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RESEARCH

Factors associated with 30-day readmission for patients hospitalized for seizures

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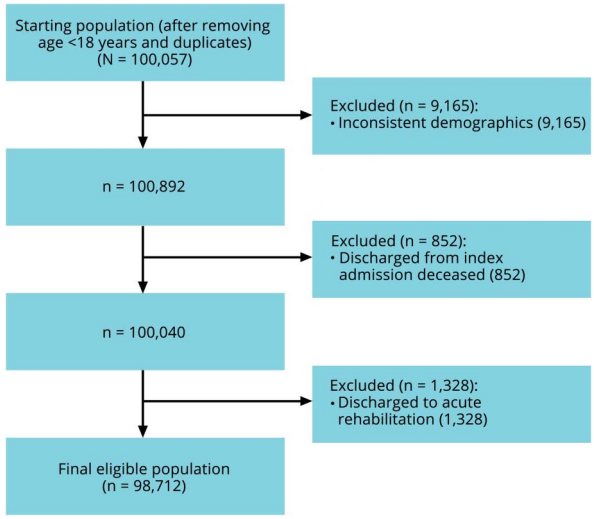
Abstract

Background

We sought to determine the cumulative incidence of readmissions after a seizure-related hospitalization and identify risk factors and readmission diagnoses.

Methods

We performed a retrospective cohort study of adult patients hospitalized with a primary discharge diagnosis of seizure (*International Classification of Diseases, Ninth Edition, Clinical Modification* codes 345.xx and 780.3x) using the State Inpatient Databases across 11 states from 2009 to 2012. Hospital and community characteristics were obtained from the American Hospital Association and Robert Wood Johnson Foundation. We performed logistic regressions to explore effects of patient, hospital, and community factors on readmissions within 30 days of discharge.



Results

Of 98,712 patients, 13,929 (14%) were readmitted within 30 days. Reasons for readmission included epilepsy/convulsions (30% of readmitted patients), mood disorders (5%), schizophrenia (4%), and septicemia (4%). The strongest predictors of readmission were diagnoses of CNS tumor (odds ratio [OR] 2.1, 95% confidence interval [CI] 1.9–2.4) or psychosis (OR 1.8, 95% CI 1.7–1.8), urgent index admission (OR 2.0, 95% CI 1.8–2.2), transfer to nonacute facilities (OR 1.7, 95% CI 1.6–1.8), long length of stay (OR 1.7, 95% CI 1.6–1.8), and for-profit hospitals (OR 1.7, 95% CI 1.6–1.8). Our main model's c-statistic was 0.66. Predictors of readmission for status epilepticus included index admission for status epilepticus (OR 3.5, 95% CI 2.6–4.7), low hospital epilepsy volume (OR 0.4, 95% CI 0.3–0.7), and rural hospitals (OR 4.8, 95% CI 2.1–10.9).

Conclusion

Readmission is common after hospitalization for seizures. Prevention strategies should focus on recurrent seizures, the most common readmission diagnosis. Many factors were associated with readmission, although readmissions remain challenging to predict.

Better surveillance data about health care utilization for patients with epilepsy are needed so that resources can be effectively focused toward an integrated approach to epilepsy care in the 21st century.[1,2]

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In this study, we explored patterns of 30-day readmissions after an acute hospitalization for seizures or convulsions using administrative data sets.

A better understanding of inpatient utilization patterns is particularly important because approximately 80% of personal costs related to epilepsy occur in the inpatient setting, and hospitalizations are increasing over time.[3,4] Studying readmissions is crucial because they may reflect preventable gaps in transitions of care after an acute hospitalization.[5,6] Furthermore, readmissions are publicly reported,[7] tied to reimbursement,[8] and are common, costly, and burdensome.[9] Limited research exists regarding readmissions in neurologic conditions as a whole[10] and only sparse, single-center work has described epilepsy readmissions in limited populations.[11,12] Broader examination of the drivers of readmissions following hospitalization for seizures would allow for identification of high-risk patients, improved patient counseling at discharge, and development of focused interventions.

In this study, we explored patterns of 30-day readmissions after an acute hospitalization for seizures or convulsions using administrative data sets. The ultimate goal is to build a sophisticated understanding of patient- and system-level factors driving hospital readmissions to better design transitions of care.

Methods

We performed a retrospective cohort study of patients hospitalized for seizure or convulsions within the State Inpatient Databases (SID) from 2009 to 2012 to describe the burden of and reasons for readmission. We linked these data to several other databases of hospital and community information (listed below) and fit multivariable logistic regressions to understand relationships between patient-, hospital-, and community-level variables and 30-day readmission.

Data sets

We used SID to identify the cohort and to collect individual-level information. SID is provided by the Healthcare Cost and Utilization Project, which gathers longitudinal health care data for the Agency for Healthcare Research and Quality.[13] SID is an all-payer database including demographics, diagnoses, comorbidities, and hospitalization characteristics such as length of stay and charges.

We linked SID data to institutional information contained in the American Hospital Association (AHA) Annual Survey Database.[14] AHA surveys over 6,300 hospitals across the country about administrative structure, academic affiliation, beds, staffing, and additional hospital services.

We also linked SID data to community information collected by the Robert Wood Johnson Foundation (RWJF) using hospital ZIP code.[15] RWJF County Health Rankings capture aspects of population health including health behaviors, quality and access, socioeconomic factors, and physical environment of nearly all counties in the United States.

Patient selection

We used 11 states (2009: Arkansas; 2009–2010: North Carolina; 2009–2011: California, Iowa, New York; 2009–2012: Florida, Washington; 2010: Massachusetts; 2011: Nebraska; 2012: Maryland, Vermont) from SID, which comprised a diverse convenience sample. SID identifies unique individuals based on encrypted person number, date of birth, and sex.

Our study population consisted of all patients with at least one hospitalization with a primary discharge diagnosis of epilepsy, seizures, or convulsions during this period. This primary discharge diagnosis was defined by an *International Classification of Diseases, Ninth Edition, Clinical Modification (ICD-9-CM)* code beginning with 345.xx or 780.3x. *ICD-9-CM* codes to identify patients with seizures in administrative data sets have been previously validated with 97%–99% positive and negative predictive values and sensitivity 99% and specificity 70% in a seizure-monitoring unit.[16] The chronologically first admission with a primary diagnosis of epilepsy, seizures, or convulsions in which the patient was not discharged to another acute facility was identified as the index admission for analysis. The latter stipulation existed to identify only the ultimate acute care hospitalization to avoid double-counting transferring hospitals. We then identified whether each patient had at least one subsequent hospitalization within 30 days of discharge from the index hospitalization.[17] Each patient could only contribute a single index admission regardless of whether they had numerous seizure admissions.

We excluded visits without a valid patient identifier, exact duplicates, and age <18 years. We excluded patients with discrepancy regarding sex (>1 sex listed across visits within a patient identifier), age, or hospitalization dates (range across rows within a patient greater than that expected from the range of calendar years listed for their hospitalizations). We excluded patients discharged to inpatient rehabilitation and patients whose next listed hospitalization began on the same day as the index discharge for a primary diagnosis of rehabilitation to avoid classifying postacute care visits as readmissions and patients who died during the index hospitalization.

Standard protocol approvals, registrations, and patient consent

The study protocol, which does not rely on human subjects, was deemed not regulated by the University of Michigan Institutional Review Board.

Data and variables

We incorporated a robust array of variables plausibly predictive of readmission using our 3 linked databases.

From SID, we abstracted the primary diagnosis of the index hospitalization (used for study entry), comorbidities potentially relevant to seizures (alcoholism, depression, congestive heart failure [CHF], drug use, and psychosis; selected *ICD-9-CM* definitions are listed in appendix e-1, links.lww.com/CPJ/A107), demographics (age, race, and sex), severity markers such as intubation (determined by procedure codes) and urgent admission (determined by SID classification), and other hospitalization characteristics (payer, whether patients were transferred in from or out to health care facilities, length of stay, and charge). We used the hospital listed in SID to link in the relevant AHA and RWJF data.

From AHA, we abstracted information about the hospital at which each patient received care. This included total hospital beds, ownership, rural location, and teaching status (defined as member of the Council of Teaching Hospitals, Accreditation Council for Graduate Medical Education residency program, and/or full-time residents or interns to licensed bed ratio > 0.25[18]). For each hospital, we calculated average yearly epilepsy volume as the total number of hospitalizations with primary *ICD-9-CM* codes 345.xx or 780.3x in SID over the study years, divided by the number of study years.

From 2012 RWJF data, for each ZIP code, we abstracted the percentage of residents within a ZIP code who are smokers, obese, uninsured, illiterate, unable to see a physician due to cost, and who have obtained a college education plus average household income and number of primary care physicians per population.

Our primary outcome was all-cause 30-day readmission. This was defined as a subsequent admission within 30 days of discharge from the index hospitalization. If a patient had multiple readmissions during this 30-day period, we only counted the first readmission.

Statistical analysis

For our primary analysis, we used logistic regressions to assess the relationship between all-cause 30-day readmission and a wide variety of factors. We performed unadjusted analyses for each factor (model 1). We then performed a multivariable logistic regression including all listed variables (model 2).

We performed several secondary analyses. First, we repeated model 2 except using the outcome of status epilepticus readmissions (model 3). We performed this analysis of status epilepticus given (1) importance as a neurologic emergency[19] and (2) plausible preventability with optimal treatment and systems of care. Then, to disentangle the effect of community- and hospital-level factors from a patient's individual set of risk factors, we fit a 3-level hierarchical logistic regression with random intercepts at the hospital level and county level for the hospital nested within counties. To determine the proportion of overall variability in all-cause readmission explained by the random effects of hospital and community after adjusting for patient-level variables, we calculated the intraclass correlation coefficient from the adjusted hierarchical mixed effects logistic regression. Appendix e-2, links.lww.com/CPJ/A107, describes additional secondary and sensitivity analyses.

For all models, we calculated the c-statistic (i.e., the area under the receiver operator curve) and R^2 to assess model discrimination and explanatory power. To assess predictiveness, we plotted calibration curves. To do so, we plotted each decile of predicted probability against its observed readmit proportion. All analyses were performed using SAS statistical software, version 9.4 (Cary, NC).

Data availability

Code used to create and analyze the data sets is available at github.com/jburke5/SIDepilepsyReadmissions. Raw data for SID (hcup-us.ahrq.gov/tech_assist/centdist.jsp) and AHA (aha.org/data-insights/aha-data-products) are available for purchase. RWJF data are available online (countyhealthrankings.org/explore-health-rankings/rankings-data-documentation).

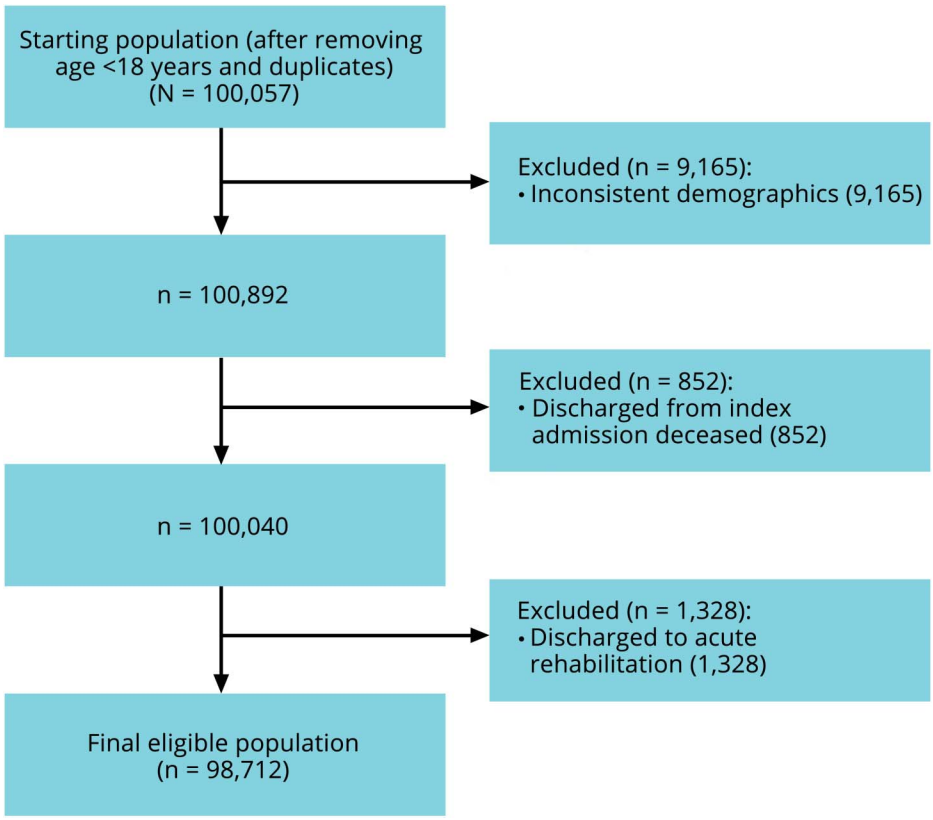
Results

Figure 1 depicts an exclusion flowchart. Our final population included 98,712 patients; 13,929 (14%) had a 30-day readmission. Our fully adjusted main logistic regression included 86,133 patients with complete data out of the eligible 98,712. Thus, 12,579/98,712 (13%) patients were excluded from the main adjusted model due to at least one missing variable. Of those patients excluded from adjusted regressions due to missingness, 5,892 (6% of the eligible population) were excluded because their state does not report a particular variable (thus, Nebraska, Massachusetts, and North Carolina in 2009 were excluded from regressions). Only 6,687 (7% of the eligible population) were excluded because at least one variable was missing otherwise.

Table 1 describes our cohort's index hospitalizations. The median age was 52 years (interquartile range [IQR] 37–67 years), 55,813 (60%) were non-Hispanic white, and 49,985 (51%) were female. The prevalence of various comorbidities ranged from 5% with CHF to 13% with depression. Index admissions were urgent for 83,9088 (85%), 7,161 (7%) were admitted for status epilepticus, the median length of stay was 3 (IQR 2–4) days, and the most common primary payer was Medicare (42,591; 43%).

Our main adjusted logistic regression (model 2) modeling all-cause 30-day readmission revealed that most patient-level and hospital-level factors demonstrated an effect on the outcome (table 2). The strongest predictors of readmission

Figure 1 Patient flowchart



"Inconsistent demographics" refers to those 9,165 patients excluded because of a discrepancy among data regarding sex (more than 1 sex listed across visits within the same patient identifier), or age or hospitalization dates (range of age or hospitalization dates, respectively, across visits within a patient identifier were greater than plausible by the range of calendar years listed for their hospitalizations during the study period). Of these, patients were excluded because of the following combinations of discrepant variables: 1472 sex and age and dates, 168 sex and age, 56 sex and dates, 6 sex only, 1500 age and dates, 5643 age only, and 320 dates only.

were a diagnosis of CNS tumor (odds ratio 2.1, 95% confidence interval 1.9–2.4) or psychosis (1.8, 1.7–1.8), an urgent index admission (2.0, 1.8–2.2), transfer to a nonacute facility (1.7, 1.6–1.8; note only transfers out to nonacute facilities were included in this study, given exclusion of transfers out to acute facilities), and long length of stay (8+ days vs 0–1 days: 1.7, 1.6–1.8). Variables with nonsignificant or relatively small effect sizes included age (despite significance in unadjusted analysis), sex, index admission status epilepticus or intubation, total hospital beds, and hospital teaching status. Community-level factors did not meaningfully predict readmissions (table e-1, links.lww.com/CPJ/A107, which is a continuation of table 2).

Variables that were strongly predictive of status epilepticus readmission (model 3) included younger age (65 + v < 35: 0.4, 0.3–0.7), status epilepticus index diagnosis (3.5, 2.6–4.7), intubation during index hospitalization (1.7, 1.2–2.5), lower yearly epilepsy hospital volume (200+ v < 50 epilepsy hospitalizations/yr: 0.4, 0.3–0.7), and rural hospital (4.8, 2.1–10.9).

To explore the effect of hospital-level and community-level factors on readmission, we calculated the intraclass correlation coefficient (ICC) for hospital and county effects of our multilevel models (table 3). The ICC represents the percent of total variation in readmissions explained by each group factor. Unadjusted ICCs were low at 0.4% for the county random effect and 1.9% for the hospital random effect. After adjusting for all variables in table 2 and table e-1, links.lww.com/CPJ/A107, ICCs were 0.3% and 1.1%, respectively.

Table 3 and figure 2 describe model characteristics. The c-statistic for our main adjusted model (model 2) was 0.66, and R^2 values were maximally 5% for all models, which suggest that such models contained modest discriminatory ability and explained a small proportion of readmission variability. Despite this, figure 2 shows that model calibration was good, given that predicted and observed readmission proportions were similar across the spectrum of readmission risk. The highest decile of predicted risk was 30%, compared with lowest 5%.

Table e-2, links.lww.com/CPJ/A107, displays the most common readmission diagnoses. The largest primary readmission diagnosis was epilepsy/convulsions (30%), followed by mood disorders (5%), schizophrenia (4%), sepsis (4%), and alcohol-related disorders (3%). Only 343 (2%) readmissions were for status epilepticus, and 401 (3%) readmitted patients died during their readmission.

Table 1 Population characteristics of index admission

	No. (%)[a] of population[a]	No. (%) readmitted[b]
Demographics		
Age, y		
18–34	21496 (22%)	2186 (10%)
35–64	49128 (50%)	7013 (14%)
65+	28088 (29%)	4730 (17%)
Race		
Non-Hispanic white	55813 (60%)	7848 (14%)
Hispanic	12665 (14%)	1780 (14%)
Black	18520 (20%)	2999 (16%)
Sex		
Female	49985 (51%)	7120 (14%) vs 6803 (14%)
Comorbidities		
Alcoholism	9523 (10%)	1592 (17%) vs 11892 (14%)
CHF	4394 (5%)	1032 (24%) vs 12897 (14%)
Depression	12751 (13%)	2019 (16%) vs 11465 (14%)
Drug use	8044 (8%)	1255 (16%) vs 12229 (14%)
Psychoses	10225 (11%)	2337 (23%) vs 11147 (13%)
Hospitalization		
Transfer in[c]		
No	93520 (95%)	12922 (14%)
Acute facility	2146 (2%)	388 (18%)
Nonacute facility	2518 (3%)	540 (21%)
Type		
Urgent/emergent	83908 (85%)	12926 (15%) vs 1002 (7%)
Severity		
Status epilepticus	7161 (7%)	1211 (17%) vs 12718 (14%)
Intubated	5245 (5%)	1004 (19%) vs 12925 (14%)
Secondary diagnoses		
Ischemic stroke	603 (0.6%)	133 (22%) vs 13796 (14%)
ICH	542 (0.6%)	128 (24%) vs 13801 (14%)
CNS tumor	1976 (2.0%)	463 (23%) vs 13466 (14%)
Meningoencephalitis	237 (0.2%)	40 (17%) vs 13889 (14%)
Cardiac arrest	158 (0.2%)	38 (24%) vs 13891 (14%)
Alcohol withdrawal	1580 (2%)	308 (19%) vs 13621 (14%)
TBI	340 (0.3%)	43 (13%) v 13886 (14%)
Major brain surgery	490 (0.5%)	47 (10%) vs 13882 (14%)
Primary payer		
Medicare	42591 (43%)	7160 (17%)
Medicaid	21773 (22%)	3254 (15%)
Private insurance	22143 (22%)	2179 (10%)
LOS, d		
0–1	21455 (22%)	2411 (11%)
2–7	68315 (69%)	9438 (14%)
8+	8939 (9%)	2080 (23%)
Transfer out[c]	15724 (16%)	3836 (24%) vs 10088 (12%)
Hospital		
Profit control		
For profit	10893 (11%)	2398 (22%) 11330 (13%)
Total beds		
<200	18388 (19%)	2781 (15%)
200–599	50182 (52%)	7289 (15%)
600+	28136 (29%)	3613 (13%)
Rural	723 (0.8%)	124 (17%) vs 13559 (14%)
Teaching	50800 (53%)	6607 (13%) vs 7076 (15%)
Yearly epilepsy hospitalizations		
1–49	27050 (28%)	3973 (15%)
50–199	47129 (48%)	6891 (15%)
200+	23356 (24%)	2933 (13%)

Abbreviations: CHF = congestive heart failure; ICH = intracranial hemorrhage; LOS = length of stay; TBI = traumatic brain injury.
[a] This column displays the proportion of the study population with each given characteristic. The numerator (No.) is the total study population with each characteristic, divided by the denominator of the total study population with an available value for that variable (i.e., 22% of the population is aged 18–34 years). Note that some percentages total <100% due to suppressed "other" categories for display.
[b] This column displays strata-specific readmission rates. The numerator (No.) is the number of patients with a 30-day readmission within a given strata, divided by the denominator of the total study population within a given strata with an available value for that variable. If a covariate is binary, this strata-specific readmission rate is listed for those with vs without the given potential risk factor (i.e., 10% of patients aged 18–34 years were readmitted).
[c] We identified the index admission for analysis above as the chronologically first seizure-related admission, which was not transferred out to another acute care facility to capture the "destination" hospital. Thus, patients could be transferred in from either an acute or nonacute facility and transferred out to a nonacute facility (such as subacute rehabilitation or skilled nursing facility).

Discussion

We found an all-cause 30-day readmission rate of 14% among patients hospitalized for seizures or convulsions. This is slightly higher than previous work, which estimated 10%.[10] Our rate of 14% was somewhat lower though still comparable to other chronic conditions. For example, Medicare beneficiaries have demonstrated an approximately 20% 30-day

Table 2 Models predicting readmission

	Model 1[a]	Model 2[b]	Model 3[c]
Demographics			
Age, y			
18–34	Ref	Ref	Ref
35–64	1.5 (1.4–1.6)	1.1 (1.1–1.2)	0.7 (0.5–0.9)
65+	1.8 (1.7–1.9)	1.1 (1.0–1.1)	0.4 (0.3–0.7)
Race			
White	Ref	Ref	Ref
Hispanic	1.0 (0.9–1.1)	1.0 (0.9–1.0)	1.4 (1.0–1.9)
Black	1.2 (1.1–1.2)	1.1 (1.1–1.2)	1.1 (0.8–1.5)
Sex			
Female	1.0 (1.0–1.1)	1.0 (1.0–1.1)	1.1 (0.9–1.4)
Comorbidities			
Alcoholism	1.3 (1.2–1.3)	1.2 (1.1–1.3)	1.1 (0.7–1.7)
CHF	1.9 (1.8–2.1)	1.5 (1.3–1.6)	0.5 (0.2–1.0)
Depression	1.2 (1.1–1.2)	1.2 (1.1–1.3)	0.9 (0.6–1.3)
Drug use	1.1 (1.1–1.2)	1.2 (1.1–1.3)	1.1 (0.7–1.6)
Psychoses	2.0 (1.9–2.1)	1.8 (1.7–1.8)	0.9 (0.6–1.3)
Hospitalization			
Transfer in			
No	Ref	Ref	Ref
Acute facility	1.3 (1.2–1.5)	1.5 (1.4–1.8)	1.9 (1.1–3.3)
Nonacute facility	1.7 (1.5–1.9)	1.1 (1.0–1.2)	1.0 (0.5–2.0)
Type			
Urgent/emergent	2.5 (2.3–2.7)	2.0 (1.9–2.2)	1.2 (0.8–1.8)
Severity			
Status epilepticus	1.3 (1.2–1.3)	1.0 (0.9–1.1)	3.5 (2.6–4.7)
Intubated	1.5 (1.4–1.6)	1.1 (1.0–1.2)	1.7 (1.2–2.5)
Secondary diagnoses			
Ischemic stroke	1.7 (1.4–2.1)	1.2 (1.0–1.5)	1.2 (0.4–3.8)
ICH	1.9 (1.5–2.3)	1.5 (1.2–1.9)	0.4 (0.1–3.0)
CNS tumor	1.9 (1.7–2.1)	2.1 (1.9–2.4)	1.6 (0.8–3.0)
Meningoencephalitis	1.2 (0.9–1.7)	1.0 (0.7–1.5)	1.7 (0.4–6.9)
Cardiac arrest	1.9 (1.3–2.8)	1.2 (0.8–1.8)	1.7 (0.4–7.1)
Alcohol withdrawal	1.5 (1.3–1.7)	1.3 (1.1–1.5)	0.7 (0.3–2.1)
TBI	0.9 (0.6–1.2)	0.9 (0.6–1.2)	N/A[d]
Major brain surgery	0.6 (0.5–0.9)	1.3 (0.9–1.8)	N/A[d]
Primary payer			
Medicare	Ref	Ref	Ref
Medicaid	0.9 (0.8–0.9)	1.0 (0.9–1.1)	1.0 (0.7–1.4)
Private insurance	0.5 (0.5–0.6)	0.8 (0.7–0.8)	0.7 (0.5–1.0)
LOS, d			
0–1	Ref	Ref	Ref
2–7	1.3 (1.2–1.3)	1.2 (1.1–1.2)	1.1 (0.8–1.5)
8+	2.4 (2.2–2.6)	1.7 (1.6–1.8)	1.4 (0.9–2.1)
Transfer out	2.3 (2.2–2.4)	1.7 (1.6–1.8)	1.4 (1.0–1.9)
Hospital			
Profit control			
For profit	1.9 (1.8–2.0)	1.7 (1.6–1.8)	1.4 (1.0–2.0)
Total beds			
<200	Ref	Ref	Ref
200–599	1.0 (0.9–1.0)	1.0 (1.0–1.1)	1.2 (0.8–1.7)
600+	0.8 (0.8–0.9)	1.1 (1.0–1.2)	1.9 (1.1–3.2)
Rural	1.3 (1.0–1.5)	1.4 (1.1–1.8)	4.8 (2.1–10.9)
Teaching	0.8 (0.8–0.9)	1.1 (1.0–1.1)	0.8 (0.6–1.2)
Yearly epilepsy hospitalizations			
1–49	Ref	Ref	Ref
50–199	1.0 (1.0–1.0)	1.0 (0.9–1.0)	0.9 (0.6–1.2)
200+	0.8 (0.8–0.9)	0.9 (0.8–1.0)	0.4 (0.3–0.7)

Abbreviations: CHF = congestive heart failure; ICH = intracranial hemorrhage; LOS = length of stay; TBI = traumatic brain injury.
[a]Model 1: unadjusted logistic, separate regression for each variable, outcome is all-cause readmission.
[b]Model 2: logistic regression, adjusted for all variables displayed in tables 2 and 3, outcome is all-cause readmission, N = 86133 (12,320 outcomes).
[c]Model 3: model 2, except outcome is status epilepticus readmission.
[d]N/A indicates separation of values due to 0 in a group causing an infinite confidence interval.

rehospitalization rate overall,[9] and within neurologic conditions, readmission rates have ranged 7%–22%.[10]

Although some readmissions may be unavoidable in a high-risk condition such as epilepsy, our work highlights potentially modifiable factors. The high seizure-related readmission rate is noteworthy. Patients could have a breakthrough seizure due to nonadherence to a newly intensified antiepileptic regimen (i.e., discharged without fully understanding medication instructions or self-discontinued medications due to side effects or cost), or lifestyle choices could contribute to recurrent events, both of which could be modifiable. Given studies showing high nonadherence rates to antiepileptics[20] and antiepileptic nonadherence has been found to be associated with both increased seizures[21] and inpatient utilization,[22] optimizing antiepileptic adherence with careful discharge counseling

Table 3 Model statistics

Model	c-statistic	R^2 (Tjur)	ICC
Model 1's	Range 0.50–0.57	All <1%	N/A
Model 2	0.66	5%	N/A
Model 3	0.72	0.5%	N/A
Model 4[a]	0.60	1%	
County			0.4%
Hospital			1.9%
Model 5[b]	0.68	5%	
County			0.3%
Hospital			1.1%

Abbreviation: ICC = intraclass correlation coefficient.
[a] Model 4: unadjusted multilevel (nesting hospital within county) logistic regression modeling all-cause readmission (N = 97,535).
[b] Model 5: model 4, adjusted for all variables in table 2 and table e-1 (N = 86,133).

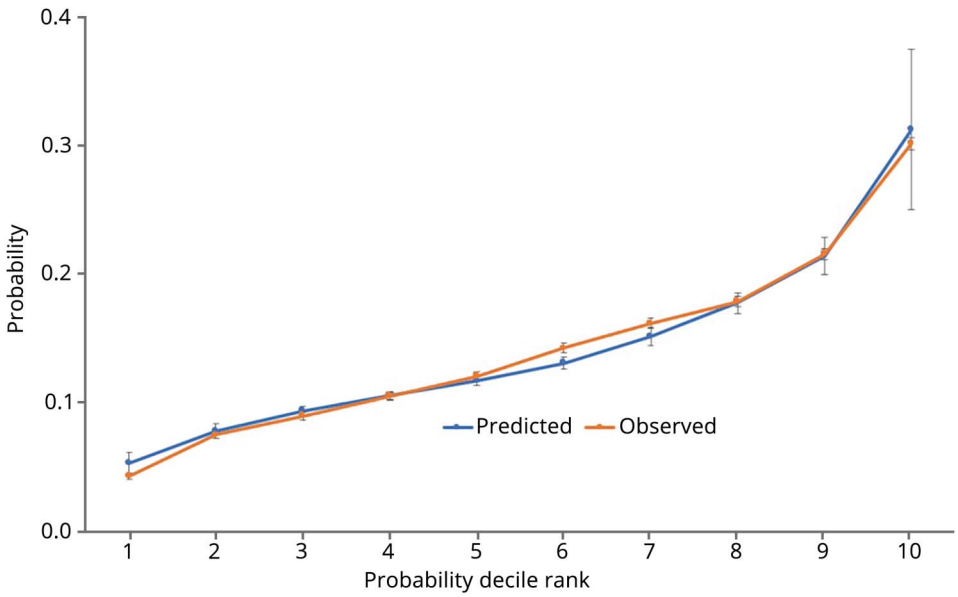
and/or postdischarge monitoring could be a critical target toward reducing readmissions.

Recognizing a high psychiatric readmission risk is valuable information toward another potential point of inpatient intervention. Patients with epilepsy have a high burden of psychiatric disease; 20%–60% of patients with uncontrolled seizures have depression, and suicidality in epilepsy is twice that of the general population.[23] However, 1 sample documented that ~80% of neurologists in the American Academy of Neurology do not routinely screen for depression in outpatient clinics.[24] Therefore, our results emphasize that seizure-related hospitalizations may be a key moment for psychiatric evaluation/intervention to prevent future mood-related morbidity and that acute mental health concerns could be a modifiable gap in care.

Our results emphasize that seizure-related hospitalizations may be a key moment for psychiatric evaluation/intervention to prevent future mood-related morbidity and that acute mental health concerns could be a modifiable gap in care.

Our work identifies numerous predictors. Groups with greater than 20% readmission risk included length of stay over 1 week, psychosis, cardiac arrest, intracranial hemorrhage, ischemic stroke, CNS tumor, and CHF. Note, though, that increased risk of readmissions in patients with such serious comorbidities may hold true regardless of an underlying diagnosis of seizures or epilepsy. Readmission for status epilepticus was associated with smaller hospital epilepsy volume and rural care, and other systems factors predicting readmissions included for-profit hospital status and transfers. Furthermore, selected hospital characteristics such as rural location and for-profit status were most strongly predictive of

Figure 2 Calibration curve



We calculated predicted probabilities of all-cause 30-day readmissions from our main analysis, model 2. Each data point for predicted probabilities above represents the mean for that decile of predicted probability from our main logistic regression. Overlaid is the observed readmission proportion for patients in each decile of predicted probability. Error bars represent SDs.

urgent seizure-related readmissions among patients with urgent initial admissions. To discuss one of these findings, existing critical care literature has suggested that higher hospital volume predicts better outcomes,[25] including lower mortality for mechanically ventilated patients at higher volume hospitals.[26] Only one study has evaluated the volume-outcome relationship for status epilepticus and actually found no relationship between status epilepticus volume and in-hospital mortality, although their study did not examine readmissions.[27] Given that our study showed lower status epilepticus readmission rates at hospitals with higher epilepsy volume, our results imply that status epilepticus may be best served at more heavily experienced centers. This may initially seem counter to our finding that higher total hospital bed size was associated with greater status epilepticus readmissions. Indeed, existing literature[28] has supported that larger hospitals have higher nonsurgical readmissions and suggested that larger hospitals might provide less attention to any individual patient at discharge and follow-up. Both possibilities may be true: (1) when adjusting for hospital size, greater epilepsy volume/experience is associated with fewer status epilepticus readmissions due to disease-specific experience, and (2) when adjusting for epilepsy experience, greater hospital size is associated with greater status epilepticus readmissions.

Our models had strengths and limitations. They were highly powered and were well calibrated (predicted risk matched observed risk closely). However, our models explained maximally 5% of the variance in readmission, and although our models nicely predicted individuals at lowest risk of readmission (lowest decile of predicted risk was 5%), they could not reliably articulate those at highest risk of readmission (highest decile of predicted risk was 30%) who would be of most interest to policy interventions. Poor predictiveness and discrimination (modest c-statistics) are certainly not unique to our study, and it is well recognized that large effect sizes do not necessarily translate into high discrimination.[29,30] Indeed, few predictive models throughout the readmissions literature have yielded c-statistics above 0.7.[31]

One way we sought to improve upon previous models within the readmissions literature was by hypothesizing that part of individual-level readmission variation might be explained by higher-level effects.[32,33] We included aggregate regional factors and also a random effect for ZIP code, given literature suggesting that neighborhood socioeconomic disadvantage may effect 30-day readmissions.[34] Despite known socioeconomic disparities in patients with epilepsy,[35] aggregate community factors had limited effect sizes, and ZIP code explained a very small percentage of total variance. We also included a hospital variable, given the plausibility that practice variation at the hospital level (diagnostic intensity, medication selection, epileptologist availability, etc.) could affect outcomes beyond individual comorbidity case-mix. Similar to previous literature not specific to epilepsy,[36,37] we found that hospital effects explained a very small amount of individual readmission variation. This implies that current hospital-based readmission penalties may not be aimed at the most important sources of readmission variation if hospital effects explain less than 2% of individual variation. Small regional and hospital effects may collectively imply that individual-level factors are more important contributors than environment of care toward variation in readmission, although as emphasized by our study, the fact remains that the most meaningful individual factors influencing readmission remain largely unknown. Additional variables credibly along the causal pathway, which could augment discriminatory ability in future studies, might include psychogenic nonepileptic seizures, antiepileptic adherence, or intensity of outpatient care.

Our study has several limitations. Misclassification is possible; psychogenic events are challenging to capture using *ICD-9-CM* coding. We did not capture other potentially important variables such as medication adherence. Finally, approximately 13% of the eligible study population was excluded from adjusted models because of missing data; note, though, that half of these were excluded due to state nonreporting, which seems unlikely to pose a threat to internal validity due to nonselective missingness. Strengths of our study include large sample size, robust linked data at multiple levels (individual, hospital, and community), national representation using the largest all-payer database in the United States, and detailed serial regression analyses.

Readmissions are common after an acute hospitalization related to epilepsy. Recurrent seizures and mental health conditions were the most frequent reasons for readmission and may both reflect modifiable gaps toward preventing readmissions. It was noteworthy that care at hospitals with higher volumes of epilepsy admissions tended to have lower readmissions for status epilepticus, which may have important implications for how care is organized for epilepsy emergencies. Although many patient-level factors predicted readmission, readmissions are challenging to predict even with extensive administrative data. Clarifying drivers for post-seizure readmissions would benefit our ability to counsel patients and better design systems of care.

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Name	Location	Contribution
Samuel W. Terman, MD, MS	University of Michigan, Ann Arbor	Major role in design and conceptualized the study; acquisition of data; analyzed and interpreted the data; and drafted the manuscript for intellectual content
Elan L. Guterman, MD	University of California San Francisco	Designed and conceptualized the study and variables; interpreted data; and drafted the manuscript for intellectual content
Chloe E. Hill, MD, MS	University of Michigan, Ann Arbor	Designed and conceptualized the study and variables; interpreted data; and drafted the manuscript for intellectual content
John P. Betjemann, MD	University of California San Francisco	Designed and conceptualized the study and variables; interpreted data; and drafted the manuscript for intellectual content
James F. Burke, MD, MS	University of Michigan, Ann Arbor	Designed and conceptualized the study; statistical review; acquisition of data; interpreted the data; and drafted the manuscript for intellectual content

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