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Investigating the "Weekend Effect" on Outcomes of Patients Undergoing Endovascular Mechanical Thrombectomy for Ischemic Stroke

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Abstract

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Contributorship Statement

RG conceived of the study, developed the analysis plan, and drafted and revised the paper. VMR developed the analysis plan and drafted and revised the paper. JPN developed the analysis plan and drafted and revised the paper. OZ developed the analysis plan and drafted and revised the paper. AdH conceived of the study plan, developed the analysis plan, conducted the statistical analysis, and drafted and revised the paper.

Disclosure

"The views expressed in this article are those of the author and do not necessarily reflect the official policy or position of the Department of the Navy, Department of Defense, nor the U.S. Government."

Objectives—With growing evidence of its efficacy for patients with large-vessel occlusion (LVO) ischemic stroke, the use of endovascular thrombectomy (EVT) has increased. The “weekend effect,” whereby patients presenting during weekends/off hours have worse clinical outcomes than those presenting during normal working hours, is a critical area of study in acute ischemic stroke (AIS). Our objective was to evaluate whether a “weekend effect” exists in patients undergoing EVT.

Materials and Methods—This retrospective, cross-sectional analysis of the 2016–2018 Nationwide Inpatient Sample data included patients ≥18 years with documented diagnosis of ischemic stroke (ICD-10 codes I63, I64, and H34.1), procedural code for EVT, and National Institutes of Health Stroke Scale (NIHSS) score; the exposure variable was weekend vs. weekday treatment. The primary outcome was in-hospital death; secondary outcomes were favorable discharge, extended hospital stay (LOS), and cost. Logistic regression models were constructed to determine predictors for outcomes.

Results—We identified 6,052 AIS patients who received EVT (mean age 68.7±14.8 years; 50.8% female; 70.8% White; median (IQR) admission NIHSS 16 (10–21)). The primary outcome of in-hospital death occurred in 560 (11.1%); the secondary outcome of favorable discharge occurred in 1,039 (20.6%). The mean LOS was 7.8±8.6 days. There were no significant differences in the outcomes or cost based on admission timing. In the mixed-effects models, we found no effect of weekend vs. weekday admission on in-hospital death, favorable discharge, or extended LOS.

Conclusions—These results demonstrate that the “weekend effect” does not impact outcomes or cost for patients who undergo EVT for LVO.

Keywords

mechanical thrombectomy; ischemic stroke; “weekend effect”; large-vessel occlusion

INTRODUCTION

The results of numerous randomized trials have demonstrated that endovascular thrombectomy (EVT) leads to improved outcomes in patients with acute ischemic stroke (AIS) due to large-vessel occlusion (LVO) in both early and late windows (1–5). However, the concept of a “weekend effect,” in which patients presenting on weekends and “off hours” have worse clinical outcomes than those who present during normal working hours has been a subject of debate, with some reports demonstrating increased morbidity and mortality (6–8) and others showing no difference (9–15). A recent multicenter publication by Williams et al. (16) demonstrated significant increases in endovascular thrombectomy case volumes, with 87% of consults that led to thrombectomy occurring during “off hours,” midnight until 04:00 am. Thus, the importance of understanding the influence of the “weekend effect” on patients undergoing EVT is crucial, given the increasing case volumes and demand on neurointerventional teams.

In this study, we aimed to investigate the “weekend effect” on outcomes in patients undergoing endovascular thrombectomy for AIS by using a large, national, administrative database, the National Inpatient Sample (NIS). Based on our experience and overall standardization of stroke care we hypothesize there are no differences in the outcomes or cost of interventional stroke procedures performed during weekend hours.

METHODS

This is a retrospective, cross-sectional analysis of 2016–2018 data from the NIS, which is the largest all-payer inpatient claims-based database in the United States and included over 4 million hospitalizations in 2020 (17). We included adult patients (≥18 years) who had a discharge diagnosis of ischemic stroke defined by International Classification of Diseases, 10th Revision (ICD-10-CM) codes I63, I64, and H34.1 and who had a procedural code for EVT (Table 1) (18, 19). We excluded patients with elective hospital admission or missing outcomes or National Institutes of Health Stroke Scale (NIHSS) data. Beginning in October of 2016, the admission NIHSS was coded in ICD-10-CM. Restricting to only patients who had a NIHSS recorded reduced our sample size but permitted the crucial step of adjusting for baseline stroke severity (20). Our study used deidentified data and was exempt from institutional review board approval.

The primary outcome was in-hospital death. Favorable discharge, defined as a discharge to home or self-care, was included as a secondary outcome, as were extended hospital stay, defined as a hospital length of stay (LOS) greater than 10 days, and hospital charges and cost-to-charge ratio. The primary predictor was whether the patient was admitted on a weekend (12:00 am Saturday–11:59 pm Sunday) or a weekday (12:00 am Monday– 11:59 pm Friday). We tested for significant differences using the chi-squared test, Student's t-test, or Wilcoxon rank sum tests, as appropriate.

To account for patient clustering by hospital and different volumes of EVT, we fit mixed-effects logistic regression models with hospital as the clustering variable (8–10). The models were adjusted for patient age, sex, race/ethnicity (White, Black, Hispanic, or other), admission NIHSS, intravenous alteplase admission, Elixhauser comorbidity index (21), All Patients Refined Diagnosis Related Groups (APR-DRG) measure of disease severity (12), mechanical ventilation, median household income for the patient's ZIP code, hospital US Census Bureau Hospital Region and Division (22), and expected payer (Medicaid, Medicare, private, other). We intended to adjust for teaching vs. non-teaching hospital, but it was collinear with APR-DRG disease severity, and was therefore excluded to keep the mean variance inflation factor <10. All analysis was conducted in Stata 16.1 (StataCorp, College Station, TX), and we defined statistical significance as $p<0.05$.

RESULTS

Baseline demographics

From 2016–18, there were 372,985 admissions in NIS with a discharge diagnosis of ischemic stroke, of which 85,720 had an NIHSS and complete outcome and demographic data. Among those, 6,052 (7.1%) received EVT and were included in our final cohort. There were 1,660 weekend admissions and 4,392 weekday admission, for an EVT rate of 7.3% vs. 7.0% for weekend vs. weekday (p=0.115). Full demographic and presentation details can be found in Table 2. The mean age was 68.7±14.8 years and 50.8% were female, and the highest proportion of patients were White (67.5%). The median (IQR) admission NIHSS was 16 (10–21), which did not differ between weekend and weekday admissions. The median Elixhauser comorbidity score was 5 (4–6) and mean number of ICD-10 diagnoses was 18.7±6.0, with no difference between comparison groups. Similar regional breakdowns were seen with the highest number of hospitals in the South Atlantic Region, followed by East North Central, Middle Atlantic, West North Central, and New England. A majority of patients were admitted to a teaching hospital (91.9%) with no difference in the proportion among cohorts. The payer in a majority of patients was Medicare (61.5%), with no differences observed in quartile of median household income by zip code.

Primary and secondary outcomes

There were no differences among the number of patients who were administered intravenous alteplase or required intubation. The primary outcome of in-hospital death occurred in 707/6,052 (11.7%) and the secondary outcome of favorable discharge occurred in 1,255/6,052 (20.7%). The mean hospital LOS was 7.8±9.1 days. There were not significant differences in the outcomes of in-hospital death (11.0% vs. 11.9%, p=0.327), favorable discharge (20.1% vs. 21.0%, p=0.467), or length of stay ≥10 days (21.0% vs. 20.5%, p=0.620) between patients admitted on a weekend vs. weekday, respectively. There were also no differences in total hospital charges or cost-to-charge ratio (Table 2).

In the mixed-effects models, we found no effect of weekend vs. weekday admission on in-hospital death, favorable discharge, or extended hospital stay (Table 3). We tested for interactions between the covariates in our model and weekend vs. weekday admission and found no significant interaction terms (data not shown).

DISCUSSION

The efficacy of EVT in AIS patients with LVO has been clearly established, but delays in care and inefficiencies might lead to poorer outcomes. A putative "weekend effect" leading to poorer outcomes in patients undergoing EVT could be ascribed to a number of factors including lack of in-house expertise, transit times for staff to arrive at the hospital, provider fatigue, and fewer resources available on weekends (15). In this study using the NIS data from 2017 and 2018, we have demonstrated that the "weekend effect" does not impact outcomes or cost for those who undergo EVT for LVO.

The conflicting results seen to date regarding the influence of "off-hours" presentation on outcomes may reflect variable care of AIS across hospitals, as well as the heterogeneity of the literature itself. A summary of the studies performed on the weekend effect is presented in Table 4. Tschoe et al. (15) reported on 1919 patients from a registry of six comprehensive stroke centers over a 6.5-year period and found no difference in functional outcomes, successful reperfusion, procedural length, hemorrhagic transformation, or length of stay between patients undergoing EVT during on hours or off hours. Our data, in which 488 EVTs (8.1%) were performed in nonteaching hospitals, support the results of the above study and may be more reflective of "real-world" results. In contrast, Almallouhi et al. (7) demonstrated worse outcomes (discharge and 90-day mRS) for EVT procedures performed during off hours when compared with business hours. Similarly, in a study using the NIS data from 2005–2011 of 12,000 patients, Saad et al. demonstrated that EVT patients admitted on the weekend experienced worse outcomes in nonteaching hospitals, but there was no outcome disparity at teaching hospitals (6); however, data on stroke severity and cost were not included in their analysis. Importantly, these data reflected a time epoch before the publication of numerous trials demonstrating the efficacy of EVT, leading to its increased use.

In the current study, it is likely the results demonstrating no difference are a result of robust infrastructure of systems of care; by using the 2017 and 2018 NIS, the results of this study serve to better generalize the results and finding of lack of the “weekend effect.” The lack of difference in total hospital charges and cost-to-charge ratios also further supports lack of a weekend effect. Interestingly, Raymond et al. (11) showed that adherence to an institutional protocol resulted in decreased door-to-puncture time during “off hours.” Potts et al. demonstrated delays in door to groin puncture times in acute ischemic stroke patients presenting on nights/weekends compared to weekdays, but no significant differences in successful reperfusion or functional outcomes (26).

Given the growing number of consults leading to EVT seen during “off hours” (15, 16), one may further suppose that increased case volumes, familiarity with the EVT procedure itself, and improved periprocedural efficiencies may also be responsible for nullifying the potential “weekend effect.” Dandapat et al. (12) proposed that 24/7 in-house anesthesia and interventional radiology tech services mitigated previously observed differences in “off-hour” outcomes after EVT, although it is recognized that this may not be feasible at all EVT-capable centers. Indeed, use of newer technologies and adoption of strategies to improve first-pass effect (23) may be responsible for improved outcomes, regardless of time of presentation. Finally, increased efficiencies of care on a regional basis through use of prehospital LVO screening scales and bypass strategies may also represent a key factor in diminishing the “weekend effect.” Sarraj et al. (24) demonstrated that EVT access within 15 minutes of stroke diagnosis is limited to less than a fifth of the U.S. population, and additional methods to increase EVT centers or bypass non-EVT centers demonstrated enhanced access for stroke patients. The study by Jayaraman et al. (25) demonstrated significantly improved outcomes in LVO patients transported directly to a comprehensive stroke center. Future efforts to further improve outcomes will likely depend on this epidemiologic information and development of strong regional/statewide stroke systems of care; thus, a thorough understanding of potential barriers to success is crucial.

Limitations

The strengths of this study are that the NIS database is large and well-documented and, by design, comprises a 20% random sample of the community hospital population, making national estimates possible and more generalizable to real-world stroke practice. Limitations include that these data are restricted to diagnostic and procedure codes and that individual patients, being deidentified, cannot be tracked after discharge. In addition, possible misclassifications and unidentifiable repeated visits, and care sought outside of the emergency department or community hospital system are not included. The definition of “weekend” is limited in the NIS and does not allow for separation for evening admissions during the week. Using strict criteria and exclusion of subjects based on missing NIHSS scores or outcomes is a limitation of study and potentially introduces bias. Additionally, the use of mortality as the primary outcome measure versus functional outcome is outside the norm for studies regarding thrombectomy; this was chosen to determine the safety profile for weekend vs. non-weekend procedures. Although the secondary outcome, defined as discharge to home or self-care, was used as is of significant relevance, the lack of specific functional outcome data is a limitation of the study.

Despite these limitations, however, this report demonstrates no significant "weekend effect" in the treatment of AIS with EVT from a large national database with data from a time period following a surge of randomized clinical data supporting mechanical thrombectomy in early and late windows. Undoubtedly, as stroke care becomes more commonplace at community hospitals, future study of similar metrics will be important.

CONCLUSIONS

We have demonstrated the "weekend effect" does not impact outcomes, namely in-hospital death, favorable discharge, extended hospital stay, and cost, in those who undergo EVT for LVO. These results, obtained using a sample of patients from the NIS from 2017 and 2018, represent patient care that occurred after a surge of evidence supporting the use of EVT in early and late windows, likely represent "real-world" care.

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Competing Interests

Dr. de Havenon's department has received funding from AMAG and Regeneron pharmaceuticals for investigator-initiated research and Dr. de Havenon receives royalties from UpToDate, Inc. Dr. Grandhi is a consultant for Cerenovus, Medtronic Neurovascular, and Balt Neurovascular.

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Table 1.

ICD-10 codes used for patient identification

Identifier	Category	Diagnosis	Code
ICD-10-CM	Stroke	Ischemic stroke	I63.x, I64.x, H34.1
ICD-10-PCS	Intervention	Endovascular thrombectomy for acute ischemic stroke	03CG3Z6, 03CG3Z7, 03CG3ZZ, 03CG4Z6, 03CG4ZZ, 03CH3Z6, 03CH3Z7, 03CH3ZZ, 03CH4Z6, 03CH4ZZ, 03CJ3Z6, 03CJ3Z7, 03CJ3ZZ, 03CJ4Z6, 03CJ4ZZ, 03CK3Z6, 03CK3Z7, 03CK3ZZ, 03CK4Z6, 03CK4ZZ, 03CL3Z6, 03CL3Z7, 03CL3ZZ, 03CL4Z6, 03CL4ZZ, 03CM3Z6, 03CM3Z7, 03CM3ZZ, 03CM4Z6, 03CM4ZZ, 03CN3Z6, 03CN3Z7, 03CN3ZZ, 03CN4Z6, 03CN4ZZ, 03CP3Z6, 03CP3Z7, 03CP3ZZ, 03CP4Z6, 03CP4ZZ, 03CQ3Z6, 03CQ3Z7, 03CQ3ZZ, 03CQ4Z6, 03CQ4ZZ

Table 2.

Baseline demographics and outcomes, stratified by weekend vs. weekday admission

Variable	Full cohort (n=6,052)	Weekend admission (n=1,660)	Weekday admission (n=4,392)	p value*
Age in years	68.7±14.8	68.9±14.9	68.7±14.7	0.611
Female sex	3,077 (50.8%)	866 (52.2%)	2,211 (50.3%)	0.205
Race				0.443
White	4,084 (67.5%)	1,100 (66.3%)	2,984 (67.9%)	
Black	854 (14.1%)	250 (15.1%)	604 (13.8%)	
Hispanic	457 (7.5%)	133 (8.0%)	324 (7.4%)	
Other or unknown	657 (10.9%)	177 (10.6%)	480 (10.9%)	
NIHSS	16, 10–21	16, 11–22	16, 10–21	0.057
Elixhauser comorbidity index	5, 4–6	5, 4–6	5, 4–6	0.764
APR-DRG severity of illness	3, 3–4	3, 3–4	3, 3–4	0.535
Number of ICD-10 diagnoses	18.7±6.0	18.7±5.9	18.7±6.0	0.867
Hospital census region				0.303
Northeast	1,117 (18.5%)	282 (17.0%)	835 (19.0%)	
Midwest	1,341 (22.1%)	369 (22.2%)	972 (22.1%)	
South	2,414 (39.9%)	672 (40.5%)	1,742 (39.7%)	
West	1,180 (19.5%)	337 (20.3%)	843 (19.2%)	
Admitted to a teaching hospital	5,564 (91.9%)	1,522 (91.7%)	4,042 (92.0%)	0.599
Payer				0.593
Medicare	3,719 (61.5%)	1,037 (62.5%)	2,682 (61.1%)	
Medicaid	570 (9.4%)	157 (9.5%)	413 (9.4%)	
Private insurance	1,392 (23.0%)	374 (22.5%)	1,018 (23.2%)	
Self-pay or other	371 (6.1%)	92 (5.5%)	279 (6.3%)	
Quartile of median household income by zip code				0.125
1st quartile	1,730 (28.6%)	451 (27.2%)	1,279 (29.1%)	
2nd quartile	1,551 (25.6%)	438 (26.4%)	1,113 (25.3%)	
3rd quartile	1,493 (24.7%)	437 (26.3%)	1,056 (24.0%)	
4th quartile	1,278 (21.1%)	334 (20.1%)	944 (21.5%)	
Intravenous alteplase	1,463 (24.2%)	403 (24.3%)	1,060 (24.1%)	0.908
Mechanical ventilation required	916 (15.1%)	251 (15.1%)	665 (15.1%)	0.984
Total hospital charges (n=6,022)	184,143±145,972	183,430±142,604	184,413±147,241	0.816
Cost-to-charge ratio (n=6,022)	41,031±27,006	41,129±26,326	40,994±27,261	0.862

Variable	Full cohort (n=6,052)	Weekend admission (n=1,660)	Weekday admission (n=4,392)	p value*
In-hospital death	707 (11.7%)	183 (11.0%)	524 (11.9%)	0.327
Favorable discharge	1,255 (20.7%)	334 (20.1%)	921 (21.0%)	0.467
Length of stay ≥10 days	1,247 (20.6%)	349 (21.0%)	898 (20.5%)	0.620

*Binary variables presented as n (%); ordinal variables as median, IQR; interval variables as mean±standard deviation. P values calculated with the chi-squared test for binary variables, the Wilcoxon rank sum test for ordinal variables, and Student's t-test for interval variables.

NIHSS, National Institutes of Health Stroke Scale; APR-DRG, All Patients Refined Diagnosis Related Groups; ICD-10, International Classification of Diseases, 10th Revision

Table 3.

Odds ratios for study outcomes for weekend admission (vs. weekday)

Outcome	Odds Ratio*	95% CI	p value
In-hospital death	0.86	0.70–1.05	0.118
Favorable discharge	0.99	0.84–1.16	0.878
Length of stay ≥10 days	1.02	0.87–1.20	0.788

*Adjusted for patient age, sex, race/ethnicity (White, Black, Hispanic, or other), admission National Institutes of Health Stroke Scale score, intravenous alteplase admission, Elixhauser comorbidity index, All Patients Refined Diagnosis Related Groups measure of disease severity, mechanical ventilation, median household income for the patient’s ZIP code, hospital region, and expected payer (Medicaid, Medicare, private, other).

Table 4.

Summary table of large series examining the “Weekend Effect” in endovascular thrombectomy for acute ischemic stroke.

Author/Year	Number of Sites	Number of Patients	Hospital Setting	Statistical Model Adjustment	Weekend Effect Detected
Almetkhlafi et al. 2014 (9)	1	110	Academic	No mention/No difference in NIHSS	Increased imaging-to-reperfusion time
Saad et al. 2014 (6)	Multicenter national database (NIS 2005–2011)	12,055	Academic and community	Stepwise logistic regression model/No control for NIHSS	Patients admitted to nonteaching hospitals more likely to have moderate-to-severe disability
Mpotsaris et al. 2015 (10)	1	98	Academic	No mention/No difference in NIHSS	Prolongation of door-to-needle time
Nikoubashman et al. 2017 (26)	1	358	Academic	No mention/No difference in NIHSS	None
Raymond et al. 2018 (11)	1	129	Academic	No mention/No difference in NIHSS	None
Zaeske et al. 2020 (8)	1	246	Academic	No mention/No difference in NIHSS	Increased in-hospital mortality
Dandapat et al. 2020 (12)	1	315	Academic	Ordinal/logistical regression models/No difference in NIHSS	None
Weddell et al. 2020 (13)	1	501[†]	Academic	Model controlled for baseline demographic and clinical characteristics/No difference in NIHSS	Door-to-imaging, door-to-groin times significantly longer, thrombectomy duration shorter
Tschoe et al. 2020 (15)	6 centers (multicenter STAR registry database[*])	1919	Academic	Multivariable ordinal logistic regression model/No difference in NIHSS	None
Potts et al. 2021 (26)	1	216	Academic	No mention/No difference in NIHSS	Increased door-to-groin puncture time
Current study	Multicenter national database (NIS 2016–2018)	6052	Academic and community	Mixed-effects logistic regression model/Controlled for NIHSS, no difference in NIHSS	None

[*]Prospective, observational database in the United States

[†]Study reported number of procedures rather than number of patients.

NIHSS, National Institutes of Health Stroke Scale; STAR, Stroke Thrombectomy and Aneurysm Registry; NIS, National (Nationwide) Inpatient Sample