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Potentially Missed Diagnosis of Ischemic Stroke in the Emergency Department in the Greater Cincinnati/Northern Kentucky Stroke Study

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Abstract

Objective—Missed diagnoses of acute ischemic stroke (AIS) in the ED may result in lost opportunities to treat AIS. Our objectives were to describe the rate and clinical characteristics of missed AIS in the ED, to determine clinical predictors of missed AIS, and to report tissue plasminogen (tPA) eligibility among those with missed strokes.

Methods—Among a population of 1.3 million in a five-county region of southwest Ohio and northern Kentucky, cases of AIS that presented to 16 EDs during 2010 were identified using ICD-9 codes followed by physician verification of cases. Missed ED diagnoses were physician-verified strokes that did not receive a diagnosis indicative of stroke in the ED. Bivariate analyses were used to compare clinical characteristics between patients with and without an ED diagnosis of AIS. Logistic regression was used to evaluate predictors of missed AIS diagnoses. Alternative diagnoses given to those with missed AIS were codified. Eligibility for tPA was reported between those with and without a missed stroke diagnosis.

Results—Of 2,027 AIS cases, 14.0% (n = 283) were missed in the ED. Race, sex, and stroke subtypes were similar between those with missed AIS diagnoses and those identified in the ED. Hospital length of stay was longer in those with a missed diagnosis (5 days vs. 3 days, $p < 0.0001$). Younger age (adjusted odds ratio [aOR] = 0.94, 95% confidence interval [CI] = 0.89 to

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Supporting Information

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0.98) and decreased level of consciousness (LOC) (aOR = 3.58, 95% CI = 2.63 to 4.87) were associated with higher odds of missed AIS. Altered mental status was the most common diagnosis among those with missed AIS. Only 1.1% of those with a missed stroke diagnosis were eligible for tPA.

Conclusion—In a large population-based sample of AIS cases, one in seven cases were not diagnosed as AIS in the ED, but the impact on acute treatment rates is likely small. Missed diagnosis was more common among those with decreased LOC, suggesting the need for improved diagnostic approaches in these patients.

Delayed diagnoses of acute ischemic stroke (AIS) may result in lost opportunities to treat and potentially worse outcomes.[1] Specifically, patients with AIS who are not diagnosed during their emergency department (ED) course will not receive time-sensitive and standard-of-care therapies recommended by the American Heart and American Stroke Associations.[2,3] Those with missed stroke diagnoses are also at risk for clinical deterioration and for not receiving appropriate secondary stroke prevention.

Although some previous studies have attempted to characterize missed stroke in the ED, these studies report wide variations in rates of missed stroke as well as conflicting information on demographic and clinical characteristics of missed strokes.[1,4] Previous studies of missed stroke in the ED have been retrospective, single-center studies, limiting their generalizability.[1,5] In addition, many previous investigations of missed strokes in the ED have focused on young stroke patients, have had very small sample sizes, or were based on convenience samples.[6,7] Also, some of the previous studies of missed strokes have not reported their rates of missed stroke. For example, a study by Dupre et al.[5] retrospectively identified missed strokes and described the most common missed diagnoses, but did not report rates of missed strokes or compare missed ED strokes to those identified in the ED. Data characterizing clinical aspects (including stroke subtypes) are also limited, although some previous suggests those patients with posterior circulation pathology are at higher risk of being missed in the ED.[6] Other data suggest that those patients with nontraditional symptoms are much more likely to have their symptoms misdiagnosed in the ED.[4]

Objectives

Overall, further investigation of the rate of missed AIS in the ED and of predictors of missed stroke diagnosis is needed. The first primary objective of our study was to use a large, population-based data set to report the rate of missed AIS in the ED. Our second primary objective was to characterize cases of missed AIS by comparing patient demographics, presenting symptoms, arrival times, stroke subtypes and locations, hospital type, and hospital length of stay to cases of AIS that were identified in the ED. Our secondary objectives were to evaluate predictors of missed ED stroke diagnoses in a multivariate regression analysis, to characterize alternate diagnoses given to patients with missed AIS, and to report tissue plasminogen (tPA) eligibility among those with missed diagnoses of stroke.

METHODS

Study Design and Setting

The Greater Cincinnati /Northern Kentucky Stroke Study (GCNKSS) is a population-based study of stroke cases among a population of approximately 1.3 million in a five-county region of southwestern Ohio and northern Kentucky. Every 5 years, data are collected over the course of a full calendar year and entered into the GCNKSS database. For example, during 2010, data were collected on all strokes among residents of the five-county study region and entered into the GCNKSS database. This database was then used to address our study objectives.

All cases of AIS among residents of the study region, aged 20 years or older, that presented to the region's 16 EDs during 2010 were first identified by screening primary and secondary discharge ICD-9 codes 430 to 436. Following this screening and review by study nurses, cases of AIS were verified by trained study physicians who were asked to classify each case as a stroke or not a stroke using all available information. Strokes occurring after patients were admitted as well as TIAs were excluded from analysis. Study nurses and physicians are trained extensively prior to case review, and detailed instructions are kept to guide reviewers on screening, abstraction and case review. Specifically, study physicians review all data from each case including clinical scenarios, presenting symptoms, and imaging (computed tomography [CT] and/or magnetic resonance imaging [MRI] images and reports). To be counted as a case, clinical information (presenting symptoms, examination findings) and imaging must be consistent with stroke and with each other. For example, during review, physicians ensure that presenting symptoms match MRI findings. In addition, senior investigators review a select sample of cases from all physician reviewers to ensure accuracy of case ascertainment, and any discrepancies or questionable cases are resolved by senior investigators. We have previously reported intraclass correlation and interrater reliability for identification of stroke cases and found excellent agreement.[8] Methodology for identification of strokes has also been published previously.[9] The institutional review board (IRB) at each participating hospital approved the study; there was no centralized IRB.

Data Collection/Outcome Measures

Criteria for missed versus not-missed diagnoses of stroke were predefined by study authors and based on ED admission diagnoses taken from the notes and final diagnoses of ED attending physicians. If patients were given diagnoses of stroke, rule-out stroke, cerebrovascular accident, transient ischemic attack, weakness, or numbness, these cases were categorized as not missed. Diagnoses of weakness/numbness were categorized as not missed to give treating ED physicians the benefit of the doubt and to avoid misclassifying cases in which ED physicians were concerned about stroke but used terms such as "weakness" or "numbness" rather than "stroke." Cases in which stroke was documented as a differential diagnosis in the ED physician note but not listed as the final admission diagnosis were categorized as not missed as well. All other diagnoses were considered missed. This included cardiac diagnoses, seizure, other neurologic diagnoses, fall/found down, headache, migraine, and diagnoses coded as "other." Diagnoses coded as "other" had associated text

descriptions. Study authors manually categorized diagnoses coded as “other” into the categories listed in Table 3.

Demographic and clinical data including sex, age, race, medical comorbidities, completion of brain imaging in the ED, mode of arrival, ED length of stay, arrival during peak hours, and hospital length of stay were abstracted from patient medical records by study staff. Peak hours were defined as Monday through Friday between 7 and 10 AM 6 PM as per prior literature. ED presenting symptoms were abstracted from patients’ medical records and assigned among eight categories: focal weakness, focal numbness, decreased level of consciousness (LOC), speech difficulties, headache, vision changes, dizziness, and other (e.g., nausea/vomiting, generalized weakness, pain, ataxia, and gait difficulty). Time to arrival was treated as a dichotomous variable and categorized as arrival within 3 hours of symptom onset versus arrival after more than 3 hours. Hospitals were categorized as academic or community.

AIS subtypes were categorized by study physicians into large vessel, small vessel, cardioembolic, other identified cause, or undetermined etiology. “Other” causes of stroke included cocaine use, dissection, surgery (perioperative or immediate postoperative), angiography/catheterization/percutaneous transluminal coronary angioplasty, cancer, hypercoagulable states, or venous thrombosis. Study physicians also categorized AIS by location, anterior or posterior.

Finally, data regarding whether patients worsened clinically after moving from the ED to the inpatient setting were abstracted from patient records. Specifically, study physicians recorded whether patients deteriorated with regard to symptoms or mental status in relation to the acute stroke; dates and times of clinically worsening were also recorded.

Data Analyses

Baseline characteristics of stroke cases were described using means with standard deviations (SDs) for continuous variables and frequencies and proportions for categorical variables. Baseline characteristics were compared between those with missed ED diagnoses and those who received ED diagnoses consistent with AIS using chi-square tests for categorical variables, t-tests for normally distributed variables, and Wilcoxon rank-sum tests for non-normally distributed variables.

Stroke subtypes and length of stay were compared between patients with and without an ED diagnosis of AIS using chi-squared test and the Mann-Whitney U-test, respectively. A generalized linear mixed model using a logit link was used to evaluate predictors of missed diagnoses; hospital site was included as a random effect. Potential covariates included demographic variables (age, race, and sex), stroke subtypes, NIH Stroke Scale (NIHSS), presenting symptoms, comorbidities, and hospital type (academic/community). NIHSS scores were determined by study staff retrospectively. Covariates that were significantly associated with missed AIS in bivariate analyses ($p < 0.15$) were entered into the initial model, and a stepwise backward elimination approach was used to find the most parsimonious model. Stepwise regression was used, as the purpose of this analysis was to generate hypotheses about significant predictors of missed stroke diagnoses. For the final

regression model, a Type I error rate of 0.05 was used, and adjusted odds ratios (aOR) with 95% confidence intervals (CIs) were reported. Model diagnostics were performed to examine model fit and examine effect of any potential outliers. Finally, descriptive statistics were used to report the alternate diagnoses given to those with missed diagnoses of AIS in the ED.

Eligibility for tPA based on standard[2] and European Cooperative Acute Stroke Study (ECASS) criteria[11] were determined for those diagnosed with stroke in the ED and for those in the missed stroke group. For a list of specific eligibility criteria used, see Data Supplement S1 (available as supporting information in the online version of this paper). For all data analyses, p-values of 0.05 or less were considered statistically significant. All data analyses were performed with SAS version 9.3.

RESULTS

Our study included 2,027 confirmed cases of AIS that presented to an ED or had stroke in the ED. Of these, 14.0% (n = 283) had an ED diagnosis that was inconsistent with AIS and thus were considered to be potentially missed AIS.

Among those with a missed diagnosis of AIS, 56.5% (n = 160) were women, 22.6% (n = 64) were black, and the mean (±SD) age was 69.5 (±15.5) years. Those whose AIS diagnosis was missed were similar in sex, age, race, and medical history compared with those diagnosed with stroke in the ED (Table 1). Patients with a missed ED AIS diagnosis had slightly lower NIHSS scores than those with identified strokes in the ED (median = 2, interquartile range [IQR] = 0–7 vs. median = 3, IQR = 1–7; p = 0.01).

The distribution of presenting symptoms also varied between those with a missed stroke diagnosis and those given diagnoses consistent with stroke; for example, a greater proportion of those diagnosed with stroke in the ED had unilateral weakness (77.5%, n = 1352 vs. 49.1%, n = 139; p < 0.0001) or numbness (40.9%, n = 713 vs. 18.7%, n = 53; p < 0.0001) compared to those with missed stroke. Additionally, those with missed stroke were more likely to have a symptom coded as “other” (60.1%, n = 170 vs. 51.4%, n = 896; p = 0.007). Within the “other” category, more patients in the missed diagnosis group presented with nausea/vomiting compared to those diagnosed with stroke in the ED (24.6%, n = 69 vs. 11.9%, n = 207, p < 0.0001; not shown in table).

ED length of stay was longer in the missed diagnosis group compared to those with stroke diagnosed in the ED, although the difference did not appear clinically important (median = 4.8 hours vs. 4.5 hours, p < 0.0001). The median length of stay in an acute care hospital was 2 days longer for those with missed AIS diagnoses compared with those diagnosed in the ED (5, IQR = 3–8 vs. 3, IQR = 2–5, p < 0.0001). The percentage of missed diagnoses in the community hospitals did not differ significantly from the percentage missed in the academic hospitals (Table 1).

The distribution of stroke subtypes among those with missed ED AIS was not significantly different from the distribution of subtypes among those diagnosed with AIS in the ED (p = 0.18). A greater proportion of those with missed ED AIS were posterior strokes, though,

compared to those with ED diagnoses indicative of stroke (29.0%, *n* = 82 vs. 22.6%, *n* = 394; p = 0.008). Those with missed ED AIS and those diagnosed with AIS in the ED were similar with respect to the proportion that demonstrated clinical neurologic worsening after leaving the ED (12.7%, *n* = 36 vs. 11.8%, *n* = 205; p = 0.64).

Our final regression model examining predictors of missed ED AIS diagnosis included age, prior stroke, and several presenting symptoms (focal weakness, focal numbness, decreased LOC, speech difficulties, and vision changes; Table 2). Patient sex and race did not meet criteria for inclusion in the initial model according to the bivariate associations between these factors and missed ED AIS diagnosis. Older age was associated with decreased odds of missed AIS (aOR = 0.99, 95% CI = 0.98 to 1.0 for each 1-year increase). Presenting symptoms that were associated with decreased odds of missed ED AIS diagnosis included focal weakness and focal numbness. Those presenting with focal weakness were 62% less likely to have missed ED AIS diagnoses (95% CI = 0.31 to 0.48). The only symptom that was associated with an increase in the likelihood of missed ED diagnosis of AIS was decreased LOC; those with a decreased LOC had 3.58 times greater odds of having missed ED AIS (95% CI = 2.68 to 4.84). The overall p-value for the final model was significant at <0.0001. The model had adequate fit as per the Hosmer and Lemeshow goodness-of-fit test (χ^2 = 8.07, df = 8, p = 0.43).

Those with a missed ED diagnosis of AIS had a large variety of hospital admission diagnoses; they included altered mental status, cardiac diagnoses, infections, and other neurologic diagnoses (Table 3). The most common diagnosis given to patients with missed ED diagnosis of AIS was altered mental status, which accounted for 35.3% of the patients with missed ED AIS. Though most patients with an ED diagnosis of altered mental status did present with a decreased LOC (98%, *n* = 98), other symptoms commonly reported in this group included speech difficulties (67%, *n* = 67) and “other” (53%, *n* = 53).

Given the large number of those with missed diagnoses of stroke and decreased LOC as a symptom (*n* = 192), further descriptive analyses were performed. Of note, of patients presenting with missed stroke and a decreased LOC, 25.5% (*n* = 49) had posterior strokes compared to 36.3% (*n* = 33) of those without a decreased LOC. Among those presenting with decreased LOC and missed diagnoses of stroke, other diagnoses that were given included altered mental status (*n* = 98, 51.0%), myocardial infarction (*n* = 10, 5.2%), seizure (*n* = 12, 6.2%), and fall (*n* = 10, 5.2%).

In regard to tPA eligibility, fewer patients with a missed ED AIS diagnosis arrived within 3 hours of symptom onset (17.7%, *n* = 50) compared to those diagnosed in the ED (26.6%, *n* = 463, p = 0.001). When all standard eligibility criteria were applied, 6.9% (*n* = 120) of those given ED diagnoses consistent with stroke were eligible for tPA treatment, while only 1.1% (*n* = 3) of those with missed stroke diagnoses were eligible for tPA. Similar results were obtained when ECASS criteria were applied; 1.1% (*n* = 3) of those with missed stroke diagnoses were tPA-eligible, while 7.0% (*n* = 123) of those with stroke diagnosed in the ED were eligible for tPA.

DISCUSSION

In our population-based study, 14.0% of the cases of ischemic stroke that either presented to or occurred in the ED were not diagnosed in the ED. Previously, rates of missed AIS diagnoses in the ED have been sporadically reported, based on single-center studies, and have varied widely. For example, a recent single-center study from a Swiss stroke registry reported a missed diagnosis rate of 2.1%,[1] whereas another single-center study reported a missed diagnosis rate of 15.3%,[4] closer to our estimate. It is likely that our estimate, based on a population-based data set of stroke cases among a population of 1.3 million people, is more representative of missed strokes in EDs across the United States than previous estimates, especially that of the Swiss stroke registry.[1] Their estimate of 2.1% was obtained from a sample of stroke patients admitted to the stroke unit or intensive care unit of a single center, academic institution in which neurology consults are ordered on the majority of patients. Their estimate of missed stroke diagnoses is less likely to be generalizable as it was conducted at a single academic hospital compared to our study that was conducted across 16 acute hospitals (many of them community-based). The fact that the Swiss study did not include patients not admitted to the stroke unit also likely contributed to their low rate of missed strokes. Compared to our findings of a missed rate of 14.0%, we propose that a more acceptable rate of missed strokes would be in the range of 1 to 2%, especially among those who are eligible for acute therapies.

It is unlikely that missed diagnoses of AIS in the ED were a result of clinical deterioration after patients left the ED or a separate event, as there was no significant difference in the proportion of patients who had clinical neurologic worsening after leaving the ED between those with missed ED strokes and those with strokes identified in the ED. It is also possible that 14% is a slight underestimate of missed AIS events, as we did not account for patients that were discharged from the ED, in whom previous literature has suggested a small number of strokes may be missed on the initial presentation.[12–16]

There are many factors that may have contributed to presumed diagnostic error in our study, one of which is anchor bias, especially in cases in which other diagnoses were more apparent. For example, in patients with clinical evidence for myocardial infarction or atrial fibrillation, physicians may have anchored on such diagnoses and not identified stroke. In fact, a significant portion of patients with missed diagnoses of stroke had other diagnoses (i.e., infection, renal disorders, syncope) that could have led to diagnostic errors including anchor bias. Higher illness severity (i.e., patients in clinical distress) could have also led to missed diagnoses if physicians were more focused on stabilizing and/or resuscitating the patient. Although we do not have data on the proportion of cases seen by neurology in the ED, it is also very possible that neurology consultants may have also missed stroke diagnoses in the ED in cases on which they were consulted. This has been shown in previous literature in which it was reported that neurology contributed to 57% of missed stroke diagnoses.[1]

We hypothesized that each missed stroke represented a potentially missed opportunity to provide treatment with tPA and/or endovascular interventions in the early hours of cerebral infarction, but our analysis showed that only a very small proportion of those in the missed

stroke group were eligible for tPA, despite almost 20% arriving with 3 hours of symptom onset. These data suggest that despite a large proportion of potentially missed strokes, the impact on acute therapy is likely small. Those patients with missed stroke diagnoses, however, may be at risk for not receiving timely interventions for secondary prevention of stroke. Future studies should investigate missed opportunities for secondary prevention as well as other outcomes in those with missed stroke diagnoses including mortality and functional outcomes after hospital discharge.

Significant predictors of missed AIS in the ED in our study included younger age and decreased LOC, whereas patients with traditional stroke symptoms including focal weakness and focal numbness were less likely to have missed diagnoses of AIS. Our finding that young age is associated with missed stroke diagnoses is consistent with prior literature[1,7] and suggests that further education of both providers and young people regarding stroke is warranted. Our finding that patients who presented with a decreased LOC were more likely to have missed diagnoses of AIS in the ED suggests the need for improved diagnostic tools in the acute setting, especially for patients who may be eligible for time-sensitive therapies. Stroke may be more difficult to diagnose in altered patients due to factors such as difficulty obtaining an accurate history or a detailed neurologic examination in someone who is not able to follow complex commands.

One approach to aid in the diagnosis of acute stroke in altered patients in the acute setting could potentially include rapid MRI protocols, although patient selection criteria for use of such protocols would need to be developed to ensure adequate diagnostic yield and cost-effectiveness. In the appropriate sample of patients, the increased sensitivity of MRI for acute infarct could potentially allow for improved diagnosis in altered patients for whom stroke is on the differential.[17,18] Alternatively, the use of other imaging modalities such as CT angiography in select altered patients could be used to identify potential strokes.

Another approach would be to identify aspects of the history or physical examination of patients with altered mental status that may prompt clinicians to consider ischemic stroke sooner in the diagnostic process. For example, we found that “speech difficulties” were a common presenting symptom among those given a diagnosis of altered mental status. Given that altered mental status and speech changes may be highly associated with each other even in some patients without stroke (i.e., overdose, intoxication), it is possible that some patients with dysarthria or aphasia (expressive or receptive) secondary to stroke are assumed to be altered because of their speech deficit; this speculation would require prospective confirmation. More knowledge about specific predictors of stroke among cohorts of patients diagnosed with altered mental status could be used to help clinicians diagnose stroke in the setting of altered mental status.

We expected to find an association between stroke subtype and missed ischemic stroke, specifically that missed stroke diagnosis was more common among those with less common stroke subtypes, especially those in the “other” category that included arterial dissection and venous sinus thrombosis. There was no significant association, but it is possible that we lacked the power to detect such an association, as less than 5% of our stroke cases fell into the other category. Another possibility, though, is that stroke etiology has less of an effect on

ED providers' ability to diagnose AIS in the ED compared with other factors, namely, presenting symptoms and age. Finally, we found that posterior strokes were more common among those with missed ED diagnoses, which is consistent with other studies that have reported an association between posterior circulation strokes and missed ED diagnoses.[1,6]

Our finding that patients with a missed diagnosis of AIS had longer hospital lengths of stay was consistent with our hypotheses and may have important cost implications. It must be noted, however, that this was a secondary study objective, and we did not adjust for potential confounders; we cannot be sure that missed diagnosis of stroke was the primary contributor to longer length of stay. Daily hospitalization costs for ischemic stroke patients have been estimated at $1,600,[19] and we found that those with missed ED AIS had median lengths of stay that were 2 days longer than those without missed AIS. Future projects should be designed to measure possible confounding factors that may affect length of hospital stay and care costs, including illness severity and in-hospital complications (e.g., hospital-acquired pneumonia and urinary tract infections). Future studies could also measure actual cost differences between patients with and without missed ED AIS diagnoses.

LIMITATIONS

Our study has some limitations. First, we could not capture potential diagnostic uncertainty of the physicians, physician perception, or the impact of competing diagnoses. It is also possible that ED providers documented correct alternative diagnoses but did not document stroke diagnoses if they felt stroke was not the primary issue. Furthermore, we did not have data on inter-rater reliability of ED diagnoses. There may be other factors such as provider experience, incomplete neurologic examinations, and ED capacity affecting missed stroke diagnoses for which we could not account. We could also not account for whether neurology consults occurred in the ED and what impact that may have had on the number of missed diagnoses. We included only admitted patients and could not describe patients with missed AIS diagnoses who were discharged from the ED. Finally, our data are from 2010, the most recent data currently available. It is unlikely, however, that patterns of missed stroke diagnoses in the ED have changed significantly since 2010.

CONCLUSIONS

In conclusion, nearly one in seven cases of acute ischemic stroke were not given an admission diagnosis consistent with stroke in the ED, suggesting that a large number of strokes are potentially missed in the ED. Our findings also suggest, however, that only a small proportion of these patients would be eligible for acute therapies. Further research should be performed to assess the impact of missed stroke on secondary prevention. Younger age was associated with missed strokes, pointing to the need for more education to increase providers' awareness of stroke in young people. The single largest alternative diagnosis was altered mental status, suggesting the need for more research and improved approaches to diagnosing stroke in this patient subgroup.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Selected Characteristics of Patients

	Those With Missed ED AIS Diagnoses (*n* = 283)	Those With ED Diagnoses Indicative of Stroke (*n* = 1744)	p-value
Gender (female), *n* (%)	160 (56.5)	961 (55.1)	0.65
Age, mean (SD)	69.5 (±15.5)	69.4 (±14.8)	0.91
Race (black), *n* (%)	64 (22.6)	372 (21.3)	0.63
Presenting symptom, *n* (%)			
Focal weakness	139 (49.1)	1352 (77.5)	<0.0001
Focal numbness	53 (18.7)	713 (40.9)	<0.0001
Decreased LOC	192 (67.8)	676 (38.8)	<0.0001
Speech	161 (56.9)	1143 (65.5)	0.005
Headache	63 (22.3)	414 (23.7)	0.59
Vision	54 (19.1)	400 (22.9)	0.15
Dizziness/vertigo	57 (20.1)	311 (17.8)	0.35
Other	170 (60.1)	896 (51.4)	0.007
Arrival by EMS, *n* (%)	185 (67.0)	936 (53.9)	<0.0001
Arrived at ED < 3 h of stroke onset, *n* (%)	50 (17.7)	463 (26.6)	0.001
Prior stroke, *n* (%)	66 (23.3)	471 (27.0)	0.19
Diabetes mellitus, *n* (%)	103 (36.4)	621 (35.6)	0.80
Hypertension, *n* (%)	237 (83.8)	1406 (80.6)	0.21
Hyperlipidemia, *n* (%)	144 (50.9)	933 (53.5)	0.41
Atrial fibrillation, *n* (%)	67 (23.7)	366 (21.0)	0.31
NIHSS, median (IQR)	2 (0–7)	3 (1–7)	0.01
Stroke subtype, *n* (%)			
Small vessel	40 (14.1)	314 (18.0)	0.18
Large vessel	34 (12.0)	248 (14.2)	
Cardioembolic	83 (29.3)	457 (26.2)	
Other known	17 (6.0)	69 (4.0)	
Undetermined	109 (38.5)	656 (37.6)	
Stroke location, *n* (%)			
Anterior	160 (56.5)	1181 (67.7)	0.0008
Posterior	82 (29.0)	394 (22.6)	
Other/unknown	41 (14.5)	169 (9.7)	
Brain imaging completed in ED, *n* (%)	232 (83.8)	1698 (97.4)	<0.0001
Academic hospital, *n* (%)	29 (10.2)	213 (12.2)	0.34
Length of stay (days), median (IQR) [range]	5 (3–8) [0–30]	3 (2–5) [0–59]	<0.0001
ED Length of stay in hours, median (IQR)	4.8 (3.7–6.7)	4.5 (3.5–5.8)	<0.0001
Arrival during peak hours (Monday through Friday 7:00 AM–6:00 PM), *n* (%)	176 (63.5)	1124 (64.5)	0.77

"Other" symptoms included nausea/vomiting, pain, ataxia, gait difficulty, as well as other symptoms that did not fall into the other seven categories.

AIS = acute ischemic stroke; ED = emergency department; EMS = emergency medical services; LOC = level of consciousness; NIHSS = National Institute of Health Stroke Scale.

Table 2

Factors Associated With Missed Diagnosis of Acute Ischemic Stroke in the ED

Variable	aOR (95% CI)	p-value
Age (in 1-y increments)	0.99 (0.98–1.00)	0.002
Prior stroke	0.75 (0.57–0.99)	0.043
Weakness present	0.38 (0.31–0.48)	<0.0001
Numbness present	0.49 (0.34–0.69)	<0.0001
Decreased LOC	3.58 (2.65–4.84)	<0.0001
Speech problem	0.52 (0.39–0.68)	<0.0001
Vision changes	0.65 (0.47–0.90)	0.01

Age was treated as a continuous variable. Hospital site was included as a random variable in the model.

aOR = adjusted odds ratio; LOC = level of consciousness.

Table 3

Diagnoses Given to Those With Missed AIS in the ED

Diagnosis Description	Percentage of All Missed Cases (*n* = 283)
Altered mental status	35.3% (*n* = 100)
Cardiac (other than MI)	11.7% (*n* = 33)
Myocardial infarction	6.7% (*n* = 19)
Infections	6.7% (*n* = 19)
Other neurologic diagnoses	6.0% (*n* = 17)
Renal/electrolyte problems/dehydration	6.0% (*n* = 17)
Found down/unresponsive	5.7% (*n* = 16)
Seizure	4.9% (*n* = 14)
Syncope/near-syncope	4.6% (*n* = 13)
Unknown	4.2% (*n* = 12)
Headache/migraine	3.9% (*n* = 11)
Gastrointestinal	3.5% (*n* = 10)
Respiratory (other than infectious)	2.8% (*n* = 8)
Trauma/injury	2.5% (*n* = 7)
Diabetes complications	2.1% (*n* = 6)

Cardiac diagnoses included atrial fibrillation, congestive heart failure, and cardiac arrest. Infectious diagnoses included pneumonia, urinary tract infections, and cellulitis. Other neurologic diagnoses included hypertensive encephalopathy, cerebral edema, Bell's palsy, benign positional vertigo, and intracerebral mass. Gastrointestinal diagnoses included nausea/vomiting and gastrointestinal bleeding. Respiratory diagnoses included chronic obstructive respiratory disease and respiratory failure. Some patients were given multiple alternate diagnoses.

MI = myocardial infarction.