.812	0.732-0.901	<0.0001
Atrial fibrillation	0.915	0.818-1.025	0.1238
CHF	1.207	1.074-1.358	0.0017
PVD	1.272	1.104-1.466	0.0009
Valvular disorders	0.709	0.61-0.825	<0.0001
Long-term use of anti-thrombotics	0.726	0.631-0.837	<0.0001
Long-term use of anticoagulants	1.026	0.873-1.207	0.7538
Insurance status			
Medicare	Reference		
Medicaid	0.885	0.727-1.076	0.2206
Private insurance	0.653	0.563-0.757	<0.0001
Self-pay	0.959	0.695-1.324	0.8002
Other	1.154	0.894-1.488	0.2712
Hospital characteristics			
Small bed-size	Reference		
Medium bed-size	1.008	0.756-1.344	0.9558
Large bed-size	0.915	0.706-1.186	0.5014
Teaching hospital versus nonteaching hospital	0.832	0.696-0.995	0.0439
Median household income by patient zip code			
0-25th percentile	Reference		
26th-50th percentile	1.077	0.925-1.255	0.3361
51st-75th percentile	1.204	1.048-1.383	0.0087
76th-100th percentile	1.036	0.9-1.193	0.6205

IVT: Intravenous thrombolysis, DHC: Decompressive hemicraniectomy, ICH: Intracerebral hemorrhage, DM: Diabetes mellitus, CHF: Congestive heart failure, PVD: Peripheral vascular disease, OR: Odds ratio, CI: Confidence interval

Table C: Covariates for adverse discharge outcome, 2010-2014

Covariate	OR	95% CI	*P*
Weekend admission (weekday reference)	1.04	0.889-1.216	0.6261
Age groups (years)			
18-49	Reference		
50-79	1.827	1.519-2.197	<0.0001
≥80	3.69	2.915-4.67	<0.0001
Female sex (male reference)	0.983	0.865-1.116	0.7891
Treatments and complications			
IVT	0.87	0.762-0.993	0.0391
DHC	2.123	1.299-3.469	0.0027
ICH	1.96	1.668-2.302	<0.0001
Hydrocephalus	5.226	2.17-12.587	0.0002
Cerebral edema	2.248	1.859-2.718	<0.0001
Comorbidities			
Hypertension	1.001	0.848-1.181	0.9931
Smoking	0.733	0.637-0.843	<0.0001
Drug abuse	1.067	0.736-1.547	0.7308
Alcohol abuse	1.122	0.885-1.422	0.3414
Obesity	0.89	0.739-1.073	0.2212
Liver failure	0.61	0.363-1.026	0.0626
Renal failure	1.074	0.835-1.38	0.5786
Hypothyroidism	0.785	0.629-0.979	0.0318
DM	1.287	1.129-1.468	0.0002
Hyperlipidemia	0.664	0.584-0.755	<0.0001
Atrial fibrillation	1.256	1.054-1.496	0.0108
CHF	1.156	0.995-1.345	0.0589
PVD	1.208	1.013-1.442	0.0355
Valvular disorders	0.834	0.72-0.967	0.0161
Long-term use of anti-thrombotics	0.797	0.655-0.97	0.024
Long-term use of anticoagulants	0.708	0.601-0.833	<0.0001
Insurance status			
Medicare	Reference		
Medicaid	0.829	0.66-1.04	0.1052
Private insurance	0.67	0.571-0.786	<0.0001
Self-pay	0.278	0.193-0.4	<0.0001
Other	0.467	0.333-0.655	<0.0001
Hospital characteristics			
Small bed-size	Reference		
Medium bed-size	0.783	0.5-1.225	0.2834
Large bed-size	0.617	0.454-0.839	0.0021
Teaching hospital versus nonteaching hospital	0.873	0.709-1.075	0.2017
Median household income by patient zip code			
0-25th percentile	Reference		
26th-50th percentile	0.815	0.662-1.003	0.0531
51st-75th percentile	0.795	0.652-0.97	0.024
76th-100th percentile	0.717	0.598-0.861	0.0004

IVT: Intravenous thrombolysis, DHC: Decompressive hemicraniectomy, ICH: Intracerebral hemorrhage, DM: Diabetes mellitus, CHF: Congestive heart failure, PVD: Peripheral vascular disease, OR: Odds ratio, CI: Confidence interval

Table D: Covariates for adverse discharge outcome, 2015-2017

Covariates	OR	95% CI	*P*
Weekend admission (weekday reference)	1.117	1.02-1.224	0.0173
Age groups (years)			
18-49	Reference		
50-79	1.692	1.458-1.964	<0.0001
≥80	3.284	2.711-3.98	<0.0001
Female sex (male reference)	1.084	0.993-1.184	0.0703
Treatments and complications			
IVT	0.892	0.818-0.974	0.0104
DHC	4.342	2-9.428	0.0002
ICH	2.548	2.25-2.885	<0.0001
Hydrocephalus	2.27	1.281-4.023	0.005
Cerebral edema	3.565	3.095-4.106	<0.0001
Comorbidites			
Hypertension	1.141	1.027-1.269	0.0145
Smoking	0.88	0.81-0.956	0.0025
Drug abuse	0.951	0.714-1.268	0.7335
Alcohol abuse	1.123	0.934-1.349	0.217
Obesity	1.143	1.007-1.298	0.0384
Liver failure	1.099	0.777-1.553	0.593
Renal failure	1.061	0.927-1.215	0.3861
Hypothyroidism	0.964	0.866-1.072	0.4993
Diabetes mellitus	1.453	1.307-1.615	<0.0001
Hyperlipidemia	0.845	0.781-0.914	<0.0001
Atrial fibrillation	1.068	0.971-1.175	0.1726
CHF	1.34	1.22-1.471	<0.0001
PVD	1.199	1.07-1.343	0.0017
Valvular disorders	0.884	0.784-0.996	0.0426
Long-term use of anti-thrombotics	0.841	0.735-0.963	0.012
Long-term use of anticoagulants	0.859	0.761-0.971	0.0147
Insurance status			
Medicare	Reference		
Medicaid	0.608	0.521-0.71	<0.0001
Private insurance	0.567	0.505-0.637	<0.0001
Self-pay	0.29	0.236-0.356	<0.0001
Other	0.614	0.47-0.802	0.0004
Hospital characteristics			
Small bed-size	Reference		
Medium bed-size	1.539	1.146-2.066	0.0042
Large bed-size	1.227	0.929-1.62	0.1501
Teaching hospital versus nonteaching hospital	0.957	0.759-1.207	0.7109
Median household income by patient zip code			
0-25th percentile	Reference		
26th-50th percentile	0.837	0.747-0.939	0.0024
51st-75th percentile	0.836	0.744-0.938	0.0024
76th-100th percentile	0.803	0.699-0.922	0.0019

IVT: Intravenous thrombolysis, DHC: Decompressive hemicraniectomy, ICH: Intracerebral hemorrhage, DM: Diabetes mellitus, CHF: Congestive heart failure, PVD: Peripheral vascular disease, OR: Odds ratio, CI: Confidence interval