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Early Stroke Recognition and Time-Based Emergency Care Performance Metrics for Intracerebral Hemorrhage

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Abstract

Background & Aim: Performance measures have been extensively studied for acute ischemic stroke, leading to guideline-established benchmarks. Factors influencing care efficiency for intracerebral hemorrhage (ICH) are not well delineated. We sought to identify factors associated with early recognition of ICH and to assess the association between early recognition and completion of emergency care tasks.

Methods: Consecutive patients with spontaneous ICH were enrolled in an observational cohort study conducted from 2009 to 2017 at an urban comprehensive stroke center, excluding patient transferred from other hospitals. We used stroke team activation as the indicator of early recognition and measured completion times for multiple ICH-relevant performance metrics including door to CT acquisition and door to hemostatic medication initiation.

Results: We studied 204 cases. All stroke-related performance times were faster in patients managed with stroke team activation compared to no activation, including quicker door to CT acquisition (median 24 versus 48 minutes, $p < 0.001$) and door to hemostatic medication initiation (63 versus 99 minutes, $p = 0.005$). These associations were confirmed in adjusted models. Stroke codes were activated in 43% of cases and were more likely in patients with shorter onset-to-arrival times, higher NIHSS scores, and higher GCS scores.

Conclusions: Stroke team activation was associated with more rapid diagnostic and therapeutic interventions for patients with ICH, but activation did not occur in the majority of cases, implying absence of early recognition. A stroke team activation process improves care performance, but

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Declaration of Conflicting Interests

The Authors declare that there is no conflict of interest.

leveraging the advantages of existing systems will require improved triage tools to identify ICH in the acute setting.

Keywords

performance; emergency; diagnosis; intracerebral hemorrhage; intracranial hemorrhage; stroke

Introduction

A decline in overall stroke mortality has been observed in recent years, although mortality for intracerebral hemorrhage (ICH), the most morbid form of stroke representing 10% of cases, has remained unchanged.^{1–3} Performance measures have been extensively studied for acute ischemic stroke, spurred by efforts to increase thrombolysis rates, and more recently, endovascular interventions.⁴ The benefit of intravenous thrombolysis and endovascular treatments for ischemic stroke generally diminish over time, so benchmarks have been established for process times in acute ischemic stroke interventions and time measurements figure prominently in quality metrics.⁵ Patients with ICH also experience high risk for early neurologic deterioration, but unlike ischemic stroke, emergency care performance metrics for ICH are fewer and supported by lower quality evidence.^{5,6}

A crucial early step in the emergency care pathway is recognizing that a patient's presenting symptoms may be due to stroke and activating the emergency stroke system to accelerate evaluation and treatment. In ischemic stroke, unilateral motor deficits and speech impairment are more readily recognized as stroke than subtle, non-specific, or atypical stroke symptoms like dizziness. For example, patients with basilar ischemia often present with signs and symptoms that are less specific for stroke and experience substantial delays in recognition that lead to prolonged door-to-needle times.^{7,8} In an analogous manner, patients with ICH may experience similar barriers to being recognized as having a stroke, resulting in harmful care delays. The objective of this study was to identify patient-level factors associated with recognition of ICH as a stroke, and to assess whether stroke code activation is associated with faster times to complete critical emergency care tasks.

Methods

Consecutive patients presenting to Northwestern Memorial Hospital with spontaneous ICH between July 2009 and January 2017 were prospectively enrolled in an observational cohort study, as previously reported in detail.⁹ Patients who were transferred from outside hospitals were excluded. All cases were diagnosed by a board-certified neurointensivist. Patients with ICH attributed to trauma, hemorrhagic conversion of ischemic stroke, structural lesions or vascular malformations were excluded. All patients were admitted to and managed in a neuro-intensive care unit. The Glasgow Coma Scale (GCS) score and National Institutes of Health Stroke Scale (NIHSS) score were prospectively recorded at the time of initial evaluation by a trained neurologist, neurosurgeon, or both. Demographic information, medical history, medication history, standardized clinical instruments, pretreatment blood pressure, laboratory data, imaging data including hematoma volumes, medical management variables, surgical interventions and medical complications were prospectively recorded.

Premorbid disability was determined by interview of the patient, family or both and review of the medical record, graded by the modified Rankin Scale (mRS). A best estimate for time of symptom onset or time last known normal was recorded at the time of admission based on history from the patient, family, emergency medical services, and collateral sources.

The main outcomes were completion times for multiple ICH-relevant performance metrics including door to CT acquisition and door to hemostatic medication initiation. The secondary outcome was identification of factors associated with early stroke recognition as indicated by stroke code activation. A prospective record of activations of the emergency stroke care protocol ("stroke codes") was maintained in a parallel database. According to our existing institutional protocol, a stroke code is activated for all instances of acute neurologic deficits potentially consistent with stroke that are identified in the emergency department. A stroke code initiates a single page activation of a team that includes ED and neurology physicians, nurses, radiology technologists, radiologists, and pharmacists to coordinate of optimal acute care for stroke patients including neuroimaging and evaluation for medical, surgical and endovascular therapies. Given our protocolized use of this stroke team activation process, stroke code activation was a marker of early recognition of suspected acute stroke.

Based on recommendations in the American Heart Association/American Stroke Association Guidelines for the Management of Spontaneous Intracerebral Hemorrhage and the Neurocritical Care Society's Emergency Neurological Life Support: Intracerebral Hemorrhage publication, we identified eight emergency management performance metrics as suitable to measure the temporal efficiency of the emergency care system: onset-to-arrival time, door-to-CT order, door-to-CT acquisition, door-to-coagulation laboratory tests order, door-to-coagulation laboratory results, door-to-antihypertensive medications, door-to-hemostatic medications, and door-to-intensive care unit or operating room arrival.^{10,11} These metrics, their definitions and clinical relevance are summarized in Table 1. Reliable contemporaneous date-times were recorded in the electronic medical record for all metrics except the medication administration record, so antihypertensive medication administration times were not queried or analyzed.

We assessed the factors associated with early stroke recognition in the ED by first comparing characteristics for patients for whom stroke codes were activated versus not using nonparametric univariate tests. Next, we used logistic regression to confirm independent associations. We pre-specified admission NIHSS and GCS scores as potential variables of interest, and given the paucity of prior research to identify other likely covariates, we included other variables significant to a threshold of $p < 0.3$ on univariate tests and used stepwise backward regression to arrive at a parsimonious model.^{12,13} We limited our evaluation to variables available to clinicians prior to the diagnosis being established by diagnostic imaging, the period in which stroke code activations are intended to occur. Similarly, we evaluated the relationship between stroke code activation and performance metrics by univariate tests, and by a linear regression model for door-to-CT that used backward stepwise variable selection to identify the best fitting parsimonious model. Log transformation of door-to-CT times yielded an approximately normal distribution suitable for linear regression. We suspected that the symptom onset-to-arrival time may strongly

influence the likelihood of activating a stroke code, so in addition to adjusting for onset-to-arrival time in the multivariable models, we also performed a subgroup analysis using only patients presenting within six hours of onset. In doing so, we sought to confirm that our results remained consistent within this high-risk subgroup in whom improvements in emergency care efficiency may be most beneficial. Statistical analyses were performed in R version 3.4.0 (R Foundation for Statistical Computing, Vienna, Austria).

The study was approved by the Institutional Review Board (IRB). Written informed consent was obtained from the patient or their legally authorized representative. The IRB approved a waiver of consent for patients who died during initial hospitalization, or who were incapacitated and for whom a legal representative could not be located.

Results

We analyzed 204 consecutive patients with acute ICH presenting directly to the ED. The demographic and clinical characteristics of the patients are detailed in Table 2 along with performance times for care metrics, separated by stroke code status. The study cohort was approximately half non-Hispanic white and half female, with a median admission GCS of 14 [interquartile range 9.5–15]. Emergency care interventions included endotracheal intubation in 26% (including pre-hospital intubation), and intravenous antihypertensive medication treatment in 78%.

Stroke code activation occurred in 88 patients (43%). Patients for whom stroke codes were activated had significantly higher NIHSS scores, higher initial systolic blood pressures, and lower onset-to-arrival times (all $p < 0.05$). Moreover, age, premorbid disability measured by mRS, and intubation status in the emergency department were identified as potentially associated with stroke code activation ($p < 0.3$). Multivariable models estimated that the likelihood of stroke code was increased by higher NIHSS score (adjusted odds ratio 1.08, 95% confidence interval [1.02, 1.15], $p = 0.013$) and higher GCS score (OR 1.27 [1.10, 1.49], $p = 0.001$), and decreased for every hour of delay between symptom onset and hospital arrival (OR 0.94 [0.91, 0.97], $p < 0.001$). In the subgroup of patients presenting within six hours of symptom onset, only NIHSS and GCS were significantly associated with stroke code activation (OR 1.11 [1.05, 1.19] and OR 1.28 [1.11, 1.49], respectively, both $p = 0.001$).

Among patients in whom stroke codes were activated, the time from arrival to code activation was generally short (median 2 minutes, interquartile range –1 to 9 minutes), with 33% of stroke codes activated as prearrival notifications (negative door to stroke code times). Shorter door to stroke code times were associated with lower GCS score (Spearman's ρ 0.26, $p = 0.034$), higher initial systolic blood pressure (ρ –0.34, $p = 0.004$) and possibly, but non-significantly, with higher NIHSS score (ρ –0.22, $p = 0.067$).

With respect to post-diagnosis characteristics and treatments, the ICH Score was similar for patients in the stroke code activation and non-activation groups, as was the need for emergency hemostatic therapies. The need for aggressive blood pressure management with intravenous medications was higher in those with stroke code activation (92.0% vs. 67.5%, $p < 0.001$).

Time performance metrics were 23-63% faster in patients with stroke code activation (all $p<0.01$; see Table 2). Using door-to-CT as a representative metric, stroke code activation was significantly associated with faster door-to-CT time ($\beta -0.25$, 95%CI -0.16 to -0.33 , $p<0.001$ for log-door-to-CT) after adjustment for onset-to-arrival time ($p<0.001$) and initial GCS score ($p=0.013$). Among patients presenting within six hours, stroke code activation was the only factor significantly associated with door-to-CT time ($\beta -0.17$, 95%CI -0.08 to -0.26 , $p<0.001$ for log-door-to-CT). Stroke code activation was similarly significantly associated with faster performance for other in-hospital metrics related to stroke care including door to coagulation ordering ($\beta -0.19$, 95%CI -0.05 to -0.34 , $p=0.008$), door to coagulation lab result reporting ($\beta -0.18$, 95%CI -0.08 to -0.28 , $p<0.001$), door to hemostatic medication administration ($\beta -0.19$, 95%CI -0.0011 to -0.39 , $p=0.049$) and time from ED arrival to arrival in the Neuro-intensive Care Unit or operating room ($\beta -0.077$, 95%CI -0.02 to -0.16 , $p=0.033$).

In contrast to stroke-related ED time metrics, among the 53 patients who were intubated in the ED (26% of all patients), the time to intubation was not different between patients in whom stroke codes were activated and those managed without stroke codes, and in an adjusted model, only the initial GCS was significantly associated with time to intubation (for stroke code: $\beta -0.075$, 95%CI -0.34 to 0.19 , $p=0.6$).

Discussion

In a single center study of patients with ICH, stroke team activation system was unused in most cases suggesting widespread delayed recognition. Stroke team activation was confirmed to be significantly associated with timely ICH care. The differences in care efficiency between patients managed through the stroke code pathway versus otherwise usual care was marked: the absence of stroke code activation approximately doubled the time to key diagnostic and therapeutic care measures in the ED. Patients in the stroke code activation and non-activation groups were similar in baseline severity and need for hemostatic treatment; the difference in care resulting from inconsistent use of the stroke code pathway appears incongruous with patients' needs. Intubation status was not associated with stroke code activation nor was stroke code activation associated with time to intubation for patients intubated in the ED. Therefore, stroke team activation does not appear to be a generic marker of emergency care efficiency, but specific to neurological care. Given the time sensitivity of stabilization and treatment interventions for patients with acute brain hemorrhage, delays of this magnitude pose substantial risk for patient harm.¹¹

The factors associated with stroke team activation we identified conform to clinical experience: a high burden of measurable, focal deficits (high NIHSS score) and an absence of stupor or coma (high GCS score) make a cerebrovascular syndrome more obvious. These findings are consistent with studies of ischemic stroke recognition; for example, patients with basilar artery syndromes similar to ICH patients, present with a relatively greater prominence of non-focal symptoms like impaired arousal, nausea and vomiting and experience treatment delays due to syndrome under-recognition compared to patients with supratentorial ischemic strokes.^{7,8}

Performance metrics for ischemic stroke are derived from clinical trial methods and post-hoc estimates of treatment effect size by time interactions. Unlike ischemic stroke, there is less randomized trial evidence to support the efficacy of therapeutic interventions for ICH, although there is substantial consensus that at least several interventions (e.g. reversing coagulopathy, ventriculostomy to relieve symptomatic hydrocephalus, evacuation of large cerebellar hemorrhages, treating severe hypertension) are beneficial and time-dependent.¹⁰ As a result, performance metrics for acute ICH care are comparatively poorly defined. The Neurocritical Care Society's Emergency Neurologic Life Support materials for ICH provide a checklist of diagnostic and management interventions that are suggested for an initial "golden hour", but without evidence to specifically support any modifying effect of time to intervention.¹¹ Few Joint Commission Comprehensive Stroke Center quality measures are relevant to ICH and none measure time-to-care-endpoint.¹⁴ Similarly, only one ICH metric in the American Heart Association-American Stroke Association's scientific statement on Metrics for Measuring Quality of Care in Comprehensive Stroke Centers measures timing of care in ICH management: median time from arrival to start of treatment to reverse the international normalized ratio (INR) for patients with warfarin-associated ICH and an elevated INR.⁵ The evidence gap between ischemic and hemorrhagic stroke emergency management performance metrics corresponds to a practice gap: recent research has shown that while 78% of hospitals have clearly established pathways for the management of acute ischemic stroke, only 30% have a clearly defined pathway for ICH.¹⁵

Notwithstanding these limitations, there is compelling evidence that early recognition of ICH is fundamental to improved care. Prior research has shown that much of the dynamic early clinical changes occur within the first 12 hours of symptom onset, defining a limited interval when interventions to halt or reverse brain injury are likely to be most effective, similar to ischemic stroke.⁶ Existing retrospective data support the concept of defining a "golden hour" for ICH, akin to ischemic stroke. For example, hematoma expansion is associated with anticoagulation and worse outcomes, and more rapid initiation of reversal agents leads to more rapid and effective reversal.¹⁶ Moreover, the risk of hematoma expansion is predictable based on information that can be readily ascertained in the emergency department.^{17,18} Similarly, delayed intraventricular hemorrhage is independently associated with worse outcomes, a risk which may be attenuated by early hemostasis interventions.^{19,20}

Maximizing opportunities to improve outcomes in hemorrhagic stroke through better emergency care will require establishing evidence-based performance goals and critical assessments of performance gaps. Certain aspects of current emergency stroke response systems may serve patients with hemorrhagic stroke well, like using stroke team activations to expedite care, whereas existing stroke recognition and triage tools are not optimal. Encephalopathy is common in the emergency department, so indiscriminately broadening the criteria for stroke team activation would strain resources. Process improvements are needed to improve the recognition and early care of ICH cases. The existing literature on process improvements for emergency ICH management is limited but promising. For example, one comprehensive stroke center reported its experience implementing three process improvements in their ICH pathway, point of care INR testing in the ED, protocolizing prothrombin complex concentrate (PCC) administration by neurologist order

in place of hematology consultations, and stocking PCC in the ED, which resulted in a 54% reduction in time to initiate hemostatic medications.²¹

This study has several limitations. Even though data collection methods were rigorous and prospective, with event times based on contemporaneous automatic time stamps in the electronic medical record, the data derive from a single center and may be biased by practice patterns at this institution that are not generalizable to other settings. Moreover, we cannot determine the extent to which unmeasured factors confounded emergency care.

Summary & Conclusion

We found evidence of widespread delayed recognition of intracerebral hemorrhage in the emergency department, which was associated with delays in diagnostic testing and treatment. Although these observations were from a single center, the effect sizes were large and the basic findings that ICH is under-recognized immediately upon presentation and that stroke code pathways are associated with accelerating care for major ICH interventions are likely to generalize in principle even if the magnitude of the effect varies from hospital to hospital. These data suggest that improving ICH emergency care is possible by increasing early recognition, but strategies for improving early recognition are not known and will require development.

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Table 1:

Time Performance Metrics

Metric	Timespan	Relevance
Arrival delay	Symptom onset (or last known normal) to ED arrival	Effectiveness of community awareness of stroke symptoms and the emergency medical services response
Door-to-CT order	ED arrival to order placement for non-contrast head CT	Efficiency of obtaining key diagnostic imaging
Door-to-CT	ED arrival to non-contrast head CT acquisition	
Door-to-coagulation lab order	ED arrival to order placement for coagulation lab studies	Efficiency of obtaining key diagnostic laboratory studies
Door-to-coagulation results	ED arrival to coagulation studies resulting (international normalized ratio as the reference when times varied)	
Door-to-antihypertensive treatment	ED arrival to first dose of intravenous antihypertensive medication	Efficiency of clinical management responses to diagnostic data
Door-to-hemostatic treatment	ED arrival to initiating the administration of hemostatic agents	
Door-to-ICU/OR	ED arrival to arrival in the neuro-intensive care unit or operating room, whichever first	Efficiency of the clinical management response in transitioning patients to a monitored subspecialty care environment

CT: computed tomography, ED: emergency department.

Table 2:**Patient Characteristics and Performance Time Metrics by Stroke Team Activation**

Variable		No Stroke Code (N=117)	Stroke Code (N=88)	p-value
Pre-Diagnosis Variables				
Age		66.2 ± 15.8	62.7 ± 13.8	0.10
Male gender		55 (47.0%)	42 (47.7%)	0.99
Race	Unknown/Refused	1 (0.9%)	0 (0%)	0.45
	American Indian/Native Alaskan	0 (0%)	2 (2.3%)	
	Asian	3 (2.6%)	4 (4.5%)	
	Black	45 (38.5%)	29 (33.0%)	
	Native Pacific Islander	5 (4.3%)	2 (2.3%)	
	White	63 (53.8%)	51 (58.0%)	
Hispanic or Latino ethnicity		8 (6.8%)	10 (11.4%)	0.36
Initial NIHSS score		5 [2, 17]	11 [6, 17]	0.005
Initial GCS score		14 [9, 15]	14 [10, 15]	0.80
History of intracerebral hemorrhage		7 (6.0%)	2 (2.3%)	0.35
Initial systolic blood pressure (mmHg)		178.1 (±49.7)	192.5 (±46.5)	0.035
Baseline disability by mRS		0 [0, 0]	0 [0, 0]	0.12
Intubated at ED arrival		0 (0%)	1 (1.1%)	0.89
Taking anticoagulant medication		13 (11.1%)	9 (10.2%)	0.99
Symptom onset to door time (minutes)		273 [48, 1346]	71 [37, 171]	<0.001
Door to stroke code time (minutes)		NA	2 [-1, 9]	NA
Post-Diagnosis Variables				
Initial hematoma volume (ml)		8.0 [2.4, 21.6]	9.4 [4.0, 30.0]	0.14
ICH Score		1 [0, 2]	1 [0, 2]	0.38
Intravenous antihypertensive treatment in ED		79 (67.5%)	81 (92.0%)	<0.001
Hemostatic medications administered		32 (27.4%)	25 (28.4%)	0.99
Emergency Care Time Intervals (minutes)				
Door to head CT order		16 [9, 36]	6 [3, 14]	<0.001
Door to head CT acquisition		48 [26, 93]	24 [18, 34]	<0.001
Door to coagulation tests order		26 [14, 67]	16 [11, 26]	<0.001
Door to coagulation test results		69 [45, 119]	39 [30, 53]	<0.001
Door to hemostatic medication initiation		99 [74, 169]	63 [41, 95]	0.005
Door to ICU/OR arrival		228 [171, 356]	176 [130, 215]	<0.001
Door to ED Intubation (n=74)		19 [11, 31]	31 [13, 55]	0.08

Data shown as mean ± standard deviation, number (%) and median [interquartile range]. GCS: Glasgow Coma Scale, ED: emergency department, ICU: intensive care unit, OR: operating room, mRS: modified Rankin Scale