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ORIGINAL ARTICLE

# Prolonged Emergency Department Length of Stay is not Associated with Worse Outcomes in Patients with Intracerebral Hemorrhage

**Jonathan Elmer · Daniel J. Pallin · Shan Liu · Catherine Pearson · Yuchiao Chang · Carlos A. Camargo Jr · Steven M. Greenberg · Jonathan Rosand · Joshua N. Goldstein**

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**Abstract**
*Background* Prolonged emergency department length of stay (EDLOS) has been associated with worse patient outcomes, longer inpatient stays, and failure to meet quality measures in several acute medical conditions, but these findings have not been consistently reproduced. We performed this study to explore the hypothesis that longer EDLOS would be associated with worse outcomes in a large cohort of patients presenting with spontaneous intracerebral hemorrhage (ICH).
*Methods* We performed a secondary analysis of a prospective cohort of consecutive patients with spontaneous ICH who presented to a single academic referral center from February 2005 to October 2009. The primary exposure variable was EDLOS, and our primary outcome was neurologic status at hospital discharge, measured with a modified Rankin scale (mRS). Secondary outcomes were ICU length of stay, total hospital length of stay, and total hospital costs.
*Results* Our cohort included 616 visits of which 42 were excluded, leaving 574 patient encounters for analysis. Median age was 75 years (IQR 63–82), median EDLOS 5.1 h (IQR 3.7–7.1) and median discharge mRS 4 (IQR 3–6). Thirty percent of the subjects died in-hospital. Multivariable proportional odds logistic regression, controlling for age, initial Glasgow Coma Scale, initial hematoma volume, ED occupancy at registration, and the need for intubation or surgical intervention, demonstrated no association between EDLOS and outcome. Furthermore, multivariable analysis revealed no association of increased EDLOS with ICU or hospital length of stay or hospital costs.
*Conclusion* We found no effect of EDLOS on neurologic outcome or resource utilization for patients presenting with spontaneous ICH.

**Keywords** Emergency medicine · Emergency department crowding · Emergency department length of stay · Intracerebral hemorrhage

J. Elmer · S. Liu · C. Pearson · C. A. Camargo Jr · J. N. Goldstein
Department of Emergency Medicine, Massachusetts General Hospital, Boston, MA, USA

Y. Chang
Department of Medicine, Massachusetts General Hospital, Boston, MA, USA

S. M. Greenberg · J. Rosand
Department of Neurology, Massachusetts General Hospital, Boston, MA, USA

J. Elmer (✉) · D. J. Pallin
Department of Emergency Medicine, Brigham and Women's Hospital, 75 Francis Street, Boston, MA, USA
e-mail: jelmer@partners.org

D. J. Pallin
Division of Emergency Medicine, Children's Hospital Boston, Boston, USA

## Introduction

Spontaneous intracerebral hemorrhage (ICH) is the most devastating form of acute stroke, affecting approximately 65,000 people in the United States annually with an associated mortality of 30–50% [1]. While the incidence of ICH is increasing with the aging population, mortality has remained relatively constant [2, 3]. Epidemiologic studies have demonstrated an association between specialized care by neurologists and admission to neurologic or neurosurgical intensive care units (ICUs) and reduced mortality, disability, and the need for long-term institutional care among patients with acute stroke [4–6]. Therefore, clinicians often wish to expedite admission of patients to such units.

Despite this desire, movement of patients from the emergency department (ED) to ICUs is often delayed, resulting in prolonged ED length of stay (EDLOS). The practice of holding patients in the ED until an inpatient bed becomes available is termed "boarding" [7]. Boarding of admitted patients is common in the United States and has been relatively constant in recent years [8–12]. An increasing volume of critically ill patients presenting to EDs, as well as limitations in ICU bed availability likely contribute to the persistence of this phenomenon [8, 10–14].

Boarding and prolonged EDLOS have been associated with worse patient outcomes, longer inpatient stays, and failure to meet quality measures in several life-threatening conditions including pneumonia, acute myocardial infarction, blunt trauma, and cerebrovascular emergencies, such as ischemic and hemorrhagic stroke [15–20]. In particular, in a landmark multicenter study of 50,322 critically ill patients, Chalfin et al. [21] demonstrated an association between ED boarding times longer than 6 h and increased hospital length of stay and inpatient mortality. Furthermore, boarding of patients in the ED is an important contributor to ED crowding, which is itself associated with reduced quality of care, a range of adverse outcomes, and impaired access to care because of increased elopement and ambulance diversion [22]. This affects not just boarding patients, but rather all patients to be cared for at times of crowding. For these reasons, the Institute of Medicine has called for an end to ED boarding in all but the most extreme cases [23].

However, not all studies have found an adverse effect of prolonged ED stays on critically ill patients [24–26], and it is likely that not all patients, disease states, and ED settings are similarly susceptible to the effects of long EDLOS. A recent study examining the effect of ED crowding, which is highly correlated with EDLOS, on patients presenting with acute stroke showed no association between crowding and time to CT scan or thrombolysis in those presenting with symptoms less than 3 h, suggesting that the subset of ED patients needing critical, time-sensitive interventions may be relatively insulated from the detrimental effects of crowding [27]. Furthermore, ICH represents a unique illness in which no single intervention has been consistently demonstrated to improve outcomes. While these patients likely benefit from specialized ICU care, it is not known whether delaying the early initiation of this care reduces or eliminates its effect.

We hypothesized that increased EDLOS would predict worse outcomes in critically ill patients with ICH. Specifically, we expected that an increase in overall EDLOS would be associated with worse neurologic outcome at hospital discharge, longer ICU and hospital stays, and higher hospital costs.

## Methods

### Study Design and Population

This was a secondary analysis of a prospective cohort of consecutive patients with spontaneous ICH who presented to a single academic referral center from February 2005 to October 2009 [28–30]. In our ED, the patients who present with ICH are typically triaged to one of ten beds capable of providing ICU level care, which are staffed with a nurse-to-patient ratio that averages 1:2. Patients are primarily cared for by emergency physicians until departure from the ED, regardless of whether a bed has been requested, and care is delivered at the discretion of the treating physician. Institutional guidelines for management of ICH are available online at http://www.stopstroke.org. In-house consultants are available 24/7, including neurology and neurosurgical residents, and a neuro-ICU fellow. Typically these consultants will become involved early in the patient's ED course and provide recommendations for management even while the patient is in the ED. After an ICU bed is requested by the emergency physician, the admitting neurology or neurosurgical team discusses the case with a nursing supervisor responsible for the hospital-wide triage of ICU-admitted patients. The patient is assigned preferentially to a neuroscience ICU bed, if possible. If no ICU beds are available in the hospital, the patient joins the queue of waiting patients, who are triaged in the order of wait time and their perceived need for specialized ICU care.

All patients or their surrogates provided informed consent, and all aspects of the study were approved by our Institutional review board. The cohort did not include patients with age $< 18$ years or those with ICH secondary to head trauma, ischemic stroke with hemorrhagic transformation, brain tumor, vascular malformation, or vasculitis. For this analysis, we further excluded patients if their goals of care were made comfort measures only (CMO) in the ED or they were not admitted to the ICU.

### Exposure, Covariates, and Outcomes

The primary exposure variable was EDLOS, which we defined as the time from patient registration to departure from the ED and treated as a continuous variable.

Our main outcome of interest was neurologic status at hospital discharge, measured as modified Rankin scale score (mRS), a reliable and reproducible assessment of recovery from stroke [31–33]. Secondary outcomes were ICU length of stay, total hospital length of stay, and total hospital costs. Hospital costs are reported as a proportion of the median cost, per agreement with the hospital to avoid disclosure of confidential financial information.

Data were collected prospectively by trained research coordinators, as previously described [28–30]. These data included age, sex, time, and date of presentation, initial laboratory values, Glasgow coma scale score (GCS), and mRS at hospital discharge. In the case of intubated patients, the verbal component of the GCS was calculated from the motor and eye component using previously validated methods to derive a numeric total GCS [34]. Hematoma volumes were determined from CT scans as previously described [35]. Additional data including the timing of intubation, external ventricular drain (EVD) placement, and surgical hematoma evacuation were determined retrospectively by medical record review. In patients for whom a mRS was not recorded prospectively, the score was determined by two independent reviewers based on discharge physical therapy and occupational therapy notes and inter-observer variation was quantified using a kappa score. EDLOS, ED occupancy at presentation, ICU and hospital length of stays, and total hospital costs were obtained via a query of the hospital's electronic medical records database.

### Statistical Analysis

We report baseline demographics and clinical characteristics using median and interquartile ranges for continuous variables and proportions for categorical variables. Our main outcome measure was mRS at hospital discharge, which we treated as an ordinal variable. Our main predictor of interest was EDLOS, which we log-transformed in multivariable analyses due to its non-normal distribution.

Covariates were selected a priori based on clinical suspicion and biological plausibility and included age, sex, ED occupancy at registration, time at presentation (day, evening, and night), month at presentation (July/August vs. other), transfer of the patient from another facility, initial GCS score, baseline hematoma volume, INR, the need for intubation before arrival or in our ED and the need for emergent external ventricular drain (EVD) placement or surgical hematoma evacuation.

In the bivariate analysis, we assessed the relationship of each of these predictors to discharge mRS using the Cochran–Mantel–Haenszel test. In constructing our multivariable analysis, we included covariates with bivariate $P$ values $< 0.2$. These predictors included age, initial GCS score, initial hematoma volume, the need for emergent intubation, EVD placement in the ED, and disposition to the operating room for emergent hematoma evacuation. We conducted the multivariable analysis in four ways to test our hypothesis. We first used logistic regression model with a proportional odds assumption with mRS treated as an ordinal variable. We then repeated our analysis using a linear regression model with mRS as a continuous variable, and using a logistic regression model with mRS dichotomized as $\leq 3$ vs. $>3$. Next, we performed a propensity score approach which adjusted for the probability of having longer EDLOS in the multivariable models and limited the analysis the middle three propensity score quintiles. Finally, we repeated our analysis after stratifying patients according to their ICH Score, a validated predictor of outcomes in this patient population [36]. With a sample size of 575 patients, our study had an 80% power to detect a mean difference of 0.25 h in EDLOS, comparing those with mRS 0–3 to those with mRS 4–6.

We analyzed hospital and ICU LOS and hospital costs as continuous variables, which we log-transformed because of their non-normal distribution, and used the Kruskal–Wallis test for univariate analysis, and linear regression for multivariable analysis. We used SAS (SAS Institute, Cary, NC) version 9.2 for all statistical analyses.

## Results

From February 2005 to October 2009, there were 616 patient visits to our ED for spontaneous ICH. Of these, 34 patients were excluded for use of CMO orders, four were not admitted to an ICU, and four presented twice for recurrent ICH (only the first presentation was used). Thus, 574 patients were included in the main analysis.

The median age of the cohort was 75 years (IQR 63–82 years) and half were female (Table 1). Median EDLOS was 5.1 h (IQR 3.7–7.1 h), and 17.9% had an EDLOS greater than 8 h. The median discharge mRS was four (IQR 3–6) (Table 2). Thirty percent of the subjects died in the hospital. Discharge mRS was captured prospectively in 546 patients and determined retrospectively in the remaining 28, with very high inter-observer reliability (unweighted $\kappa = 0.96$).

In our bivariate analysis, we noted that longer EDLOS predicted lower discharge mRS (Spearman's $r = -0.25$, $P < 0.0001$) (Table 3; Fig. 1). This change was driven primarily by a reduced mortality (mRS = 6) observed in patients with a longer EDLOS; the number of patients with severe disability (mRS = 4 or 5) remained relatively constant between EDLOS quartiles (Table 3; Fig. 1). Other variables significantly associated with discharge mRS were age, initial GCS score, initial hematoma volume, ED occupancy at registration, and the need for intubation, EVD placement, or hematoma evacuation. We did not find any

**Table 1** Baseline demographics and clinical characteristics of patients presenting to the emergency department with intracranial hemorrhage

| Characteristic | Cohort, $n = 574$ |
|---|---|
| Age (years), median (IQR) | 75.4 (63.4–82.0) |
| Female, *n* (%) | 285 (49.7%) |
| Initial GCS score, *n* (%) | |
| 3–8 | 138 (24.0%) |
| 9–13 | 123 (21.4%) |
| 14–15 | 313, (54.5%) |
| Initial hematoma volume (ml), median (IQR) | 22.5 (7.3–52.2) |
| Warfarin use, *n* (%) | |
| No warfarin | 464 (80.8%) |
| On warfarin, initial INR, *n* (%) | |
| <1.5 | 8 (1.4%) |
| 1.5–3 | 61 (10.6%) |
| >3 | 41 (7.1%) |
| Intubation, *n* (%) | |
| Before arrival | 133 (23.2%) |
| In ED | 56 (9.8%) |
| Not done or >24 h after admission | 385 (67.0%) |
| EVD placement in ED, *n* (%) | 71 (12.4%) |
| Emergent hematoma evacuation, *n* (%) | 40 (7.0%) |
| Presentation in July/August, *n* (%) | 101 (17.6%) |
| Time of presentation, *n* (%) | |
| Day (7a.m–3p.m) | 265 (46.2%) |
| Evening (3–11p.m) | 180 (31.4%) |
| Night (11p.m–7a.m) | 129 (22.5%) |
| EDLOS (hours), median (IQR) | 5.1 (3.7–7.1) |

*GCS* Glasgow Coma scale, *INR* international normalized ratio, *ED* emergency department, *EVD* external ventricular drain, *EDLOS* emergency department length of stay

**Table 2** Outcomes among patients presenting with intracerebral hemorrhage

| Outcome | Cohort, $n = 574$ |
|---|---|
| Discharge modified Rankin scale score, *n* (%) | |
| 0 | 9 (1.6%) |
| 1 | 24 (4.2%) |
| 2 | 41 (7.1%) |
| 3 | 101 (17.6%) |
| 4 | 180 (31.4%) |
| 5 | 48 (8.4%) |
| 6 | 171 (29.8%) |
| ICU length of stay (days), median (IQR) | 2 (1–4) |
| Hospital length of stay (days), median (IQR) | 5 (3–9) |
| Total hospital costs*, median (IQR) | 1 (0.59–1.89) |

*ICU* Intensive care unit

* Rescaled by dividing the actual cost by the median cost

statistically significant interaction when examining the relationship between disease severity (GCS or hematoma volume) and EDLOS in predicting mRS.

Our multivariable analysis revealed that increasing EDLOS did not have a statistically significant association with discharge mRS after controlling for the above covariates. In this model, predictors significantly associated with worse discharge mRS included age, larger initial hematoma volume, lower initial GCS score, and the need for intubation (C statistic = 0.83) (Table 4). Repeating the analysis treating mRS as a continuous variable or as a dichotomized variable replicated these results, as did our propensity score analysis (data not shown). Another means of adjusting for disease severity is to stratify patients according to their ICH Score; after doing so, we found no significant affect of EDLOS patient outcome in any stratum.

Our analysis of the secondary outcomes yielded similar results. In our bivariate analysis, increased EDLOS was associated with shorter ICU LOS ($r = -0.21$, $P < 0.0001$), shorter hospital LOS ($r = -0.09$, $P = 0.04$), and lower total hospital costs ($r = -0.23$, $P < 0.0001$). Controlled multivariable analysis revealed no association between increasing EDLOS and ICU LOS (slope estimate = −0.06, $P$ = NS), total hospital LOS (slope estimate = −0.07, $P$ = NS), or total hospital costs (slope estimate = −0.11, $P$ = NS).

## Discussion

In this large cohort of consecutive patients presenting with ICH, increasing EDLOS was not associated with worse neurologic outcomes. This finding stands in distinction to the detrimental effects of prolonged EDLOS suggested by some other studies of emergency medical conditions [15, 16, 18–20], and does not support our initial hypothesis. In bivariate analysis, simple correlation suggested improved outcomes among patients with longer EDLOS. However, we identified multiple covariates that were associated with both unfavorable neurologic outcome and shorter EDLOS. In other words, at our institution, it appears that patients with more severe disease are transferred to the ICU more rapidly (despite the fact that no formal mechanism for doing so exists, and that clinical providers are not aware of any such influence). Any association between EDLOS and outcome disappeared, after we controlled for disease severity.

The fact that our results do not support our hypothesis suggests either a Type II error whereby our dataset was unable to capture a true effect of prolonged EDLOS on outcome, or that no such effect exists. To the first point, we believe that our study was adequately powered, but was limited by its observational nature. Unidentified

**Table 3** Stratified bivariate predictors of modified Rankin scale score at hospital discharge among patients with intracerebral hemorrhage

| Characteristic | mRS mean score | Good outcome (mRS score ≤2) (%) | Mortality (%) | *P* value* |
|---|---|---|---|---|
| Age | | | | 0.004 |
| <75, *n* = 280 | 4.0 | 16.4 | 25.7 | |
| ≥75, *n* = 294 | 4.4 | 9.5 | 33.7 | |
| Sex | | | | 0.26 |
| Female, *n* = 285 | 4.2 | 10.9 | 31.2 | |
| Male, *n* = 289 | 4.1 | 14.9 | 24.8 | |
| GCS score | | | | <0.0001 |
| 3–8, *n* = 138 | 5.4 | 1.4 | 71 | |
| 9–13, *n* = 123 | 4.7 | 1.6 | 35.8 | |
| 14–15, *n* = 313 | 3.4 | 22.4 | 9.3 | |
| Hematoma volume | | | | <0.0001 |
| <30, *n* = 318 | 3.5 | 20.4 | 8.2 | |
| 30–60, *n* = 113 | 4.6 | 3.5 | 34.5 | |
| >60, *n* = 117 | 5.7 | 0.9 | 81.2 | |
| International normalized ratio (INR) | | | | 0.65 |
| Off warfarin, *n* = 464 | 4.1 | 13.1 | 28.7 | |
| <1.5, *n* = 8 | 4.1 | 12.5 | 12.5 | |
| 1.5–3.0, *n* = 61 | 4.4 | 8.2 | 36.1 | |
| >3.0, *n* = 41 | 4.1 | 17.1 | 36.6 | |
| Intubation | | | | <0.0001 |
| Before arrival, *n* = 133 | 5.4 | 0.8 | 69.2 | |
| In ED, *n* = 56 | 5.4 | 0 | 67.9 | |
| Not done or > 24 h after admission, *n* = 383 | 3.6 | 19.1 | 10.4 | |
| EVD placement | | | | <0.0001 |
| In ED, *n* = 71 | 5.0 | 0 | 52.1 | |
| Other, *n* = 503 | 4.1 | 14.7 | 26.6 | |
| Emergent hematoma evacuation | | | | 0.0009 |
| No, *n* = 526 | 4.1 | 14.1 | 28.7 | |
| Yes, *n* = 28 | 4.9 | 0 | 41.7 | |
| Presentation month | | | | 0.59 |
| July/August, *n* = 101 | 4.1 | 10.9 | 25.7 | |
| Other, *n* = 473 | 4.2 | 13.3 | 30.7 | |
| Time of presentation | | | | 0.24 |
| Day (7a.m–3p.m), *n* = 265 | 4.2 | 11.3 | 30.6 | |
| Evening (3–11p.m), *n* = 180 | 4.1 | 15.0 | 26.1 | |
| Night (11p.m–7a.m), *n* = 129 | 4.3 | 13.2 | 33.3 | |
| ED occupancy at presentation | | | | 0.046 |
| 1st quartile, *n* = 143 | 4.4 | 11.2 | 36.4 | |
| 2nd quartile, *n* = 142 | 4.1 | 14.8 | 26.8 | |
| 3rd quartile, *n* = 143 | 4.3 | 10.5 | 31.5 | |
| 4th quartile, *n* = 146 | 3.9 | 15.1 | 24.7 | |
| EDLOS | | | | <0.0001 |
| 1st quartile, *n* = 143 | 4.5 | 8.4 | 38.5 | |
| 2nd quartile, *n* = 144 | 4.4 | 9.7 | 35.4 | |
| 3rd quartile, *n* = 144 | 4.1 | 10.4 | 27.8 | |
| 4th quartile, *n* = 143 | 3.6 | 23.1 | 17.5 | |

*mRS* modified Rankin scale, *GCS* Glasgow Coma scale, *INR* international normalized ratio, *ED* emergency department, *EDLOS* emergency department length of stay

* *P* values are determined using the Cochran–Mantel–Haenszel modeling mRS as an ordinal variable

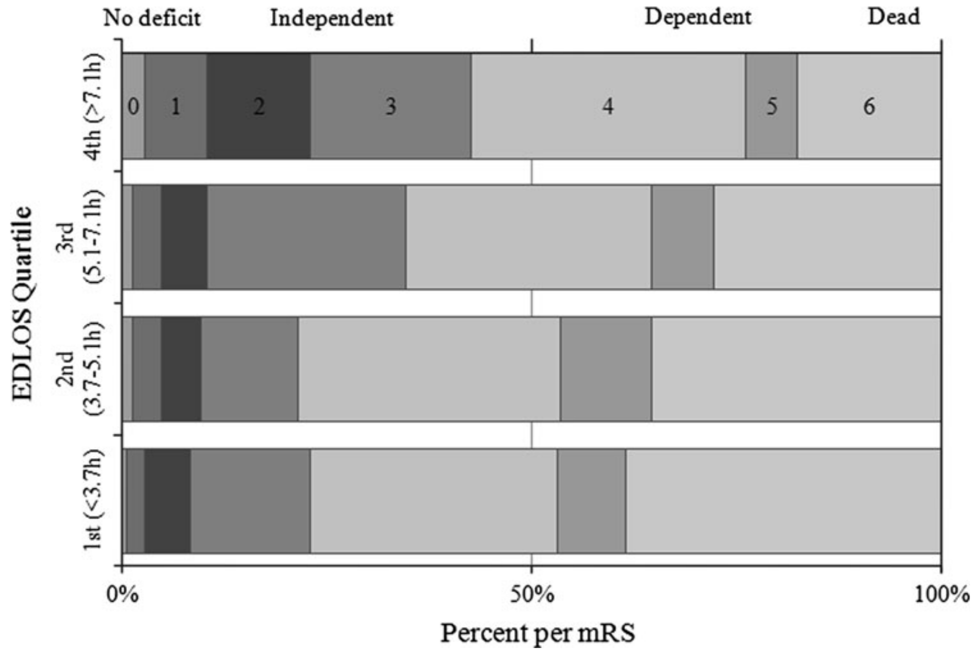


**Fig. 1** The distribution of modified Rankin Scale score on hospital discharge stratified by quartile of emergency department length of stay. *EDLOS* emergency department length of stay, *mRS* modified Rankin scale

**Table 4** Independent predictors of higher modified Rankin scale score (worse outcome), using a proportional odds logistic regression model of modified Rankin scale score on hospital discharge

| Characteristic | Odds ratio (95% CI) |
|---|---|
| Age | 1.04 (1.03–1.06) |
| GCS score (referent 14–15) | |
| 3–8 | 3.76 (1.99–7.10) |
| 9–13 | 2.73 (1.74–4.27) |
| Hematoma volume (referent <30 ml) | |
| 30–60 ml | 3.94 (2.54–6.12) |
| >60 ml | 15.01 (8.11–27.78) |
| Intubation (referent = not done or performed >24 h after admission) | |
| Before arrival (EMS or sending facility) | 3.93 (2.10–7.36) |
| Performed in ED | 5.96 (2.77–12.84) |
| EVD placement in ED | 0.98 (0.52–1.85) |
| Emergent hematoma evacuation | 1.24 (0.59–2.58) |
| ED occupancy at presentation | 0.99 (0.98–1.00) |
| EDLOS, in log scale | 0.78 (0.58–1.04) |

*GCS* Glasgow Coma scale, *EMS* emergency medical services, *EVD* external ventricular drain, *ED* emergency department, *EDLOS* emergency department length of stay

C statistic = 0.83 for this model

confounders, including the effects of different care teams and hospital crowding at the time of presentation, may have impaired our ability to detect an effect of EDLOS. Unfortunately, it is impractical and potentially unethical to randomize patients to longer or shorter EDLOS, precluding the possibility of more rigorous study designs. Notably, our results remained quite similar in our propensity score analysis, which was limited to the middle three propensity score quintiles, and after stratifying patients according to their ICH Score, a validated predictor of clinical outcome [36]. However, given the strong trend toward rapid disposition of the sickest patients, there may still be additional unmeasured factors by which providers recognize the most critically ill and expedite their transfer to the ICU that confounded our analysis. This is only a hypothesis; while our data seem to suggest a selection bias for rapid transfer to the ICU, there is no formal policy for doing so. Therefore, the variables that we could not control for may have contributed to a selection process on the part of the triage nursing supervisors or charge nurses in our hospital. Finally, there is no universally accepted measure of disease severity in this patient population. While we included a range of biologically plausible and clinically relevant covariates in our analysis, as well as the well-validated ICH Score, these may not adequately capture the severity of illness in this patient population.

We also note that just over half of the patients in this cohort were admitted within 5 h of presentation, which may not have been long enough for negative effects of long EDLOS to appreciate. In other words, the detection of such harm may only be possible at significantly longer EDLOS than those observed in our cohort. Previous work by Chalfin et al. [21] examined a cohort of ED patients boarding greater than 6 h, finding increased mortality in this subset. While our median EDLOS was 5.1 h, we observed no increase in adverse outcomes among patients in the 4th quartile of EDLOS (EDLOS > 7.1 h), suggesting that our findings are not due to the cutoffs of EDLOS chosen for our analysis. This highlights one challenge of investigating the effects of events EDLOS: because time spent in the ED represents a relatively small proportion of a total hospital stay, its effects on outcomes may be difficult to detect. For this reason, some authors have chosen to examine adherence to quality measures, rather than patient-specific outcomes, to imply detrimental effects of longer EDLOS [16, 18]. However, we chose to focus on a clinical outcome, as it is not clear that adherence to performance measures is consistently a valuable surrogate for improved outcome [18, 37–41].

Another limitation of our cohort is that approximately half of the patients were transferred from other hospitals. There may be a selection bias, in which the ED does not accept a transfer patient unless an ICU bed is readily available, inducing a bias in our cohort toward patients with an expected short EDLOS. Also, with the exception of intubation, we were unable to control for the potentially confounding effects of care given before transfer. Nearly a quarter of patients were intubated before their arrival to our ED, highlighting that substantially important elements of patient care occur in the prehospital setting or during a patient's stay at a sending facility.

Interestingly, intubation was independently associated with worse neurologic outcome in our cohort. This may be due to confounding by indication and an incomplete modeling of disease severity despite our inclusion of multiple covariates. Alternatively, intubation may lead directly to worse outcomes. In traumatic brain injury, a GCS score of $<8$ is considered an indication for intubation [42, 43], a heuristic that is frequently generalized to other disease states including cerebrovascular emergencies, despite a paucity of evidence to support the practice. Intubation is associated with a variety of adverse outcomes including ventilator associated pneumonia, hypotension, and inadvertent hyperventilation, which may be particularly detrimental after spontaneous ICH [8, 44–48].

While our dataset may be limited by the factors discussed above, an alternate interpretation of our results is that EDLOS has no effect on outcomes. To our knowledge, only one study has demonstrated an adverse effect of prolonged EDLOS on outcomes in stroke patients [20]. The authors did not include a subgroup analysis of patients presenting with ICH, making it difficult to compare our results with theirs. Furthermore, recent evidence suggests that the subset of stroke patients presenting within the window for thrombolysis is relatively insulated from the effects of ED crowding [27]. While this study was underpowered to examine patients with ICH specifically, the protection imparted by clinicians' perceptions of acuity may extend to the patients presenting with ICH.

Alternatively, as no specific intervention has been consistently demonstrated to improve outcomes for the patients with ICH, it may not matter whether care is provided in an ED or an ICU. This may be particularly true at academic stroke centers such as ours, with an ED equipped to provide ICU level care and in-house neurology consultation services. While this interpretation is possible, we feel that it is unlikely. Multiple studies have demonstrated the benefit of admission to a stroke unit or specialized ICU [4–6], and it is unlikely that a busy ED, with staff trained to handle a wide range of medical conditions, can be as well suited for cerebrovascular emergency management as a neuroscience ICU. In addition, the fact that disease severity-adjusted mortality is higher in institutions with a high rate of DNR usage [4, 36, 49–55] suggests that more aggressive care applied systematically does provide clinically relevant benefit, even if no single intervention has yet been demonstrated in a phase III clinical trial.

It may be that the care of boarders in the ED at our institution is not representative of the same in other centers. Emergency care, achievement of quality measures, and patient-related outcomes vary considerably between institutions, and particular heterogeneity has been demonstrated between urban academic centers and others [56–59]. In their study, Chalfin et al. [21] made no distinction between community and academic EDs, and both were heavily represented in the analysis. Many community hospital EDs may lack the 24-h in-house neurologic specialty services, and may have staffing constraints such as higher nurse-to-patient ratios that increase the difficulty of providing ongoing care to critically ill boarders.

At our institution, patients with ICH are cared for in a high-acuity area with a low nurse–patient ratio and active collaboration between neurologic specialists (in-house at all times) and emergency physicians. This environment may protect our patients from the detrimental effects of ED crowding observed in some studies [13, 18, 60–62], and explain why we observed no effect of ED occupancy on patient outcomes. Similar to our ED environment, previous studies which found no detrimental effect of prolonged EDLOS on outcomes have been conducted at centers where early aggressive initiation of supportive care, invasive monitoring, and active participation of intensivists in ED care are standard [24, 25]. In our cohort, the practice environment may have ensured that patients in the ED received adequate intensive and neurospecialist care, eliminating any impact of longer EDLOS.

This study adds to a small but growing body of literature, which has found no harmful effects of long EDLOS on critically ill patients [24–26]. Viewed in the larger context of previous study by Chalfin et al. [21] which examined a broad and heterogeneous cohort of medical and surgical patients, as well as other studies specific to diseases like pneumonia, blunt trauma, or myocardial infarction [15, 16, 63], our findings highlight the differing observed effects of prolonged EDLOS on patient outcomes.

## Conclusions

In this analysis, longer EDLOS did not independently predict worse neurologic outcomes or increased resource utilization.

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