Influence of hospital-level practices on readmission after ischemic stroke

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ABSTRACT

Objective: To inform stroke quality improvement initiatives by determining the relationship between hospital-level stroke practices and readmission after accounting for patient-level factors.

Methods: Retrospective cohort study of adult patients hospitalized for ischemic stroke (principal *ICD-9-CM* codes 433.x1, 434.x1, and 436) in 5 states from 2003 to 2009 from State Inpatient Databases. The primary outcome was any unplanned readmission within 30 days. Multilevel logistic regression was used to estimate the association between hospital-level practice patterns of care (diagnostic testing, procedures, intensive care unit, tissue plasminogen activator, and therapeutic modalities) and readmission after adjustment for patient factors and whether individual patients received a given practice.

Results: Thirty-day unplanned readmission occurred in 15.2% of stroke admissions; the median hospital readmission rate was 13.6% (interquartile range 9.8%–18.2%). Of the 25 hospital practice patterns of care analyzed, 3 practices were associated with readmission: hospitals with higher use of occupational therapy and higher proportion of transfers from other hospitals had lower adjusted readmission rates, whereas hospitals with higher use of hospice had higher predicted readmission rates. Readmission rates in lowest vs highest utilizing quintile were as follows: occupational therapy 16.2% (95% confidence interval [CI] 14.5%–18.0%) vs 12.3% (95% CI 11.3%–13.2%); transfers 13.8% (95% CI 13.2%–14.5%) vs 12.5% (95% CI 11.6%–13.5%); and hospice 13.1% (95% CI 12.3%–14.0%) vs 14.8% (95% CI 13.5%–16.1%).

Conclusions: Hospital practices have a role in stroke readmission that is complex and poorly understood. Further work is needed to identify specific strategies to reduce readmission rates and to ensure that public reporting of readmission rates will not result in adverse unintended consequences. *Neurology®* 2014;82:2196–2204

GLOSSARY

CI = confidence interval; **CMS** = Centers for Medicare & Medicaid Services; **HCUP** = Healthcare Cost and Utilization Project; ***ICD-9-CM*** = *International Classification of Diseases, ninth revision, Clinical Modification*; **LST** = life-sustaining treatment; **OR** = odds ratio; **OT** = occupational therapy; **SID** = State Inpatient Databases; **tPA** = tissue plasminogen activator.

The Centers for Medicare & Medicaid Services (CMS) reports risk-adjusted readmission rates after hospital discharge as a quality measure for a variety of clinical conditions and will likely expand this program to include acute stroke.[1,2] Although readmission is common after stroke,[3–6] relatively little is known about the factors that contribute to the problem. Both hospital characteristics, such as stroke patient volume and accreditation status,[4,7] and individual-level factors, such as age, comorbidities, and the degree of poststroke disability, predict readmission to some extent,[8] but less is known about how practice patterns influence readmission. Of the small number of patient-level practices studied,[9] a significant reduction in readmission in patients receiving neuroimaging has been found in a single small study.[10] Hospital-level practice patterns may also influence readmission because there is wide variation in hospital-level stroke management practices[11–13] and readmission rates after stroke.[4,7] However, little is known about how hospital-level practice patterns influence stroke readmission.[9]

Supplemental data at Neurology.org

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The known variation in hospital-level stroke care practices, such as the use of tissue plasminogen activator (tPA),[11] neuroimaging,[12] and carotid endarterectomy,[13] can be used to describe hospitals (e.g., "a high tPA-utilizing hospital"). Because little is known about how hospitals influence readmission, we investigated the associations between a variety of hospital-level practices and readmission. By quantifying these associations, we sought to generate hypotheses about how individual hospitals may reduce readmission rates and which hospital-level practices may be latent measures of quality.[14]

METHODS

This retrospective cohort study included all patients discharged alive after an ischemic stroke hospitalization between 2003 and 2009 in 5 states. Our primary outcome measure was all unplanned readmissions within 30 days of the index discharge.

Standard protocol approvals, registrations, and patient consents. The study protocol, which does not rely on human subjects, was deemed not regulated by the University of Michigan Institutional Review Board.

Dataset. Ischemic stroke discharges were identified using the State Inpatient Databases (SID) of the Healthcare Cost and Utilization Project (HCUP) from the Agency for Healthcare Research and Quality.[15] SID captures all acute care hospitalizations within a given state for a given year. This study included SID data from 5 states: New York (2003–2009), North Carolina (2004–2009), Washington (2003–2009), Arizona (2003–2007), and Nebraska (2004–2009). These 5 states and years were selected because they were the only states with available UB-92 revenue codes (to define hospital-level practices where *ICD-9* codes are known to be unreliable[16]), HCUP revisit files[17] (to link the admission record to the readmission record), and patient-level zip code information (to link to census socioeconomic data). Collectively, these states contained approximately 14% of the US population in 2010 and have substantial variation in demographics, health care expenditures, and stroke mortality (table 1).

Cohort definition. Patients were included if they had a hospitalization with a principal discharge diagnosis of ischemic stroke (*ICD-9-CM* codes 433.x1, 434.x1, and 436).[18] Hospitalizations for patients younger than 18 years were excluded. Transfers were assigned to the hospital that received the transfer, and transfer-in status was adjusted for in all models.

Primary outcome measure. Our primary outcome was any unplanned hospital admission within 30 days of discharge after the index stroke admission. We excluded all readmissions with a principal procedure diagnosis that suggested a planned readmission (e.g., carotid endarterectomy, patent foramen ovale closure) using methods detailed in appendix e-1 on the *Neurology*® Web site at Neurology.org.[7]

Characterization of stroke management practices. We used several strategies to identify the specific practices used for individual patients during their index hospitalization including *ICD-9* procedure codes, HCUP utilization flags, diagnosis-related groups, and discharge location codes, as outlined in appendix e-1. The equivalent hospital-level practices were characterized using the mean proportion of individual stroke patients receiving the practice at that hospital.

Modeling rationale. Case-mix adjustment is described in appendix e-1. The decision to implement a specific practice in an individual patient is based on both patient characteristics and hospital-level practice patterns. For each practice of interest, we sought to separately estimate the association between 30-day readmission (yes vs no) and (1) receipt of the practice at an individual patient level, and (2) receipt of care at a hospital that relies more or less on the practice. We were primarily interested in the association between hospital-level

Table 1 Demographics, stroke mortality, and Medicare expenditures in included states

	New York	North Carolina	Washington	Arizona	Nebraska
2010 Census[7,36]					
Total population	19,378,102	9,535,483	6,724,540	6,392,017	1,826,341
% Black	15.9	21.5	3.6	4.0	4.5
% Hispanic	17.6	8.4	11.2	29.6	9.2
% Older than 65 y	13.5	12.9	12.3	13.8	13.5
CDC Stroke Atlas[37,38]					
Stroke mortality rate per 100,000 population	NR	155	134	NR	117
Stroke mortality in blacks per 100,000 population	NR	210	173	NR	176
Stroke mortality in whites per 100,000 population	NR	143	133	NR	116
Dartmouth Atlas[26]					
Total Medicare reimbursement per enrollee (2010)	$9,384	$8,924	$7,782	$9,101	$8,742
% Medicare deaths occurring in the hospital by race (2010)	36.0	28.5	23.2	18.4	24.7

Abbreviations: CDC = Centers for Disease Control and Prevention; NR = not reported.

practices and readmission rates. These associations may be interpreted in several ways. For example, they may measure (1) the effect of the practice of interest at the hospital level (e.g., individual patient-level variables may reflect unmeasured confounders such as stroke severity while the hospital-level variable more accurately captures the effect of the practice itself); (2) hospital-level effect modification (e.g., the average effect of a practice on readmission may differ among hospitals); or (3) the effect of other practices that vary at the hospital level associated with the practice of interest (e.g., unmeasured confounding at the hospital level).[8,14,19]

While the limited prior data do not suggest that stroke severity is a strong predictor of readmission,[9,20] our analysis was designed to mitigate the potential impact of factors that may predict readmission, such as stroke severity, prestroke disability, or poststroke functioning, that were not measured in this dataset. Specifically, we assume that these hospital-level variables will serve as better and more conservative measures of the effect of the practices on readmission than the individual-level variables—an assumption that has also been applied in similar analytic contexts.[10,21] This assumption is based on the idea that, in general, it is likely that within-hospital variation in practice variables will correlate more strongly with unmeasured patient-level variables such as severity than between-hospital variation. This is supported by the observation that there is less variation in unmeasured individual variables at the hospital level than at the individual level[4,7,22] and that patients who receive many practices (e.g., tPA, life-sustaining treatments [LSTs], intensive care unit care) are more likely to have more severe strokes than patients who do not.

Primary analysis. To measure the association between hospital-level practices and readmission, we used multilevel logistic regression and added both patient-level (as binary variables) and hospital-level practice indicators (as continuous variables representing the mean level of utilization) to a model including all case-mix adjustors and a random hospital-level intercept[9,23] (hospital practices model). For hospital-level practices that were significantly associated with readmission, we estimated the effect of those practices on readmission across quintiles of utilization for each practice, using average marginal effects.[11,24] All analyses were performed using Stata statistical software, release 12 (StataCorp LP, College Station, TX).

Estimating the effect of hospitals on readmission. The maximum effect of hospitals on readmission was estimated using a model based on the hospital practices model that included all case-mix adjustors but excluded patient and hospital-level practice variables (case-mix adjusted model). Using the case-mix adjusted model, we were able to estimate hospital-level readmission rates after accounting for patient-level factors. The aggregate effect of hospitals on readmission was estimated using 3 approaches: (1) the intraclass correlation coefficient—the proportion of variance explained at the hospital level compared with the total amount of variance explained by the model; (2) the median odds ratio—the increase, on median, of the likelihood of moving from a lower readmission hospital to a higher readmission hospital; and (3) conditional effects across quintiles of quality of care.[12,25] Model predictiveness was determined by calculating the C statistic.

Secondary analyses. To improve our statistical power to explore the relationship between the use of LSTs, which are rarely performed, and readmission, we repeated our primary model by replacing the separate individual and hospital-level LST covariates (e.g., gastrostomy, tracheostomy) with individual-level (sum of individual LSTs) and hospital-level LST indices (LST model). Finally, to determine whether hospital effects may reflect regional variation as opposed to hospital-level effects, per se, we repeated our primary models by adjusting for all hospital referral regions, as fixed effects.[26]

RESULTS The cohort included a total of 138,668 admissions for ischemic stroke from 568 different hospitals; 53.7% of the cohort was female and the mean age was 72 (SD 14) years. For 129,676 admissions at least 30 days of follow-up time was available, and these admissions were included in subsequent analyses. Unplanned readmission within 30 days occurred for 21,018 (15.2%) of admissions; 935 (4.4%) planned/procedural readmissions were excluded from our primary outcome measure. The median hospital readmission rate was 13.6% (interquartile range 9.8%–18.2%) (table 2). The most common principal diagnoses of readmission visits were related to ischemic stroke (33% of readmissions), infection (septicemia, aspiration pneumonia, pneumonia, urinary tract infection—collectively 14.5% of readmissions), or cardiac problems (dysrhythmia, congestive heart failure, chest pain, acute myocardial infarction—collectively 10.4% of readmissions).

Impact of individual-level practices on readmission rates. In the hospital practices model, we found that, of the individual-level practice variables significantly associated with readmission, most predicted an increased readmission rate (table e-1; intensive care unit utilization, discharge locations other than home, all individual LST variables, and all therapy variables). Only 2 individual-level variables were significantly associated with a decreased readmission rate—carotid endarterectomy (odds ratio [OR] 0.73; 95% confidence interval [CI] 0.62–0.87) and echocardiography (OR 0.94; 95% CI 0.90–0.98). This pattern is consistent with our assumption that individual-level practice variables, in general, more accurately capture the stroke severity–readmission association than the practice–readmission association.

Impact of hospital-level practices on readmission rates. Table 3 shows the variation in hospital-level practices and association between hospital-level practices and 30-day readmission using the hospital practices model. Hospitals characterized by higher use of occupational therapy (OT) and higher transfer-in rates had lower readmission rates, independent of whether a patient actually received OT or was transferred in. Estimated readmission rates in the lowest utilizing OT quintile (where 0.2% of patients received OT) were 16.2% (95% CI 14.5%–18.0%) vs 12.3% (95% CI 11.3%–13.2%) in the highest utilizing OT quintile (where 82.3% of patients received OT). Similarly, estimated readmission rates were 13.8% (95% CI 13.2%–14.5%) in hospitals

Table 2 Patient characteristics and variation in hospital-level practices between readmitted and non-readmitted patients

	No readmission (n = 117,650)	Readmission (n = 21,018)	Total (n = 138,668)
Age, y, mean (SD)	71.5 (14.3)	74.0 (13.4)	71.9 (14.2)
Female	62,749 (53.3)	11,666 (55.5)	74,415 (53.7)
Race/ethnicity			
White	59,432 (50.5)	11,092 (52.8)	70,524 (50.9)
African American	14,635 (12.4)	3,012 (14.3)	17,647 (12.7)
Hispanic	6,760 (5.7)	1,373 (6.5)	8,133 (5.9)
Other/missing	36,823 (31.3)	5,541 (26.4)	42,364 (30.6)
Insurance			
Medicare	76,576 (65.1)	15,546 (74.0)	92,122 (66.4)
Medicaid	9,486 (8.1)	1,622 (7.7)	11,108 (8.0)
Private	25,359 (21.6)	3,225 (15.3)	28,584 (20.6)
Other	6,229 (5.3)	625 (3.0)	6,854 (4.9)
Vascular risk factors			
Hypertension	87,301 (74.2)	15,517 (73.8)	102,818 (74.1)
Hyperlipidemia	42,219 (35.9)	6,361 (30.3)	48,580 (35.0)
Diabetes	36,195 (30.8)	7,120 (33.9)	43,315 (31.2)
Atrial fibrillation	22,652 (19.3)	5,211 (24.8)	27,863 (20.1)
Coronary artery disease	26,937 (22.9)	5,807 (27.6)	32,744 (23.6)
Charlson comorbidities			
Dementia	6,274 (5.3)	1,361 (6.5)	7,635 (5.5)
COPD	16,037 (13.6)	3,481 (16.6)	19,518 (14.1)
Rheumatologic conditions	2,406 (2.0)	537 (2.6)	2,943 (2.1)
Peptic ulcer	924 (0.8)	254 (1.2)	1,178 (0.8)
Mild liver	973 (0.8)	244 (1.2)	1,217 (0.9)
Moderate-severe liver	8,090 (6.9)	2,394 (11.4)	10,484 (7.6)
Renal	3,339 (2.8)	992 (4.7)	4,331 (3.1)
Cancer	112 (0.1)	49 (0.2)	161 (0.1)
Metastases	1,281 (1.1)	484 (2.3)	1,765 (1.3)
AIDS	77 (0.1)	8 (0.0)	85 (0.1)
LSTs			
LST index mean (SD)	5,986 (5.1)	2,285 (10.9)	8,271 (6.0)
Gastrostomy tube insertion	4,432 (3.8)	1,886 (9.0)	6,318 (4.6)
Tracheostomy	605 (0.5)	313 (1.5)	918 (0.7)
Hemodialysis	1,318 (1.1)	569 (2.7)	1,887 (1.4)
Intubation	2,159 (1.8)	780 (3.7)	2,939 (2.1)
CPR	59 (0.1)	12 (0.1)	71 (0.1)
Hemicraniectomy	147 (0.1)	53 (0.3)	200 (0.1)
Ventriculostomy	1 (0.0)	0 (0.0)	1 (0.0)
Procedures			
tPA	3,574 (3.0)	728 (3.5)	4,302 (3.1)
IA thrombolysis	854 (0.7)	185 (0.9)	1,039 (0.7)
Endarterectomy	1,474 (1.3)	168 (0.8)	1,642 (1.2)
Carotid stent	416 (0.4)	66 (0.3)	482 (0.3)
ICU	21,225 (18.0)	4,544 (21.6)	25,769 (18.6)

Continued

Table 2 Continued			
	No readmission (n = 117,650)	Readmission (n = 21,018)	Total (n = 138,668)
Intermediate ICU	13,820 (11.7)	2,419 (11.5)	16,239 (11.7)
ECG	101,029 (85.9)	18,363 (87.4)	119,392 (86.1)
Telemetry	11,946 (10.2)	2,234 (10.6)	14,180 (10.2)
Discharge location			
Hospice	2,825 (2.4)	487 (2.3)	3,312 (2.4)
LTAC	92 (0.1)	88 (0.4)	180 (0.1)
Skilled nursing facility	28,091 (23.9)	6,749 (32.1)	34,840 (25.1)
Acute rehabilitation	17,946 (15.3)	4,464 (21.2)	22,410 (16.2)

Abbreviations: COPD = chronic obstructive pulmonary disease; CPR = cardiopulmonary resuscitation; IA = intra-arterial; ICU = intensive care unit; LST = life-sustaining treatment; LTAC = long-term acute care facility; tPA = tissue plasminogen activator.
Data are n (%) unless otherwise indicated.

that receive no transfers in vs 12.5% (95% CI 11.6%–13.5%) in the quintile of hospitals that receive the most transfers in (19.1% of patients transferred in). Conversely, hospitals characterized by higher use of hospice had higher readmission rates—14.8% (95% CI 13.5%–16.1%) in the highest utilizing hospice quintile (where 7.7% of discharges went to hospice) vs 13.1% (95% CI 12.3%–14.0%) in the lowest utilizing hospice quintile (where no patients were discharged to hospice). For the other hospital-level practice patterns of care analyzed, no significant associations were identified.

Model performance and effect of hospitals on readmission. The case-mix adjusted model had a C statistic of 0.62, which increased slightly to 0.65 in the hospital practices model after patient- and hospital-level practices were added to the model. In both models, the proportion of variance at the hospital level was modest; intraclass correlation coefficient was 0.046 (95% CI 0.038–0.055) in the case-mix adjusted model and 0.039 (95% CI 0.032–0.047) in the hospital practices model. In the case-mix adjusted model, the median OR of the random hospital-level intercept was 1.46 (95% CI 1.41–1.52) meaning that the odds of readmission increase 1.46 times, on median, if a patient at a randomly selected hospital was instead admitted to a hospital with a higher readmission rate. Similarly, the readmission rate, after accounting for all measured differences among patients, is predicted to increase from 10.1% (quintile 1) to 12.6% (quintile 2) to 13.8% (quintile 3) to 15.3% (quintile 4) to 20.3% (quintile 5). The ability of these models to discriminate between the effects of individual hospitals on readmission is relatively limited, however, because the CIs for the hospital effects overlap substantially (figure).

Secondary analyses. In the LST model, hospitals characterized by higher LST utilization had higher readmission rates (OR 2.9; 95% CI 1.1–7.6). The estimated readmission rates increased across LST utilization quintiles from 12.5% (95% CI 11.5%–13.6%) in hospitals that used no LST to 14.5% (95% CI 13.5%–15.5%) in the highest utilizing LST quintile (0.15 LST/patient). All of the significant effects in the primary analysis remained significant after adjusting for region.

DISCUSSION In this large multistate sample, we found that a wide variety of hospital-level practices had no association with readmission rates after ischemic stroke admissions. We anticipated hospitals that were high utilizers of practices known to reduce poststroke disability (e.g., IV tPA) or reduce recurrent stroke (e.g., carotid endarterectomy) would have lower readmission rates either because of residual effects of these practices at the hospital level or because they are latent measures of overall quality of care.[13,14] Instead, despite substantial variation in readmission at the hospital level,[14,27] we found that only a small number of hospital practices were associated with readmission. For hospital-focused readmission interventions to succeed, a significant proportion of the variation in hospital-level readmission rates (a 10 percentage point difference between hospitals in the highest and lowest quintile) must be attributable to variation in the quality of hospital care as opposed to variation in unmeasured patient variables or in the access to or quality of postacute care. While our data do not definitively address this question, the lack of association between high-quality hospital practices and readmission raises some doubt about the extent to which hospital quality of care influences 30-day readmission.

Little is known about specific strategies that hospitals can implement to reduce readmission rates for stroke patients. Our hypothesis-generating finding that hospitals characterized by higher use of OT have

Table 3 Variation in hospital-level practices and association with readmission

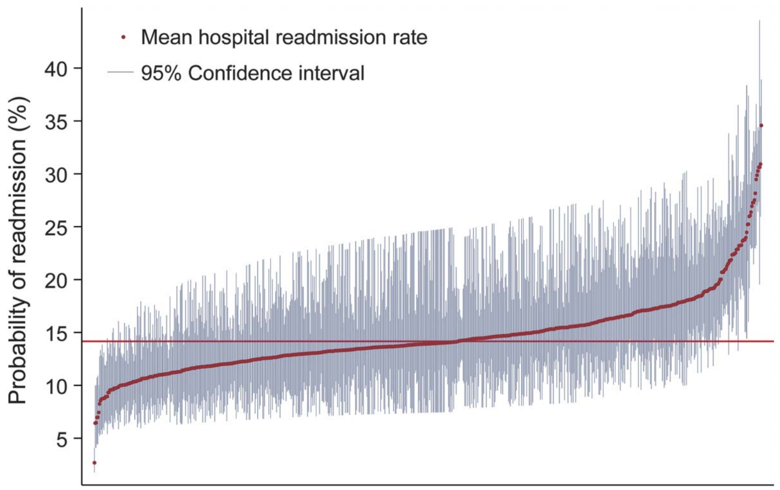
	Hospital-level variation, %					Association of hospital-level practice and readmission	
	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	OR (95% CI)	*p* Value
Transfer-in percentage	0.0	0.0	0.1	0.7	19.1	0.55 (0.37–0.81)	<0.01
Transfer-out percentage	0.1	1.1	2.4	4.3	10.9	1.01 (0.52–1.96)	0.98
ICU utilization	0.0	4.7	9.7	16.9	47.2	0.95 (0.74–1.21)	0.66
Tissue plasminogen activator	0.0	0.0	0.5	1.5	3.9	0.45 (0.17–1.15)	0.09
Diagnostic testing							
MRI	0.4	17.3	42.7	64.9	81.8	1.07 (0.88–1.31)	0.49
Echocardiogram	0.0	2.0	13.2	39.6	77.0	0.98 (0.81–1.18)	0.81
ECG	27.4	74.3	89.2	94.4	98.5	0.97 (0.74–1.26)	0.80
Telemetry	0.0	0.0	0.0	9.2	57.1	1.11 (0.90–1.37)	0.22
Interventional procedures							
Carotid endarterectomy	0.0	0.0	0.2	0.8	2.9	0.72 (0.02–23.8)	0.86
Carotid artery stenting	0.0	0.0	0.0	0.0	1.0	0.00 (0.00–4.2)	0.09
Life-sustaining technology							
Gastrostomy	0.0	1.1	2.6	4.3	8.7	1.14 (0.18–7.23)	0.89
Intubation	0.0	0.0	0.7	1.5	3.6	8.5 (0.07–1,036)	0.38
Dialysis	0.0	0.0	0.5	1.2	3.6	8.3 (0.41–167)	0.38
Discharge practices							
Skilled nursing facility	9.3	20.7	29.0	38.4	58.3	0.78 (0.50–1.24)	0.30
Acute rehabilitation	0.0	2.2	7.6	15.8	29.8	0.79 (0.48–1.34)	0.36
Hospice	0.0	0.0	0.8	2.3	7.7	5.86 (1.13–30.3)	0.04
Therapy							
Physical therapy	47.9	72.1	78.8	84.1	92.6	0.83 (0.55–1.22)	0.35
Occupational therapy	0.2	19.0	45.0	63.7	82.3	0.59 (0.46–0.77)	<0.01
Speech therapy	2.2	27.6	46.1	56.8	74.8	0.84 (0.63–1.12)	0.23

Abbreviations: CI = confidence interval; ICU = intensive care unit; OR = odds ratio.
Hospital-level variation is represented as the mean utilization rate for each hospital-level quintile of utilization. The association between practices and readmission is represented with OR—the change in the odds of readmission for a change in hospital utilization (e.g., OR 0.66 means that the readmission odds decline by 0.66 if a hospital went from never utilizing a practice to utilizing it in all patients). All practices in the model where the practice was utilized in >0.5% of patients in the highest utilizing hospital quintile are included in the table. ORs <1.0 signify that a practice is associated with decreased readmission rates and coefficients >1.0 signify that a practice is associated with increased readmission rates. Only 2 practices were associated with decreased readmissions: receiving transfers and using occupational therapy. Only one practice was associated with increased readmissions: discharge to hospice.

lower readmission rates suggests one area for future research on strategies to reduce readmission rates. There are many possible explanations for this association. First, to the extent that individual-level variation in OT utilization is driven by unmeasured patient-level factors such as stroke severity and this effect is captured by the individual-level practice variables, it may be that higher use of OT itself is causally related to lower readmission rates. Alternatively, this may reflect confounding by other hospital-level practices—hospitals that use more OT may also use other processes that cause lower readmission rates, such as earlier, more intensive, or more standardized therapy in the inpatient setting. This interpretation is supported by the observation that more intensive therapy is associated with better outcomes in the postacute setting.[15,28–30] Further study is needed to clarify whether a causal pathway exists between OT and readmission rates and, if so, to define this pathway.

While publicly reporting hospital-level outcome measures is intended to incentivize hospitals to improve their quality of care, there is also potential for unintended consequences. For example, our data suggest that hospitals that use more hospice care have higher readmission rates. Thus, hospitals that discharge a large proportion of patients to hospice may score worse than otherwise expected on the CMS readmission measure. Similarly, hospitals characterized by higher LST use also have higher readmission rates; thus, hospitals more reliant on LSTs may also score

Figure **Hospital-level readmission rates**



Readmission rates of all hospitals in the sample after adjusting for patient-level characteristics. The red dot represents the mean estimated readmission rate for a hospital and the vertical line represents the 95% confidence interval. The horizontal red line represents the mean readmission rate.

worse than expected. These effects may result in undesirable incentives in light of generally high levels of satisfaction that patients express with hospice care and the uncertain effects of higher LST use on patient satisfaction.[16,31]

Finally, consistent with prior work,[17,32] we found that after adjusting for patient-level demographics, vascular risk factors, and comorbidities, variability in hospital-level readmission rates is substantial—more than 10 percentage points separate hospitals in the highest and lower quintiles. Given that many important potential predictors of readmission, such as stroke severity, were not measured in this dataset and these predictors vary between hospitals,[18,22] the actual difference between hospitals is likely smaller. If these differences between hospitals were entirely mediated through quality of care, this difference would describe the ceiling effect of hospital-focused quality improved initiatives. It is likely, however, that many non-quality-related hospital practices would reduce this effect—accounting for all practices in the current study, for example, reduced the total amount of variance explained at the hospital level by 15%. It is also possible that this difference is explained by hospital practices not available in this dataset. For example, postdischarge care coordination, which was not available, is associated with decreased readmission rates.[33] Similarly, it is tempting to infer that organized stroke unit care[34] or early supported discharge[35] may reduce readmissions, given their favorable effects on disability. However, to our knowledge, these topics have not been directly studied. Further studies that prospectively measure stroke severity, quality of care, and readmission rates may be able to confirm or refute the hypothesis-generating findings of this study and offer a more refined estimate of the impact of hospital quality of care on readmission rates and insight into other factors that may mediate the hospital-readmission association.

The primary limitation of this study is that some potential predictors of stroke readmission (e.g., stroke severity, baseline disability, access to and quality of postdischarge care) are not available in claims data, contributing to limited model predictiveness and possibly introducing bias into the measured associations between hospital-level practices and readmission. Our approach of adjusting for hospital-level practices at the individual level and reporting the association between mean hospital-level practices and readmission should partially mitigate the risk of confounding by severity. Furthermore, while all 3 of the significant hospital practice effects are likely associated with higher severity, 2 of the hospital practices (OT and transfer-in status) were associated with lower readmission rates, suggesting that associations are unlikely attributable to severity alone. In addition, while it is possible that the 30-day time frame studied is too short to detect the effect of many quality practices on readmission, this is the time frame specified by the CMS measure. Similarly, while it is possible that the hospital effects measured here may reflect broader geographic variation in patient severity or regional availability of services as opposed to hospital effects, per se, the proposed CMS measure will similarly fail to account for these possibilities. Claims-based measures are intrinsically limited. Comorbidity measures are somewhat insensitive and specific practices are coarsely measured, potentially failing to account for effectiveness-modifying context. For example, we are unable to differentiate timeliness of tPA administration. Finally, the failure to find associations between specific hospital-level practices and readmission may be a consequence of limited statistical power to find small hospital-level effects.

Hospital practices have a role in stroke readmission that is complex and poorly understood. Further work is needed to identify specific strategies to reduce readmission rates and to ensure that public reporting of readmission rates will not result in adverse unintended consequences.

AUTHOR CONTRIBUTIONS

Dr. Burke drafted the initial manuscript, developed the study concept, developed the study design, performed the primary data analysis, and acquired the data. Dr. Skolarus, Dr. Adelman, and Dr. Reeves revised the manuscript for content, participated in development of the study design, and participated in data interpretation. Dr. Brown revised the manuscript for content, initially developed the study concept, participated in formulation of the study design, and participated in data interpretation.

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