# Emergency Department Length of Stay and Outcome after Ischemic Stroke

Artin Minaeian, MD,\* Anand Patel, MD,\* Basad Essa, MD,\* Richard P. Goddeau Jr., DO,\* Majaz Moonis, MD,\* and Nils Henninger, MD\*+†

> Background: Emergency department length of stay (ED-LOS) has been associated with worse outcomes after various medical conditions. However, there is a relative paucity of data for ischemic stroke patients. We sought to determine whether a longer ED-LOS is associated with a poor 90-day outcome after ischemic stroke. Methods: This study is a retrospective analysis of a single-center cohort of consecutive ischemic stroke patients (n = 325). Multivariable linear and logistic regression models were constructed to determine factors independently associated with ED-LOS as well as a poor 90-day outcome (modified Rankin Scale [mRS] score >2), respectively. Results: The median ED-LOS in the cohort was 5.8 hours. For patients admitted to the inpatient stroke ward (n = 160) versus the neuroscience intensive care unit (NICU; n = 165), the median ED-LOS was 8.2 hours versus 3.7 hours, respectively. On multivariable linear regression, NICU admission (P < .001), endovascular stroke therapy (P = .001), and thrombolysis (P = .021) were inversely associated with the ED-LOS. Evening shift presentation was associated with a longer ED-LOS (P = .048). On multivariable logistic regression, a greater admission National Institutes of Health Stroke Scale score (P < .001), worse preadmission mRS score (P = .001), hemorrhagic conversion (P = .041), and a shorter ED-LOS (P = .016) were associated with a poor 90-day outcome. Early initiation of statin therapy (P = .049), endovascular stroke therapy (P = .041), NICU admission (P = .029), and evening shift presentation (P = .035) were associated with a good 90-day outcome. Conclusions: In contrast to prior studies, a shorter ED-LOS was associated with a worse 90-day functional outcome, possibly reflecting prioritized admission of more severely affected patients who are at high risk of a poor functional outcome. Key Words: Ischemic stroke-emergency department-length of stay-functional outcome.

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From the \*Department of Neurology, University of Massachusetts Medical School, Worcester, Massachusetts; and †Department of Psychiatry, University of Massachusetts Medical School, Worcester, Massachusetts.

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Address correspondence to Nils Henninger, MD, Departments of Neurology and Psychiatry, University of Massachusetts Medical School, 55 Lake Ave., North Worcester, MA 01655. E-mail: nils.henninger@umassmed.edu.

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#### Introduction

Emergency department (ED) overcrowding is a major public health problem worldwide because it has been shown to adversely affect patient outcomes across a variety of clinical conditions.<sup>1,2</sup> Although the specific effects of ED crowding on outcome remain to be clarified, an important factor is an increased emergency department length of stay (ED-LOS), particularly among critically ill patients.<sup>3</sup>

Stroke comprises one of the most frequent neurological emergencies in EDs,<sup>4</sup> yet there is a surprising paucity of data regarding the association between the ED-LOS and outcome among stroke patients. Results have been conflicting: whereas some studies found an association between ED-LOS and outcome,<sup>5-7</sup> others did not.<sup>8-10</sup> These differences may in part relate to absent differentiation between ischemic and hemorrhagic stroke etiology, subsequent admission to a stroke ward versus an intensive care unit, as well as differences between study settings including a widely varying ED-LOS.<sup>6-9</sup>

To better understand the impact of the ED-LOS on outcome after ischemic stroke, we conducted a retrospective analysis of a cohort of ischemic stroke patients admitted to a single tertiary care academic stroke center. Our primary goal was to determine whether a longer ED-LOS predicts a poor 90-day functional outcome after adjusting for relevant confounders. Because delayed admission to dedicated stroke wards may reduce adherence to stroke guidelines in ED boarders and may contribute to worse outcomes after stroke,<sup>11-13</sup> we also determined adherence to Get With The Guidelines (GWTG)-Stroke treatment measures and their association with the outcome. In secondary analyses, we sought to determine whether the association of the ED-LOS and outcome differed between patients admitted to the stroke ward versus the neuroscience intensive care unit (NICU).

#### Methods

#### Study Population

The present study was reviewed and approved by our institutional review board. We retrospectively analyzed consecutive patients with acute ischemic stroke as shown on brain imaging that were prospectively included in our local stroke registry between January 2013 and December 2013.

The ED-LOS was defined as the time (in minutes) spent in the ED from the time of patient registration in the ED to the arrival on our in-hospital stroke ward or NICU. All patients were evaluated within 5 minutes from ED arrival by a member of the stroke service. Patient demographics, laboratory data, comorbidities, preadmission medications, and stroke etiology (using the Trial of Org 10172 in Acute Stroke Treatment [TOAST] classification) after the completion of the diagnostic evaluation were collected from all patients.<sup>14</sup> National Institutes of Health Stroke Scale (NIHSS) scores were assessed at the time of presentation by NIHSS-certified members of the stroke team. The modified Rankin Scale (mRS) score was assessed at 90 days by a stroke-trained physician or a stroke study nurse certified in mRS via an in-person or phone interview.<sup>15,16</sup> We defined academic months as well as 4 academic quarters (3 months each) with the first academic month starting on July 1 and the first academic quarter ranging from July to September 2013 to determine whether the ED-LOS varied over the course of the academic year. To determine whether the time of patient presentation to the ED was associated with the ED-LOS or outcome, we stratified the time to presentation into 7 AM-3 PM, 3-11 PM, and 11 PM to 7 AM shifts, which most closely represented both neurology and ED staff shifts.

We assessed the adherence to the following GWTG achievement and quality measures: early antithrombotics, antithrombotics at discharge, venous thromboembolism prophylaxis, anticoagulation for atrial fibrillation, smoking cessation advice, statin therapy, dysphagia screen, stroke education given, rehabilitation considered, and recombinant tissue plasminogen activator (rtPA) within 60 minutes of arrival by 2 and 3.5 hours, respectively.

We adhered to the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) guidelines (www.strobe-statement.org).

#### Outcomes

The primary outcome was a good functional outcome (mRS score 0-2) measured at 90 days.

### Statistical Analysis

Unless otherwise stated, continuous variables were reported as mean  $\pm$  standard deviation or median (interquartile range). Categorical variables were reported as proportions. Normality of data was examined using the Shapiro–Wilk test. Categorical variables were compared using the  $\chi^2$  test or the Fisher exact test. The Mann–Whitney *U* test was performed for the analysis of continuous variables. The Spearman rank correlation was used to determine the strength of association between the ED-LOS and clinical variables.

To assess predictors of the ED-LOS, we performed multivariable linear regression including baseline characteristics associated with the ED-LOS in univariable analyses (*P* value for inclusion <.2: small-vessel disease, admission NIHSS score, preadmission mRS score, NICU versus stroke ward admission, intravenous rtPA, endovascular stroke therapy, academic quarter, and time of admission). The presence of hemorrhagic transformation, withdrawal of care, and 90-day mRS score were not included in this model as these outcome measures were unknown at the time of ED presentation. To avoid model overfitting, a backward elimination method (likelihood ratio) was used for linear multivariable modeling. The ED-LOS was log transformed to achieve a more suitable distribution for linear regression.

Multivariable logistic regression analysis was performed to determine whether ED-LOS was independently associated with the 90-day mRS score (dependent variable). Analyses were adjusted for factors associated with the 90-day outcome in univariable analyses, NICU admission; presentation during the evening shift (3-11 PM), academic quarter of presentation, thrombolysis with rtPA, endovascular stroke therapy, statin therapy, dysphagia screening, and their interaction terms with the ED-LOS. Variables remaining statistically significant after multivariable adjustment formed the final model.

Collinearity diagnostics were performed (and its presence was rejected) for all multivariable regression models. The Hosmer–Lemeshow goodness-of-fit statistic was used to assess the model fit. Two-sided significance tests were used throughout and, unless stated otherwise, a *P* value less than .05 was considered statistically significant. All statistical analyses were performed using IBM SPSS Statistics Version 22 (IBM, Armonk, NY).

# Results

# Study Population

During the study period, a total of 442 patients with a clinical diagnosis of ischemic stroke or transient ischemic attack were admitted to our ED. To avoid potential confounding by misclassification of stroke mimics, we excluded patients with imaging negative transient ischemic attacks (i.e., absent ischemic infarct signs on head computed tomography or brain magnetic resonance imaging; n = 50). We excluded all patients who were transferred from another hospital, discharged home from the ED, and lost to follow-up by day 90-day (n = 67), leaving 325 patients for analysis. Table 1 summarizes the baseline characteristics of included patients as stratified by the 90-day mRS score.

#### Factors Associated with the ED-LOS

Supplemental Table S1 summarizes the baseline characteristics of included patients in relation to the ED-LOS in the entire cohort. The median (25th-75th percentile) time to admission was 349 minutes (198-576 minutes) for the entire cohort, 491 minutes (326-800 minutes) for the stroke ward (n = 160), and 221 minutes (136-393 minutes) for the NICU (n = 165) admitted patients.

Strongest associations with a shorter ED-LOS were noted for factors that were related to worse stroke severity and need for NICU admission. After adjustment, the relationship between NICU admission and emergent stroke treatment remained independently associated with the ED-LOS (P < .001, Table 2), indicating prioritized transfer from the ED to specialized inpatient units of the most severely affected patients. To better understand the factors that contribute to a greater ED-LOS depending on the admission to the stroke ward versus the NICU, we created separate multivariable linear regression models for each condition. Among patients admitted to the stroke ward, treatment with rtPA (P = .038), presentation during the evening shift (P < .001), and presentation earlier in the academic year (P = .006) were independently associated with a longer ED-LOS (Supplemental Table S2). For patients admitted to the NICU, treatment with rtPA (P = .010) and endovascular stroke therapy (P = .002) were associated with a shorter ED-LOS (Supplemental Table S3).

# Association of Adherence to GWTG Measures with the 90-Day Outcome

Supplemental Table S4 summarizes the adherence to GWTG measures. In the unadjusted analyses, patients who did not undergo dysphagia screening had a worse 90day mRS score than screened patients (rho -.159, P = .004). When stratified by the admission status, patients admitted to the NICU without dysphagia screen more frequently had a worse outcome (rho -.278, P < .001). There was no association between dysphagia screen nonadherence and outcome among patients admitted to the stroke ward (rho .047, P = .557). Patients surviving to discharge significantly more frequently underwent dysphagia screening than those whose goals of care were shifted to comfort measures or had died by discharge (93% versus 70%, P = .003). Not receiving statins was associated with a worse 90-day mRS score among patients admitted to the stroke ward (rho -.187, P = .018) but not among patients admitted to the NICU (rho -.058, P = .297). There was no difference between patients who survived to discharge versus those who did not survive or were on comfort measures (P = .645). All other GWTG measures were not significantly associated with the 90-day outcome in the entire cohort and when stratified by the admission status (not shown).

#### Factors Associated with 90-Day Functional Outcome

Patients with a poor 90-day outcome had a significantly shorter ED-LOS than patients with a good outcome (P = .006) (Table 1). After adjustment, a higher admission NIHSS score (P < .001), greater preadmission mRS score (P = .001), hemorrhagic transformation (P = .041), and a shorter ED-LOS (P = .035) were independently associated with a poor 90-day outcome (Table 3). Statin administration (P = .049), endovascular stroke therapy (P = .041), NICU admission (P = .029), and presentation during the evening shift (P = .016) were associated with a good 90-day outcome.

To account for unmeasured confounders unique to the stroke ward versus the NICU, we repeated the multivariable analyses separately for each unit. Among patients admitted to the stroke ward, a higher admission NIHSS

Table 1	. Baseline cl	haracteristics	(unadjusted)	of the	studied	patient p	population	as stratified by	the 90-d outcome
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Characteristics	All patients $(n = 325)$	Good outcome $(n = 212)$	Poor outcome $(n = 113)$	P Value
Female sex	134 (41)	75 (35)	59 (52)	.004
Age (v)	70 (23)	67 (18)	80 (25)	<.001
NICU admission	165 (51)	100 (47)	65 (58)	.081
Admission NIHSS score	5 (9)	3 (6)	11 (17)	<.001
Preadmission mRS score	0(1)	0(1)	1 (2)	<.001
ED-LOS (min)	354 (371)	375 (330)	267 (382)	.006
Pre-existing risk factors				
Hypertension	261 (80)	161 (76)	100 (89)	.008
Dyslipidemia	196 (60)	127 (60)	69 (61)	.905
Diabetes mellitus	100 (31)	59 (28)	41 (36)	.130
Stroke or transient ischemic attack	67 (21)	39 (18)	28 (25)	.196
Atrial fibrillation	81 (25)	40 (19)	41 (36)	.001
Coronary artery disease	94 (29)	53 (25)	41 (36)	.040
Congestive heart failure	45 (14)	21 (10)	24 (21)	.007
Peripheral artery disease	25 (8)	15 (7)	10 (9)	.663
Smoking	68 (21)	47 (22)	21 (19)	.478
Alcohol abuse	42 (13)	29 (14)	13 (12)	.729
Preadmission medications				
Statin	164 (51)	105 (50)	59 (52)	.727
Antihypertensives	230 (71)	142 (67)	88 (78)	.041
Antiglycemic	69 (21)	40 (19)	29 (26)	.158
Antiplatelet	170 (52)	100 (47)	70 (62)	.014
Oral anticoagulant	38 (12)	21 (10)	16 (15)	.204
Final TOAST stroke mechanism				
Large-artery atherosclerosis	88 (27)	56 (26)	32 (28)	.793
Small-vessel disease	61 (19)	47 (22)	14 (12)	.037
Cardioembolic	94 (29)	50 (24)	44 (39)	.005
Other determined	21 (7)	15 (7)	6 (5)	.640
Undetermined	61 (19)	44 (21)	17 (15)	.235
Academic quarter of admission				.212
July-September	95 (29)	70 (33)	25 (22)	
October-December	89 (27)	56 (26)	33 (29)	
January-March	57 (18)	34 (16)	23 (20)	
April-June	84 (26)	52 (25)	32 (28)	
Time of admission				.142
7 am-3 pm	152 (47)	93 (4)	59 (52)	
3 рм-11 рм	133 (41)	95 (45)	38 (34)	
11 рм-7 ам	40 (12)	24 (11)	16 (14)	
Acute interventions				
i.v. rtPA therapy*	67 (21)	43 (20)	24 (21)	.886
Time to rtPA (min)	87 (92)	90 (90)	80 (83)	.410
Endovascular stroke therapy†	30 (9)	17 (8)	13 (12)	.319
Hemorrhagic conversion	33 (11)	16 (8)	17 (16)	.017

Abbreviations: ED-LOS, emergency department length of stay; i.v., intravenous; LDLc, low-density lipoprotein cholesterol (within 24 h of admission); mRS, modified Rankin Scale; NICU, neuroscience intensive care unit; NIHSS, National Institutes of Health Stroke Scale; rtPA, recombinant tissue plasminogen activator; TOAST, Trial of Org 10172 in Acute Stroke Treatment.

Data are n (%), mean (±standard deviation), or median (interquartile range). Data are complete for all variables.

\*Without concomitant endovascular stroke therapy.

†With or without concomitant i.v. rtPA.

score (P < .001) and a greater preadmission mRS score (P = .008) were associated with a poor 90-day outcome. Statin therapy was associated with a good outcome, but this did not reach statistical significance (P = .059, not shown).

Among patients admitted to the NICU, a worse admission NIHSS score (P < .001), a greater preadmission mRS score (P = .024), hemorrhagic transformation (P = .042), shorter ED-LOS (P = .027), and evening shift by ED-LOS interaction (P = .028) were associated with a poor 90-day

 Table 2. Multivariable linear regression analysis of factors
 independently associated with the final (log-transformed) time

 spent in the emergency department (all patients)

Independent variable	Coefficient (95% CI)	P Value
NICU admission	623 (795 to450)	<.001
Endovascular	438 (696 to180)	.001
stroke therapy Thrombolysis with rtPA	229 (424 to035)	.021
Admission between	.148 (.001295)	.048
3 PM and 11 PM Academic quarter*	058 (120 to .005)	.070

Abbreviations: CI, confidence interval; ED-LOS, emergency department length of stay; NICU, neuroscience intensive care unit; rtPA, recombinant tissue plasminogen activator.

\*Repeating the analysis using the definition of academic month did not meaningfully change the results: NICU admission (P < .001), thrombolysis with rtPA (P = .019), and endovascular stroke therapy (P = .001) were significantly associated with a shorter ED-LOS, whereas admission between 3 PM and 11 PM (P = .049) was associated with a longer ED-LOS (not shown).

outcome (not shown). Endovascular stroke therapy (P = .012) and presentation during the evening shift (P = .004) were associated with a good 90-day outcome (not shown).

# Discussion

The main goal of our study was to determine whether a longer ED-LOS was associated with a poor 90-day functional outcome among ischemic stroke patients. We found that factors known to adversely affect outcome were associated with a poor 3-month mRS score indicating the overall validity of our model. However, contrary to our original hypothesis, we found that a *shorter* ED-LOS was independently associated with a poor functional outcome at 90 days.

This finding contrasts with other studies that either found no association between the ED-LOS and outcome or noted a worse outcome with longer ED boarding times.<sup>6-9</sup> In our cohort, the median time to stroke ward (5.8 hours) and NICU (3.7 hours) admissions was relatively short as compared to other studies (range 4.5-20 hours),<sup>5-7,9-11</sup> minimizing the overall impact of the ED-LOS on outcome. We hypothesize that our findings reflect triage decisions with prioritized admission of most severely affected patients with a greater likelihood for a poor outcome. For example, patients with small-vessel disease-related strokes and who generally have a mild stroke severity had the longest ED-LOS. The association between ED-LOS and outcome did not depend on NICU admission as indicated by absent interactions. Nevertheless, it is important to note that the ED-LOS × evening shift presentation interaction approached significance, suggesting that triage in the evening may be suboptimal and may contribute to a worse outcome.

Sensitivity analyses stratified by the admission status also indicated that a shorter ED-LOS predicted a poor outcome among patients admitted to the NICU. The ED-LOS × evening shift presentation interaction was significant, indicating that suboptimal triage for critically sick patients in the evening was related to a worse outcome. Interestingly, in a prior study investigating the impact of NICU admission delay in patients presenting with cerebrovascular emergencies, ED-LOS and intracerebral hemorrhage (ICH), but not ischemic stroke, were independently associated with the outcome.6 These differences may in part relate to therapeutic options as well as the natural history of ICH versus ischemic stroke. For example, spontaneous and treatment-associated reversal of catastrophic acute neurological deficits is frequently achieved after ischemic stroke, but not ICH.17,18 Hence, among ICH patients, outcome is more uniformly related to the initial deficit severity. This finding may better allow determination of factors that correlate both with a worse

Table 3. Multivariable logistic regression analysis for factors independently associated with a poor 90-d outcome

Independent variable	Crude OR (95% CI)	P Value	Adjusted OR (95% CI)	P Value
ED-LOS (per h)	.962 (.924-1.001)	.052	.894 (.806992)	.035
ESP	.624 (.388-1.003)	.057	.284 (.103787)	.016
$ED-LOS \times ESP$	.979 (.944-1.016)	.272	1.116 (.997-1.251)	.057
Admission NIHSS score (per point)	1.152 (1.106-1.200)	<.001	1.196 (1.133-1.262)	<.001
Preadmission mRS score (per step)	1.521 (1.190-1.943)	.001	1.561 (1.206-2.022)	.001
NICU admission	1.517 (.957-2.403)	.076	.438 (.209917)	.029
Hemorrhagic conversion	2.321 (1.134-4.752)	.021	2.514 (1.036-6.098)	.041
Endovascular stroke therapy	1.491 (.696-3.193)	.304	.308 (.099953)	.041
Statin therapy	.522 (.148-1.842)	.312	.252 (.064994)	.049

Abbreviations: CI, confidence interval; ED-LOS, emergency department length of stay; ESP, evening shift presentation; mRS, modified Rankin Scale; NICU, neuroscience intensive care unit; NIHSS, National Institutes of Health Stroke Scale; OR, odds ratio. Hosmer–Lemeshow goodness-of-fit  $\chi^2$  10.632, P = .223. outcome and a delayed admission, such as blood pressure control.<sup>13,19</sup>

A key goal of our study was to determine whether the ED-LOS was associated with adherence to stroke guidelines and whether guideline nonadherence was related to worse outcomes. The two most frequently nonadhered GWTG measures were dysphagia screening and statin therapy. Nonadherence to early statin therapy was associated with a poor 3-month outcome consistent with prior data.<sup>20</sup> Importantly, adherence to statin therapy was not associated with the survival status at hospital discharge, indicating that statin treatment was not withheld due to perceived poor patient prognosis. Thus, our observation highlights a possible opportunity to improve stroke outcome in stroke patients though enhancing stroke guideline implementation among patients boarding in the ED.

The strength of our study is related to the inclusion of consecutive patients, the collection of extensive clinical information, detailed analyses of the ED-LOS with outcome measures with the rigorous adjustment for important factors associated with poststroke functional outcome, and the inclusion of additional analyses stratified by the admission status. The limitations of our study are related to the fact that the original data collection was done before trial data demonstrated the efficacy of endovascular stroke therapy.<sup>18</sup> However, we have been routinely employing this therapy since 2012, and thus our results are expected to apply to contemporary stroke care. Given our single-center study design, triage decisions and other unmeasured factors may not apply to other centers. Lastly, because of the study's retrospective and observational nature, as well as the modest sample size; observations should only be considered hypothesis generating pending confirmation by future prospective studies.

# Conclusions

In contrast to prior studies, we found an inverse association between the ED-LOS and the 90-day functional outcome after ischemic stroke, which may suggest the treatment options and clinical resources of an academic stroke center, including prioritized admission of severely affected patients counterpoise potential adverse contributions of prolonged ED-LOS. Interaction term analyses suggested that in critically ill patients, evening presentation may have been related to worse outcome through a longer ED-LOS. Future studies seeking to determine the association between ED-LOS and outcome should include acute triage and patient-flow metrics.

### Appendix: Supplementary material

Supplementary data to this article can be found online at doi:10.1016/j.jstrokecerebrovasdis.2017.04.040.

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