Accuracy of Two Scores in the Diagnosis of Stroke Subtype in a Multicenter Cohort Study

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Study objective: The distinction between hemorrhagic and ischemic stroke has critical implications for management. For that purpose, clinical scores have been proposed to be used in areas with limited health care resources where brain computed tomographic (CT) scan is not readily available. We conducted this study to evaluate the predictive value of the Allen and Siriraj scores in the differential diagnosis of stroke subtypes.

Methods: We prospectively collected data for 4 years on the clinical characteristics of patients with stroke in a multicenter study. For all patients, we calculated the Allen and the Siriraj scores and we assessed their accuracy in predicting stroke subtypes with receiver operating characteristics (ROC) curves.

Results: We assessed 1,023 patients. Of these, 82.7% (n=846) had ischemic stroke. The area under the ROC curve was higher for Siriraj score compared with the Allen score (0.780 versus 0.702; P=.04). Using the original cutoff points, Siriraj score has a sensitivity for the diagnosis of hemorrhage of 60% and a specificity of 95%; the corresponding values for the Allen score are 55% and 70%, respectively. The negative predictive value was higher for Siriraj score compared to the Allen score (90% versus 80%). The diagnosis of stroke subtype was best predicted at Siriraj score less than −4.

Conclusion: Siriraj score is a valid and useful tool for predicting stroke subtype in a clinical setting in which financial constraints make systematic brain CT scan unfeasible. [Ann Emerg Med. 2009;53:373-378.]

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INTRODUCTION

Early detection of intracranial blood is essential for the rational use of antihemostatic drugs in stroke patients. Clinical differentiation of stroke types is often challenging even for experienced physicians, and the computed tomographic (CT) scan has now become the main component of the diagnosis.[1-3] In areas with limited brain imaging facilities, scoring models have been proposed to clinically distinguish hemorrhage from infarction.[4,5] The Allen and Siriraj scores are the 2 main existing models derived from logistic regression techniques and devised to differentiate clinically between hemorrhagic and ischemic stroke.[4-6] Despite initial reports of favorable accuracy, their clinical use has proved limited by the conflicting results observed in the following validation studies.[7-13] Accordingly, the application of these models to a different population can be done only once they have been tested and validated on that population because demographic and ethnic differences could have a significant effect on their performance. We therefore aimed to validate and compare the Allen and Siriraj scores in a large independently selected group of Tunisian patients by using discrimination statistical methods.

MATERIALS AND METHODS

Three tertiary care centers, all with 24-hour access to CT, were involved in this prospective study. All patients older than 45 years and hospitalized in one of the 3 participating centers for acute stroke during a 4-year period (January 2001 to December 2005) were systematically included. The diagnosis of acute stroke was based on the World Health Organization definition: acute neurologic deficit lasting more than 24 hours with no alternative to vascular cause. Patients were included in the study at presentation but no later than 72 hours after stroke onset. Patients were included if their symptoms were present for

Editor's Capsule Summary

What is already known on this topic

Neuroimaging for patients with acute stroke is often unavailable in developing countries. Treatment decisions, including the use of aspirin and antithrombotic medications, must be made on clinical criteria.

What question this study addressed

With what accuracy can consciousness, vomiting, headache, blood pressure, and atherosclerotic risk factors differentiate ischemic from hemorrhagic stroke?

What this study adds to our knowledge

The Siriraj clinical score correctly categorized 85% of the 695 acute ischemic strokes and 63% of the 144 acute hemorrhagic strokes, as defined by computed tomographic (CT) imaging in Tunisia.

How this might change clinical practice

In the developing world, when brain CT is unavailable clinical scoring can predict stroke subtypes, albeit imperfectly. Scoring may influence treatment, guide allocation of limited neurosurgical and imaging resources, or improve epidemiologic data in these countries.

more than 30 minutes, were not rapidly improving, and were distinguishable from other causes such as syncope, seizure, migraine, or hypoglycemia. Patients with previous severe neurologic disorder and receiving anticoagulant therapy were excluded.

The study was approved by the ethical review board of Monastir University Hospital in Tunisia, which waived informed consent because this was a descriptive study without intervention.

DATA COLLECTION

Before this study was started, meetings were organized with emergency physicians in community-based hospitals surrounding the 3 participating centers. They were asked to transfer all their patients with suspected stroke to the nearest tertiary care center within 24 hours of stroke attack. In each of the participating centers, there is a coordinating physician who assessed all patients in detail and reviewed the standardized data collection forms.

After patients' admission, clinical data were prospectively collected, including patients' demography, comorbidity, and all variables required to calculate Allen and Siriraj scores (Table 1). Results of laboratory tests performed on admission were also recorded and included WBC counts, blood glucose urea nitrogen coagulation tests, chest radiography, and 12-lead ECG. The collected data set included vital status at hospital discharge and type of stroke according to the findings of brain CT scan. All scans were reviewed by both radiologist and neurologist. If there was a disagreement, a third expert was involved and a second CT scan was performed if required 24 to 72 hours later to confirm or to exclude cerebral infarction. The 2 clinical scores were calculated before obtaining the results of the CT

Table 1. The Allen and Siriraj stroke scores.

Variable	Clinical Feature	Score
Allen score		
Apoplectic onset (loss of consciousness, headache within 2 h, vomiting, neck stiffness)	One or none of these	0
	Two or more	21.9
Level of consciousness (24 h after admission)	Alert	0
	Drowsy	7.3
	Unconscious	14.6
Plantar responses	Both flexor or single extensor	0
	Both extensor	7.1
Diastolic blood pressure (24 h after admission, in mm Hg)	Times	0.17
Atheroma markers (angina, claudication, diabetes history)	None	0
	One or more	–3.7
History of hypertension	Not present	0
	Present	–4.1
Previous event (transient ischemic attack or stroke)	None	0
	Any number of events	–6.7
Heart disease	None	0
Aortic or mitral murmur		–4.3
Cardiac failure		–4.3
Cardiomyopathy		–4.3
Atrial fibrillation		–4.3
Cardiomegaly (from radiograph)		–4.3
Myocardial infarct (within 6 mo)		–4.3
Constant		–12.6
Siriraj score		
Consciousness	Alert	0
	Drowsy or stupor	2.5
	Coma or semicoma	5
Vomiting	No	0
	Yes	2
Headache (within 2 h)	No	0
	Yes	2
Diastolic blood pressure (in mm Hg)	Times	0.1
Atheroma markers (history of diabetes, intermittent claudication, or angina)	None	0
	One or more	–3
Constant		–12

Table 2. Demographic and clinical characteristics of patients with either cerebral infarction or intracranial hemorrhage.

Characteristics	Hemorrhage, N=177		Infarction, N=846		Differences (95% CI)	
Age, y	69	(26)	67	(9)	2	(–2 to 6)
Male sex	104	(59)	412	(49)	10%	(2 to 18)
Comorbidity						
Diabetes	51	(29)	295	(35)	–6%	(–13.4% to 1.4%)
Hypertension	123	(70)	510	(60)	10%	(2.5% to 17.5%)
Previous TIA	20	(11)	151	(18)	–7%	(–12.3% to –1.7%)
Myocardial infarction	1	(1)	15	(2)	–1%	(–2.7% to 0.7%)
Atrial fibrillation	12	(7)	97	(11)	–4%	(–8.3% to 0.3%)
Hyperlipidemia	4	(2)	77	(9)	–7%	(–9.8% to –4.2%)
Clinical presentation at admission						
Headache	72	(40)	262	(31)	9%	(1.1% to 16.9%)
GCS	14	(8)	12	(1)	2	(–2.6 to 6.9)
Vomiting	11	(7)	44	(5)	2%	(–2% to 6%)
Dizziness	46	(26)	138	(16)	10%	(–0.3% to 20.3%)
Hemiparesis	151	(85)	736	(87)	–2%	(–7.7% to 3.7%)
Systolic blood pressure, mm Hg	176	(55)	177	(36)	–1	(–9.5 to 7.5)
Diastolic blood pressure, mm Hg	93	(24)	99	(36)	–6	(–10.3 to –1.7)
Pulse rate, beats/min	85	(18)	83	(16)	2	(–1 to 5)
Death rate	50	(28.2)	65	(11.2)	17%	(7.6% to 26.4%)
Length of hospital stay, days	10.5	(6)	9.0	(5)	1.5	(0.5 to 2.5)
Allen score	16	(5)	5	(3)	11	(8.6 to 13.4)
Siriraj score	0.5	(0.8)	–2.5	(1.3)	3	(1.2 to 4.8)

TIA, Transient ischemic attack; *GCS,* Glasgow Coma Scale.
Data are given as mean±SD or number of patients and percentage of each group, as appropriate.

scan. All patients' records were finally checked for accuracy by the study coordinator (S.N.).

PRIMARY DATA ANALYSIS

All values were calculated as means and SD unless otherwise stated. Predictive accuracy of the models was assessed using receiver operating characteristic (ROC) curves (discrimination). The ROC curve shows the ability of the scores to discriminate between ischemic and hemorrhagic strokes. The cutoff levels for the 2 scores reported in the original studies were used to calculate sensitivity, specificity, and positive and negative predictive values with standard methods. Comparison between areas under the ROC curves was done using the z statistic according to methods of Hanley and McNeil.[14] $P<.05$ was accepted as statistically significant. Statistical analysis was performed with SPSS software (version 11; SPSS, Inc., Chicago, IL).

RESULTS

Data were collected on 1,200 consecutive stroke patients. Their ethnic profile is white and was representative of the Tunisian population. Of these, 177 were excluded because of missing variables required to calculate the scores. In this subset of patients, demographic and clinical characteristics were similar to those of the rest of the population. Thus, 1,023 patients were included and formed the basis of this study. Patients' demographics in both groups, including comorbidity, diagnostic category, and hospital outcome, are summarized in Table 2. All the included patients had their brain CT scan within 72 hours of stroke onset. The mean delay from the onset of stroke to brain scanning was 29 hours, with 81.1% of CT scans being performed within 48 hours. The prevalence of hemorrhage was 17.3% (n=177) and 82.7% (n=846) for infarction. The Allen and Siriraj scores were significantly higher in the group with hemorrhage. When we applied the original cutoff levels for the diagnosis of hemorrhage and infarction, agreement between the 2 scores was observed in 722 (70.5%) patients (Table 3). The score values were in the uncertain ranges in 268 (26.2%) patients for Allen score and in 174 (17.0%) patients for Siriraj score. Figure 1 shows the individual distribution of Allen (Figure 1A) and Siriraj scores (Figure 1B) in patients with hemorrhage and infarction. Comparison of Allen and Siriraj scores with results of CT is shown in Table 4. Area under the ROC curve was significantly higher with Siriraj score (0.78; 95% confidence interval [CI] 0.75 to 0.82) than with Allen score (0.70; 95% CI 0.66 to 0.74), as shown in Figure 2 ($P<.05$).

Table 3. Diagnostic agreement of Allen and Siriraj scores.

	Allen Score		
	Hemorrhage	Infarction	Uncertain
Siriraj score			
Hemorrhage	122	4	69
Infarction	9	518	117
Uncertain	21	71	82

The sensitivity of the 2 scores for hemorrhage was 63% and 49%, respectively, for Siriraj and Allen scores. Conversely, both scores had higher specificity (85% and 84% for Siriraj and Allen scores, respectively) and negative predictive value (92% and

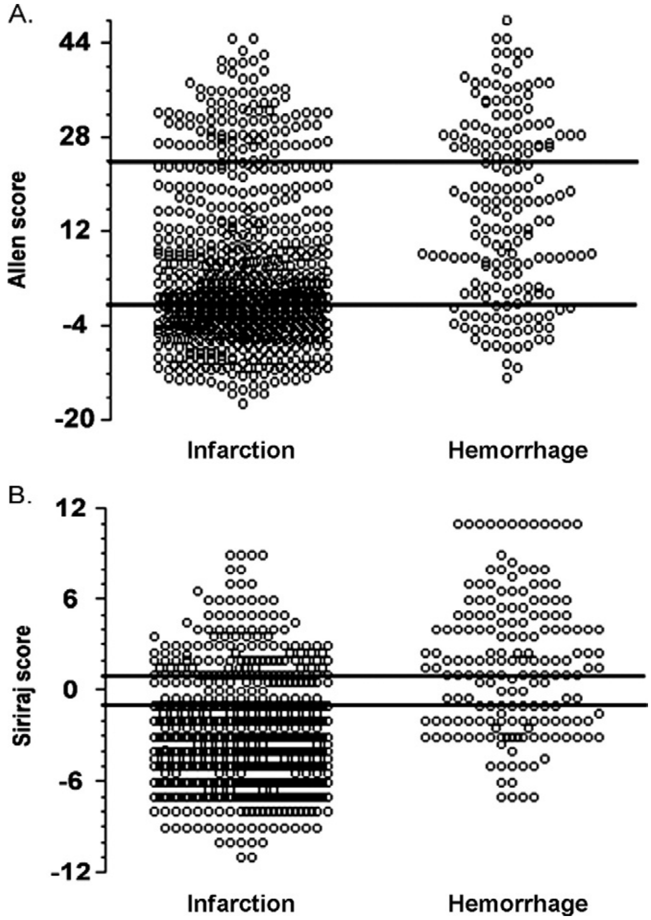

Figure 1. *A*, Individual values (open circles) of Allen score in patients with hemorrhagic stroke and ischemic stroke. Bold lines indicate threshold values that predicts infarction (<4), hemorrhage (>24) and uncertain range (4 to 24). *B*, Individual values (open circles) of Siriraj score in patients with hemorrhagic stroke and ischemic stroke. Bold lines indicate threshold values that predicts infarction (<–1), hemorrhage (>1) and uncertain range (–1 to 1).

Table 4. Comparison of stroke subtype predicted by Allen score with results of CT.

	CT	
	Hemorrhage	**Ischemia**
Allen score		
Hemorrhage	52	100
Ischemia	53	540
Siriraj score		
Hemorrhage	91	104
Ischemia	53	591

91% for Siriraj and Allen scores, respectively), with an overall accuracy of 81% and 79%, respectively. In patients with a Siriraj score less than −4 (n=369), only 16 patients (4.1%) had hemorrhagic stroke. At this cutoff, the negative predictive value was 96%.

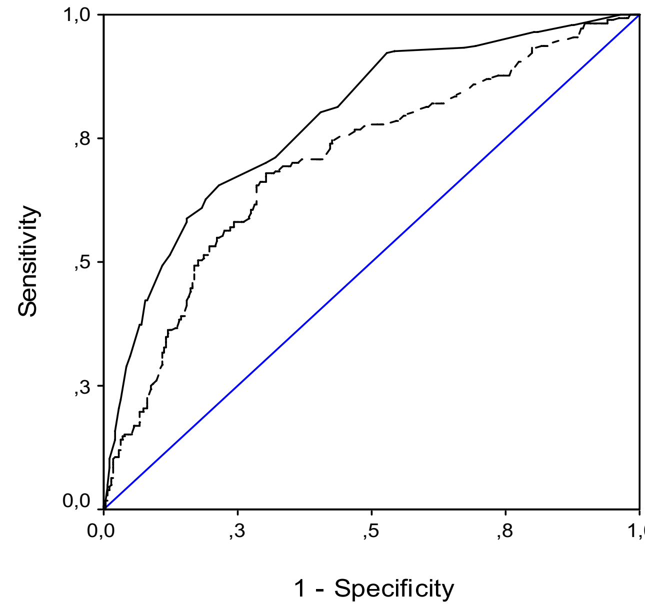

Figure 2. ROC curves with Siriraj score (continuous line) and Allen score (dotted continuous line). Area under the curve was significantly higher with Siriraj score (0.78 versus 0.70; *P*<.05). The line straight down the middle represents the area under the curve of 50%, which means pure chance correlation.

LIMITATIONS

There are several potential limitations to our study that should be acknowledged. First, although our study has the largest sample size, it may not reflect the full spectrum of patients with stroke because we did not include those admitted to nonteaching hospitals or patients treated in an ambulatory setting. However, many of these patients were secondarily transferred to our emergency departments to be investigated with CT scan. Second, although data collection reliability was checked, we acknowledge that some classification errors could not be excluded. The assessment of the level of consciousness and particularly the Glasgow Coma Scale score in intubated, sedated patients is clearly open to much interpretation, with significant intraobserver and interobserver variability. However, for accurate collection of data, we dedicated data collectors with a consistent clinical background. Accordingly, it seems unlikely that few incorrect values would substantially change the final results. Third, although most of our findings would be equally applicable to other developing countries, differences in types and causes of stroke need to be taken into account when our results are extrapolated. Fourth, more needs to be known about the real effects of using the Siriraj score in routine clinical practice. Such experience should be investigated to provide the evidence for its potential benefit.

DISCUSSION

Stroke is an important public health problem that dramatically affects millions of people annually and incurs enormous and direct costs.[1] In countries with limited health care facilities, it is clear that not all victims of stroke will have access to brain imaging procedures. According to a recent review, the use of imaging differs considerably in developing countries. However, it was reported that 18 African countries had no CT scanners and 13 countries had 1 each.[15] Accordingly, scoring systems that aid the clinical distinction between cerebral hemorrhage and ischemia could be useful because they may allow to initiate appropriate treatment without the need for CT scan.

We performed this prospective cohort study to externally assess the performance of the Allen and Siriraj scores. Overall, we found for both models an acceptable discrimination power, as assessed by the area under the ROC curves. Both scores had good negative predictive value and specificity but had low sensitivity in the diagnosis of cerebral hemorrhage. The discriminatory power of the Siriraj score system was higher than that of the Allen score system.

It is important that the performance of available scoring systems be assessed in a sample of new patients outside the original study context. Given some differences in patient characteristics, it is not surprising that the predictive power of the Allen and Siriraj scores in the present cohort was less than that reported in original studies. Because of the relatively low proportion of patients with hemorrhagic stroke, the positive predictive values for both scores were uniformly low in our study cohort compared with those of other studies.[16-19] Indeed, the Siriraj score is validated in a population with a high proportion of hemorrhagic stroke,[4] and the Allen score was developed in patients younger than 76 years, which would overestimate their positive predictive value.[6] Previous external validation studies assessing these scores found conflicting results, but many of them have been conducted in a small sample size and they were retrospective in their design. A recent South African study[17] conducted in 222 patients showed that both Allen and Siriraj scores failed to diagnose more than 80% of stroke, even with a new cutoff score. The high proportion of intracranial hemorrhage (70 of 222 [32%]) and the low rate of CT scan performed (222 of 329 [68%]) in this study may explain the discrepancy with our study results. In addition, in that study, patients with uncertain scores were included in the final assessment of the scores' performance. Two other retrospective African studies have reported a low performance for the Siriraj score. Their findings could not be generalized to other settings because of the small sample size (Nigerian study [n=96]; Ethiopian [n=41]). In the retrospective study conducted in United Kingdom[20] and suggesting a poor accuracy of both scoring systems for differential diagnosis of stroke subtype, less than half of the patients included had complete data. The convention applied in that study, assuming that individual patient value for particular variable is scored 0 if it is not recorded or uncertain, would bias the score performance for patients who had limited available data. Using the same cutoff as in the original description, our results were consistent with those found in some studies conducted in other developing countries.[11,21] Although the degree of performance is not perfect, the high negative predictive value suggests that these scores may be more useful as a "rule out" than a "rule in" tool. As for the majority of our patients for whom thrombolytics are not a therapeutic option, using a score that could exclude intracranial hemorrhage with a reasonable degree of medical certainty would encourage physicians in remote areas to initiate anticoagulation or at least early aspirin therapy.

When there is evidence that a given prediction model is not fully appropriate in a particular clinical setting, apart from the development of a new model, one can usually improve diagnostic performance by refitting the model (customization) or expanding it. Developing a new model derived from a single institution requires a new validation process in stroke cohorts from other institutions, which will likely lead to more controversial results. Expanding the Siriraj or the Allen scores by adding routinely collected variables would improve their prediction without increasing the burden of data collection. However, when we added new clinical variables to those included in the Siriraj and the Allen scores (data not shown), the resulting area under the ROC curve did not significantly change. Seemingly, there was not much information added to the models by including more variables. It is also unlikely that combining the 2 scores would increase the accuracy because they share many common variables.

The ideal score to predict stroke type should have a good balance between validity, simplicity, and utility. The superiority of the Siriraj score over the Allen score is first related to its better discrimination. Second, the Siriraj score is more advantageous because it is simple to collect and immediately available, whereas the Allen score requires 24 hours to be calculated. Third, the use of Siriraj score is likely to result in a substantial cost saving in low-income countries. The indiscriminate use of CT scan may result in increased health care costs. The considerable number of patients would make it impossible to follow the ideal strategy of free access to CT to all stroke patients. At a cutoff value of −4, nearly 38% of all stroke patients could be treated safely without the need for CT scan. We believe that this rate reduction in the number of CT scans by using stroke scores would potentially save much money. With this cutoff, only a low proportion of patients screened for acute stroke would be diagnosed wrongly as having ischemic stroke. In addition, for academic and epidemiologic goals, the Siriraj score could be a useful instrument to classify strokes when systematic CT scans could not be performed.

In conclusion, while a more accurate clinical scoring system is awaited, the use of the Siriraj score could be particularly suitable in developing countries with poor access to brain imaging; this would lead to better patient care and cost-effective management.

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