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Original Article

Effects of delay to stroke unit admission in patients with ischemic and hemorrhagic stroke

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ABSTRACT: ***Objective*****:** To determine the association between delay in transfer to a central stroke unit from peripheral institutions and outcomes. ***Methods*****:** We conducted a retrospective cohort study of all patients with acute stroke, admitted to a comprehensive stroke center (CSC) from three emergency departments (EDs), between 2016 and 2018. The primary outcomes were length of stay, functional status at 3 months, discharge destination, and time to stroke investigations. ***Results*****:** One thousand four hundred thirty-five patients were included, with a mean age of 72.9 years, and 92.4% ischemic stroke; 663 (46.2%) patients were female. Each additional day of delay was associated with 2.0 days of increase in length of stay (95% confidence interval [CI] 0.8–3.2, $p = 0.001$), 11.5 h of delay to vascular imaging (95% CI 9.6–13.4, $p < 0.0001$), 24.2 h of delay to Holter monitoring (95% CI 7.9–40.6, $p = 0.004$), and reduced odds of nondisabled functional status at 3 months (odds ratio 0.98, 95% CI 0.96–1.00, $p = 0.01$). Factors affecting delay included stroke onset within 6 h of ED arrival (605.9 min decrease in delay, 95% CI 407.9–803.9, $p < 0.0001$), delay to brain imaging (59.4 min increase in delay for each additional hour, 95% CI 48.0–71.4, $p < 0.0001$), admission from an alternative service (3918.7 min increase in delay, 95% CI 3621.2–4079.9, $p < 0.0001$), and transfer from a primary stroke center (PSC; 740.2 min increase in delay, 95% CI 456.2–1019.9, $p < 0.0001$). ***Conclusion*****:** Delay to stroke unit admission in a system involving transfer from PSCs to a CSC was associated with longer hospital stay and poorer functional outcomes.

RÉSUMÉ : Effets des délais d'admission au sein d'une unité de soins des AVC chez des patients victimes d'un AVC ischémique ou hémorragique. ***Objectif*** **:** Déterminer l'association entre les délais de transfert de patients vers une unité de soins des AVC depuis des établissements de santé périphériques ; déterminer également l'évolution de leur état de santé. ***Méthodes*** **:** Pour ce faire, nous avons effectué une étude de cohorte rétrospective de tous les patients victimes d'un AVC aigu et admis dans un centre de soins complets des AVC à partir de trois services d'urgence, et ce, entre 2016 et 2018. Les principaux aspects évalués ont été la durée de leur séjour, leur autonomie fonctionnelle au bout de trois mois, leur lieu de destination après l'obtention d'un congé et le temps écoulé avant qu'on n'investigue les causes de leur AVC. ***Résultats*** **:** Au total, ce sont 1435 patients qui ont été inclus dans cette étude. Leur âge moyen était de 72,9 ans et 92,4 % d'entre eux avaient été victimes d'un AVC ischémique. Ajoutons aussi que 663 patients (46,2 %) étaient de sexe féminin. Dans l'ensemble, chaque jour supplémentaire de délai a été associé à une augmentation de 2,0 jours en ce qui concerne la durée des séjours (IC 95 % 0,8-3,2 ; $p = 0{,}001$), à un délai moyen d'accès de 11,5 heures à des examens d'IRM vasculaire (IC 95 % 9,6-13,4 ; $p < 0{,}0001$), à un délai moyen d'accès à une surveillance par la méthode Holter de 24,2 heures (IC 95 % 7,9-40,6 ; $p = 0{,}004$) ainsi qu'à une probabilité réduite de jouir d'une autonomie fonctionnelle au bout de trois mois (RC = 0,98 ; IC 95 % 0,96-1,00 ; $p = 0{,}01$). Les facteurs qui ont affecté ces délais ont inclus les débuts d'un AVC dans les six heures suivant l'arrivée à un service d'urgence (une diminution de 605,9 minutes dans les délais ; IC 95 % 407,9-803,9 ; $p < 0{,}0001$), des délais d'accès à des examens d'IRM du cerveau (des délais accrus de 59,4 minutes pour chaque heure additionnelle ; IC 95 % 48,0-71,4 ; $p < 0{,}0001$), une admission à partir d'un service d'urgence alternatif (des délais accrus de 3918,7 minutes ; IC 95 % 3621,2-4079,9 ; $p < 0{,}0001$) et finalement un transfert à partir d'un centre de soins primaires des AVC (des délais accrus de 740,2 minutes ; IC 95 % 456,2-1019,9 ; $p < 0{,}0001$). ***Conclusion*** **:** Les délais d'admission au sein d'une unité de soins des AVC dans un système impliquant un transfert à partir de centres de soins primaires des AVC ont été associés à un séjour hospitalier plus long et à de moins bons résultats sur le plan de l'autonomie fonctionnelle.

Keywords: Health Care Outcome Assessment; Hemorrhagic stroke; Ischemic stroke; Quality improvement; Systems of care; Time-to-treatment

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Introduction

A stroke unit is a form of organized inpatient care, where acute stroke patients are managed by a specialized interdisciplinary team of physicians, nurses, and allied healthcare professionals with expertise in stroke in a geographically defined location.[1] Stroke unit care is associated with lower mortality, better functional status, and increased probability of living at home 1 year following stroke.[2] Location of regional stroke activity in a central unit has the benefit of concentrating expertise and services but may introduce delay between first contact with the emergency department (ED) and stroke unit admission particularly if there are multiple pathways for admission.[3] Although early stroke unit admission may be associated with lower mortality,[4] it is yet unclear whether longer delay affects patients' functional outcomes and hospital resources.[1] The objective of this study was to determine whether shorter time to transfer of acute ischemic and hemorrhagic stroke patients from the ED to the stroke unit was associated with better patient and system-level outcomes.

Methods

This was a single-center retrospective cohort study. The stroke unit in this study is located at a comprehensive stroke center (CSC) affiliated to a comprehensive stroke network, located in Hamilton, Ontario, Canada. It is comprised of a ward-level care unit and a stepdown-level care unit. Only the CSC offers acute reperfusion therapies including thrombolysis and endovascular therapy (EVT). Hyperacute stroke patients are either sent directly to the CSC or urgently transferred to the latter from the ED of one of two primary stroke centers (PSC) involved in this study. Following hyperacute stroke care (neuroimaging with or without reperfusion therapy) in the ED, they are admitted to the stroke unit with the highest priority. Acute stroke patients who present themselves to an ED at the CSC outside of hyperacute treatment window (more than 6 h from stroke onset) are also directly admitted to the stroke unit. If no bed is available on the stroke unit, stroke patients are temporarily admitted to an alternative inpatient unit under internal medicine. Out-of-window stroke patients who present themselves to an ED at a PSC are either transferred directly to the stroke unit or temporarily admitted under internal medicine at the PSC. Patients eligible to be admitted to the stroke unit include all patients with acute ischemic and hemorrhagic stroke, as well as selected cases of transient ischemic attacks, regardless of age, comorbidities, or eligibility for rehabilitation. Patients are not admitted to the stroke unit if they require intensive care unit, if they are diagnosed with aneurysmal subarachnoid hemorrhage, or if their initial goals of care are not compatible with active treatment (e.g., palliative goals of care).

Approval from our local research ethics board (Hamilton Integrated Research Ethics Boards) was obtained prior to initiating this study, and the board waived the need for patient consent. We were fully compliant with the Declaration of Helsinki.

Study Population

Subjects in this study included all consecutive patients with confirmed acute ischemic or hemorrhagic stroke diagnosed at the three hospital sites, who were subsequently transferred to the stroke unit, and whose date of stroke unit admission occurred between January 1, 2016 and December 31, 2018. Subjects were excluded if they were admitted to the intensive care unit prior to the stroke unit, if their primary reason for admission was not acute stroke (e.g., stroke occurring during hospital stay), or if they were diagnosed with aneurysmal subarachnoid hemorrhage, transient ischemic attack, or stroke mimic.

Data Collection

The following data were collected for all subjects: demographics, stroke onset, initial stroke severity as measured by the National Institute of Health Stroke Scale (NIHSS), ED arrival time (weekday daytime [8 AM–5 PM] vs weekend or nighttime, ED length of stay), initial brain imaging time, acute stroke treatment (administration of tissue plasminogen activator [tPA], onset-to-needle time, door-to-needle time, and EVT), and delay between ED arrival and arrival to the stroke unit.

The primary outcomes were delays (intervals) between ED arrival and stroke investigations (vascular imaging, echocardiography, and Holter monitoring), discharge location from the stroke unit, total length of stay in hospital (from ED arrival to discharge from stroke unit), modified Rankin scale (mRS) at 3 months poststroke,[5] death at 3 months poststroke, and nondisabled functional status at 3 months poststroke defined by mRS of 0–2. The mRS was assessed by the stroke neurologist either via in-person visit or via telephone if in-person visit was not possible.

Statistical Methods

Multivariable logistic regression analysis was used to determine whether delay to stroke unit admission was associated with each of the primary outcomes, adjusted for the following variables: age, sex, comorbidities (coronary artery disease, hypertension, diabetes mellitus, dyslipidemia, atrial fibrillation or atrial flutter, and chronic kidney disease), stroke type, initial NIHSS, administration of tPA, and/or EVT. Of note, death at 3 months poststroke was considered as an outcome only in a sensitivity analysis. Subgroup analysis was stratified according to age (<65 years, 65–75 years and >75 years), sex, stroke type (ischemic, hemorrhagic), and NIHSS (mild 0–5, moderate 6–11, severe 12, and above). Subgroup analysis stratified according to the source of patient admission (admitted directly from CSC, transferred from PSCs) was also performed as a sensitivity analysis.

Multivariable analysis evaluating the correlation between potential determinants of delay (age, sex, comorbidities, stroke type, initial NIHSS, hospital of origin, admission from an alternative service, ED arrival during weekday daytime, stroke onset within 6 h of ED arrival, delay to brain imaging, administration of tPA, and EVT) and delay to stroke unit admission was also performed. Of note, stroke onset within 6 h of ED arrival and delay to brain imaging were included as covariates in the sensitivity analysis.

All comparisons were carried out using a two-sided test at a significance level of 0.05. Missing values were accounted for using simple imputation by mean for continuous characteristics and imputation by mode for categorical variables.

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Results

This study included 1435 patients, 663 (46.2%) female, with a mean (SD) age of 72.9 (13.5) years. Ischemic stroke patients comprised of 92.4% of the cohort (N = 1326), while the remaining 109 (7.6%) patients had hemorrhagic stroke. The median initial NIHSS was 5 (interquartile range [IQR] 2–10). tPA was administered in 299 patients (20.8%), EVT was performed on 93 patients (6.5%), and 62 patients (4.3%) received both tPA and EVT. The median delay to stroke unit admission was 7.7 h (IQR 3.8–15.1), and the range of delay was between 4 and 31,745 min (22.0 days). Two hundred and eight (14.5%) patients were admitted to the stroke unit with delays of at least 1 day. See Tables 1 and 2. Most patients were admitted directly from ED at the CSC to the stroke unit (N = 1208, 84.2%). Patients' locations of origin are illustrated in Figure 1.

The median delays to stroke investigations were vascular imaging, 11.8 h (IQR 0.2–41.8), transthoracic echocardiogram, 65.5 h (IQR 43.4–98.9), and Holter monitoring, 95.0 h (IQR 60.5–168.2). The median length of hospitalization was 10.0 days (IQR 4.0–26.9), and 545 (38.0%) patients were discharged home directly from the stroke unit. The median mRS at 3 months poststroke was 2 (IQR 1–4), 175 (12.2%) patients were deceased at 3 months, and 801 (55.8%) patients were nondisabled at 3 months with mRS 0–2. Full details related to patient and system outcomes are presented in Table 3.

After adjusting for covariates, the effects of delay to stroke unit admission on primary outcomes are in Table 4. For each additional day of delay, we noted 2.0 days of increase in total length of stay in hospital (95% confidence interval [CI] 0.8–3.2, $p = 0.001$), 11.5 h of additional delay to initial vascular imaging (95% CI 9.6–13.4, $p < 0.0001$), 24.2 h of additional delay to initial Holter monitoring (95% CI 7.9–40.6, $p = 0.004$), and 1.02 time greater odds of discharge to home from the stroke unit (95% CI 1.01–1.04, $p = 0.01$). Each additional day of delay in stroke unit admission was also associated with a reduction in the odds of non-disabled functional status at 3 months (odds ratio 0.98, 95% CI 0.96–1.00, $p = 0.01$).

The most significant factor affecting delay was stroke onset within 6 h of ED arrival (605.9 min decrease in delay, 95% CI 407.9–803.9, $p < 0.0001$), delay to brain imaging (59.4 min increase in delay for each additional hour, 95% CI 48.0–71.4, $p < 0.0001$), admission from an alternative service (3918.7 min increase in delay, 95% CI 3621.2–4079.9, $p < 0.0001$), transfer from a PSC (740.2 min increase in delay, 95% CI 456.2–1019.9, $p < 0.0001$), and older age (6.2 min increase in delay for each additional year, 95% CI 0.1–12.4, $p = 0.046$). See Table 5.

Discussion

We found that delay to stroke unit admission was associated with longer hospital stay and longer delays to stroke investigations. It was also associated with poorer functional outcomes in stroke patients, especially among those aged 75 years and above (see Table 6). Arrival to ED within 6 h of stroke onset and shorter delays to brain imaging predicted shorter delays to stroke unit admission, while transfer from a PSC or from an alternative service, as well as older patient age, predicted longer delays.

Compared to the Ontario Stroke Registry,[6] our cohort showed similar age, gender distribution, and stroke severity. However, our study population reported higher proportion of ischemic stroke (92.4% vs 86.0%), higher prevalence of cardiovascular risk factors including hypertension (76.4% vs 67.0%), diabetes (33.6% vs

Table 1: Baseline characteristics (N = 1435 unless otherwise specified)

Characteristics	Study population	Admission from CSC (N = 1274)	Transferred from PSC (N = 161)
Age in years – mean (SD)	72.9 (13.5)	72.8 (13.2)	73.7 (14.1)
Female sex – n (%)	663 (46.2)	584 (45.8)	79 (49.1)
Comorbidities			
Coronary artery disease – n (%)	354 (24.7)	312 (24.5)	42 (26.1)
Hypertension – n (%)	1096 (76.4)	963 (75.6)	133 (82.6)
Diabetes mellitus – n (%)	482 (33.6)	431 (33.8)	51 (31.7)
Dyslipidemia – n (%)	880 (61.3)	772 (60.6)	108 (67.1)
Atrial fibrillation or atrial flutter – n (%)	328 (22.9)	289 (22.7)	39 (24.2)
Chronic kidney disease – n (%)	126 (8.8)	115 (9.0)	11 (6.8)
Stroke type			
Ischemic – n (%)	1326 (92.4)	1178 (92.5)	148 (91.9)
Hemorrhagic – n (%)	109 (7.6)	96 (7.5)	13 (8.1)
Initial NIHSS – median (IQR)*	5 (2, 10)	7 (3, 12)	5 (3, 9)

CSC = comprehensive stroke center; NIHSS = National Institute of Health Stroke Scale; PSC = primary stroke center; SD = standard deviation.
*Missing data: initial NIHSS = 7.

Table 2: Treatment characteristics and delays (N = 1435 unless otherwise specified)

Characteristics	Study population
Administration of tissue plasminogen activator – n (%)	299 (20.8)
Endovascular therapy – n (%)	93 (6.5)
Emergency department arrival during weekday daytime (8 AM–5 PM), – n (%)*	616 (42.9)
Stroke onset within 6 h of emergency department arrival – n (%)	741 (51.6)
Delay between emergency department arrival and initial brain imaging in minutes – median (IQR)*	42 (12, 174)
Onset-to-needle time in minutes – median (IQR)*†	113 (84.5, 160.0)
Door-to-needle time in minutes – median (IQR)*†	37 (31.0, 45.0)
Emergency department length of stay in hours – median (IQR)*	7.0 (3.8, 13.0)
Delay between emergency department arrival and arrival to an alternative service in hours – median (IQR)‡	17.0 (9.1, 26.9)
Delay between arrival to and departure from an alternative service in hours – median (IQR)*‡	44.6 (20.9, 79.4)
Delay to stroke unit admission in hours – median (IQR)*	7.7 (3.8, 15.1)

IQR = interquartile range.
*Missing data: emergency department arrival during weekday daytime = 4, delay between emergency department arrival and initial brain imaging = 3, onset-to-needle time = 2, door-to-needle time = 2, emergency department length of stay = 2, delay between arrival to and departure from an alternative service = 7, delay between emergency department arrival and arrival to the stroke unit = 12.
†N = 299.
‡N = 161.

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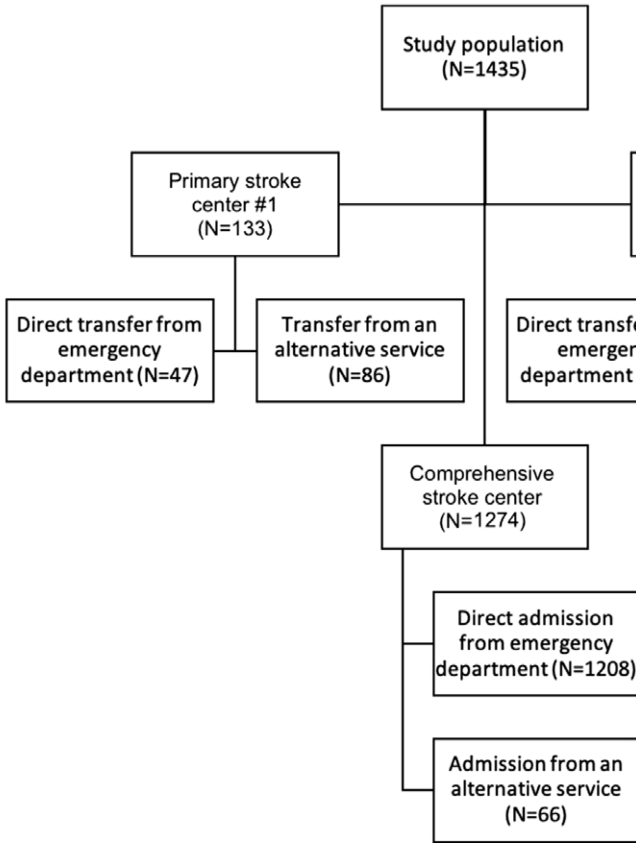

Figure 1: Patient journey prior to stroke unit admission.

Table 3: Primary study outcomes (N = 1435 unless otherwise specified)

Outcomes	Study population
Delay between emergency department arrival and initial stroke investigations in hours	
Vascular imaging – median (IQR)*†	11.8 (0.2, 41.8)
Transthoracic echocardiogram – median (IQR)*‡	65.5 (43.4, 98.9)
Holter monitoring – median (IQR)*§	95.0 (60.5, 168.2)
Total length of stay in hospital in days – median (IQR)*	10.0 (4.0, 26.9)
Discharge location from the stroke unit*	
Home – n (%)	545 (38.0)
In-patient rehabilitation – n (%)	650 (45.1)
Long-term care facility – n (%)	99 (6.9)
Death – n (%)	141 (9.8)
mRS at 3 months poststroke – median (IQR)*	2 (1, 4)
Death at 3 months poststroke – n (%)	175 (12.2)
Nondisabled functional status at 3 months poststroke (mRS of 0–2) – n (%)*	801 (55.8)

IQR = interquartile range; mRS = modified Rankin Scale.
*Missing data: vascular imaging = 3, transthoracic echocardiogram = 3, Holter monitoring = 3, total length of stay in hospital = 62, discharge location from the stroke unit = 60, mRS at 3 months poststroke = 2, nondisabled functional status at 3 months poststroke = 2.
†N = 1231.
‡N = 1153.
§N = 829.

Table 4: Effect of 1 day of additional delay to stroke unit admission on primary outcomes (N = 1435)

Effect on primary outcomes	Odds ratio or effect size	95% confidence interval	*p*-Value
Functional outcomes			
Death at 3 months poststroke	0.99	0.98, 1.00	0.18
Nondisabled functional status at 3 months poststroke (mRS 0–2)	0.98	0.96, 1.00	0.01
mRS at 3 months poststroke	0.02	−0.04, 0.08	0.47
Discharge to home from the stroke unit	1.02	1.01, 1.04	0.01
System outcomes			
Delay to initial vascular imaging in hours	11.5	9.6, 13.4	<0.0001
Delay to initial transthoracic echocardiogram in hours	5.3	−3.4, 13.9	0.23
Delay to initial Holter monitoring in hours	24.2	7.9, 40.6	0.004
Total length of stay in hospital in days	2.0	0.8, 3.2	0.001

mRS = modified Rankin Scale.

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Table 5: Effect of potential predictors on delay to stroke unit admission (N = 1435)

Predictors	Planned analysis			Sensitivity analysis†		
	Effect on delay to stroke unit admission in minutes*	95% confidence interval	*p*-Value	Effect on delay to stroke unit admission in minutes*	95% confidence interval	*p*-Value
One additional year in age	6.3	0.1, 12.6	0.048	6.2	0.1, 12.4	0.046
Female sex	0.3	−156.5, 157.0	1.00	0.2	−157.3, 158.6	0.98
Coronary artery disease	−93.6	−279.0, 91.8	0.32	−92.1	−278.0, 92.0	0.31
Hypertension	40.9	−151.1, 233.0	0.68	41.2	−149.2, 231.7	0.66
Diabetes mellitus	101.6	−65.3, 268.5	0.23	100.1	−64.8, 259.4	0.24
Dyslipidemia	−56.5	−220.5, 107.4	0.50	−57.4	−214.2, 106.2	0.48
Atrial fibrillation or atrial flutter	156.0	−31.1, 343.2	0.10	152.3	−39.0, 359.6	0.12
Chronic kidney disease	−242.7	−513.4, 28.1	0.08	−239.0	−502.9, 29.5	0.09
Hemorrhagic stroke instead of ischemic stroke	−131.0	−421.0, 159.1	0.38	−139.0	−408.2, 167.3	0.29
One unit increase on the initial NIHSS	−9.2	−21.8, 3.4	0.15	−9.1	−20.7, 3.9	0.19
Transfer from a primary stroke center	735.7	448.4, 1023.0	<0.0001	740.2	456.2, 1019.9	<0.0001
Admission from an alternative service	3803.1	3511.0, 4095.2	<0.0001	3918.7	3621.2, 4079.9	<0.0001
Emergency department arrival during weekday daytime (8 AM–5 PM)	77.5	−74.0, 229.1	0.32	78.6	−73.2, 233.4	0.34
Stroke onset within 6 h of emergency department arrival	N/A	N/A	N/A	−605.9	−803.9, −407.9	<0.0001
One hour of additional delay to brain imaging	N/A	N/A	N/A	59.4	48.0, 71.4	<0.0001
Administration of tissue plasminogen activator	−151.5	−352.5, 49.5	0.14	−150.7	−350.3, 48.7	0.16
Endovascular therapy	−219.3	−550.2, 111.5	0.19	−229.4	−578.5, 120.7	0.29

N/A = not applicable; NIHSS = National Institute of Health Stroke Scale.
*Positive value indicates increased delay. Negative value indicates decreased delay.
†In sensitivity analysis, two additional predictors were added: (1) stroke onset within 6 h of emergency department arrival and (2) 1 h of additional delay to brain imaging.

Table 6: Subgroup analysis of the effect of 1 day of additional delay to stroke unit admission on nondisabled functional status at 3 months poststroke (modified Rankin Scale of 0–2)

Subgroup	N	Odds ratio (95% confidence interval)	*p*-Value
Age, years			
<65	395	1.01 (0.97, 1.05)	0.66
65–75	376	0.98 (0.94, 1.02)	0.41
>75	664	0.97 (0.95, 0.99)	0.01
Sex			
Female	663	0.98 (0.96, 1.00)	0.09
Male	772	0.98 (0.95, 1.00)	0.06
Stroke type			
Ischemic	1326	0.98 (0.96, 0.99)	0.009
Hemorrhagic	109	1.006 (0.94, 1.06)	0.86
Initial National Institute of Health Stroke Scale			
Mild (0–5)	790	0.99 (0.97, 1.01)	0.42
Moderate (6–11)	336	0.97 (0.95, 1.00)	0.07
Severe (12 and above)	309	0.97 (0.92, 1.02)	0.23
Source of patient admission			
Admitted directly from the comprehensive stroke center	1274	0.99 (0.96, 1.01)	0.30
Transferred from a primary stroke center	161	0.98 (0.96, 1.01)	0.23

24.4%), dyslipidemia (61.3% vs 36.7%), atrial fibrillation (22.9% vs 15.8%), and renal disease (8.8% vs 7.9%), as well as higher rate of thrombolysis among ischemic stroke patients (22.5% vs 14.7%).

Longer delays to stroke unit admission were associated with increased length of hospital stay and longer delays to stroke investigations, especially vascular imaging and Holter monitoring. There were two additional days of hospitalization for every one additional day of delay to stroke unit admission. Shorter length of stay may reduce stroke-related healthcare costs, considering that a hospitalized stroke patient cost $4700 USD per day in the United States in 2007.[7–9] Although shorter delays to stroke unit admission may be associated with shorter hospitalization, it is worth noting that efforts specifically targeted at reducing delays to investigations may also lead to shorter length of stay.[10]

Longer delays to stroke unit admission were associated with lower likelihood of nondisabled functional outcome as defined by mRS 0–2, and older patients aged 75 years and over may have worse outcomes with longer delays in the subgroup analysis. Although stroke units have been found to reduce dependency or death (mRS 3–6) in a meta-analysis and earlier admission may be associated with lower mortality, it was unclear whether stroke unit admissions were time-sensitive in regard to functional outcome,[4,11] a knowledge gap which we aimed to fill. Shorter delays to stroke unit admission were, however, not associated with a leftward shift in the mRS distribution or lower mortality. Reducing delays to stroke unit admission may not result in benefits as clinically significant as reducing delays to tPA administration or EVT, given that most clinically meaningful therapeutic strategies occur in the hyperacute stage.[12] Interestingly, longer delays to stroke unit admission were associated with increased likelihood of discharge to home. This would contradict previous studies,[2] and likely represented reverse causation, as patients who were more likely to be discharged home may have received less priority to stroke unit admission as the initial event was mild.

Arrival to ED within 6 h of stroke onset and shorter delays to brain imaging predicted shorter delays to stroke unit admission. Given the high risk of clinical deterioration and recurrent stroke in the hyperacute stage, in addition to possible complications following reperfusion therapies, patients assessed in the context of a “code stroke” often receive priority admission when bed resources are limited on the stroke unit, compared to patients who present to ED in the subacute stage.[13] Furthermore, given that radiological evidence of an acute stroke is often required for stroke unit admission and that earlier brain imaging may be a marker for higher stroke acuity, shorter delays to brain imaging may also lead to faster stroke unit admission. Transfer of patients from PSCs and alternative service predicted longer delays to stroke unit admission. However, ED arrival on weekends and during nighttime did not predict delay to stroke unit admission in this study, in contrast to previous studies showing longer delays to admission during these times.[14,15] This may reflect specific aspects of local practices not necessarily generalizable to other institutions. Lastly, older patient age predicted longer delays to stroke unit admission, in keeping with previous literature reporting longer delays in accessing stroke care among older patients.[16] This is relevant especially given that older patients may be at increased risk of delirium related to prolonged ED stay and that these patients may benefit more from faster stroke unit admission according to our subgroup analysis.[17] Time spent on consultation with other services regarding most appropriate admission service may also lead to longer delays to stroke unit admission.

This study had several limitations. This was a single-center observational study, which reported a patient population that may differ from the regional stroke patient profile. When compared to the Ontario Stroke Registry,[6] patients in our study showed a higher proportion of ischemic stroke, a more severe cardiovascular risk profile, and were more likely to receive thrombolysis. In addition, the finding of poorer functional outcomes with longer delays should be interpreted with caution as the upper limit of the 95% CI overlapped with the null hypothesis despite $p < 0.05$. Moreover, patients transferred from PSCs were associated with longer delays to stroke unit admission, in contrast to patients admitted directly to the CSC. These two groups of patients may have different stroke characteristics. However, if patients transferred from PSCs were excluded, the effects of delays on functional outcomes would become statistically insignificant due to the narrower range of delays among patients admitted directly from the CSC. Our results may not be generalizable to systems where the workflow does not include admission to PSCs prior to transfer to a regional stroke unit. Furthermore, this study excluded any patients who required intensive care prior to stroke unit admission, among which patients with hemorrhagic stroke were likely more prevalent than those with ischemic stroke.[18] Lastly, 10 other hospital sites not mentioned in this study transferred patients to the CSC only for the purpose of EVT. These patients were excluded as they returned to their hospitals of origin shortly after EVT. Results from this study may not be generalizable to other comprehensive stroke networks and need to be replicated. Further studies using multicentered data registries are needed to clarify whether shorter delays to stroke unit admission may lead to better outcomes. While we have accounted for relevant factors in the analysis, reverse causation cannot be completely eliminated in observational data.

This study showed better functional outcomes among patients with a shorter delay to stroke unit admission. Moreover, shorter delays were associated with better system-level outcomes including shorter length of stay and shorter delays to stroke investigations, which may reduce healthcare costs. If future additional studies successfully replicate these key benefits and provide further evidence to the time-sensitive nature of stroke unit admission, a strong argument could be made in favor of optimizing healthcare resources in order to reduce delays to stroke unit admission. Beyond allocating more resources into funding additional beds and personnel on the stroke unit, the creation of a “stroke navigator” role may to lead to faster stroke unit admission by optimizing patient flow and facilitating discharges from the stroke unit.[19]

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Data Availability. Requests for data from this study will be considered 1 year after the date of publication.

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