Identifying Stroke in the Field
Prospective Validation of the Los Angeles Prehospital Stroke Screen (LAPSS)

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Background and Purpose—Reliable identification of stroke patients in the field by prehospital personnel could expedite delivery of acute stroke therapy. The Los Angeles Prehospital Stroke Screen (LAPSS) is a 1-page instrument designed to allow prehospital personnel to rapidly identify acute stroke patients in the field. We performed a prospective, in-the-field validation study of the LAPSS.

Methods—Paramedics assigned to 3 University of California at Los Angeles–based advanced life support units were trained and certified in use of the LAPSS. Over 7 months, paramedics completed the LAPSS on noncomatose, nontrauma patients with complaints suggestive of neurological disease. LAPSS form stroke identification results were compared with emergency department and final hospital discharge diagnoses. Sensitivity, specificity, positive predictive value, negative predictive value, accuracy, and likelihood ratios were calculated for LAPSS identification of ischemic stroke, currently symptomatic transient ischemic attack, and intracerebral hemorrhage.

Results—Of a total of 1298 runs, 34% were for nontraumatic, noncomatose neurologically relevant complaints. Thirty-six of these patients (3% of all transports) had a final diagnosis of acute symptomatic cerebrovascular disease (21 ischemic strokes, 7 transient ischemic attacks, and 8 intracerebral hemorrhages). LAPSS forms were completed on 206 patients. Paramedic performance when completing the LAPSS demonstrated sensitivity of 91% (95% CI, 76% to 98%), specificity of 97% (95% CI, 93% to 99%), positive predictive value of 86% (95% CI, 70% to 95%), and negative predictive value of 98% (95% CI, 95% to 99%). With correction for the 4 documentation errors, positive predictive value increased to 97% (95% CI, 84% to 99%).

Conclusions—The LAPSS allows prehospital personnel to identify patients with acute cerebral ischemia and intracerebral hemorrhage with a high degree of sensitivity and specificity. (Stroke. 2000;31:71-76.)

Key Words: emergency medical services ■ stroke, acute ■ stroke assessment

Despite several years of education and experience since the Food and Drug Administration approved intravenous tissue plasminogen activator as the first effective treatment for acute ischemic stroke, >95% of cerebral infarction patients are still not receiving thrombolytic therapy.1–3 Presentation beyond the narrow 3-hour therapeutic time window continues to be the leading reason for treatment disqualification, indicating an urgent need to develop methods that decrease delays to presentation.2–7

The importance of the 911 system in optimizing rapid transport for patients with acute stroke has been demonstrated in several studies.8–11 Since emergency medical services (EMS) provide the first medical contact for 35% to 70% of all stroke patients,9,10,11 prehospital personnel are in a unique position to reduce delays in presentation and treatment.12 Reliable identification of stroke patients in the field could decrease delays by permitting paramedics to notify receiving hospitals by radio or cellular phone of the imminent arrival of a stroke case. Prehospital notification allows rapid mobilization of stroke teams and early access to a CT scanner on hospital arrival.

However, prior studies have found that the accuracy of stroke identification by paramedics and emergency medical technicians (EMTs) is modest and variable from one community to another. Sensitivity for stroke recognition by prehospital personnel has ranged widely, and positive predictive values have remained between 64% and 77%.13–15 These studies have consistently suggested a tendency for prehospital personnel to overdiagnose stroke by not recognizing stroke mimics, such as patients with alcohol and drug intoxication, postictal hemiparesis, hypoglycemia or other metabolic encephalopathies, and other nonstroke causes of acute neurological deficits.

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We developed the Los Angeles Prehospital Stroke Screen (LAPSS) as a stroke recognition tool designed specifically for prehospital personnel (Figure). The LAPSS was constructed employing hypothesis-driven test design methodology using a modified Delphi approach. It is a 1-page instrument that takes 3 minutes to complete and consists of 4 history items, a blood glucose measure, and 3 examination items designed to detect unilateral motor weakness. Items were chosen not only to identify the most common acute stroke patients but also to exclude likely stroke mimics. In a prior retrospective study, the LAPSS demonstrated a high degree of sensitivity for identifying ambulance-arriving stroke patients, and a substantial theoretical time savings was calculated if paramedics had initiated neuroprotective drug administration in the field. The present study was designed to characterize the real-life test performance of the LAPSS in a prospective, in-the-field validation study.

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Subjects and Methods
The Los Angeles City Fire Department (LAFD) provides a 2-tiered EMS system employing approximately 500 paramedics staffing 58 advanced life support (ALS) rescue ambulances and 9 ALS engine companies serving a population of 3.7 million persons in Los Angeles. We identified the paramedics assigned to the 2 LAFD rescue ambulances and 1 paramedic engine for which the University of California at Los Angeles (UCLA) Medical Center is the primary receiving hospital. In a 60-minute LAPSS-based stroke training session, 3 of the authors (C.S.K., S.S., K.W.) educated these paramedics on use of the LAPSS as well as general emergency stroke care knowledge, emphasizing accurate stroke identification and rapid transport.

A brief certification tape was created that consisted of 5 video vignettes of paramedics performing the LAPSS examination on 3 stroke patients, 1 stroke mimic (alcohol intoxication), and 1 normal subject. After the LAPSS-based education session, we administered the certification tape, requiring the paramedics to complete the LAPSS examination on each vignette. Certification for use of the LAPSS required correct completion of the LAPSS examination on all 5 patients. If certification was not achieved on the first trial,
paramedics underwent further education in a small group setting focused on typical examination errors and then repeated the certification examination until all 5 patients were correctly identified. To both reinforce and determine the impact of the training sessions, we administered a 19-item stroke knowledge test before and after the education session. The test included 8 items regarding stroke symptoms and diagnosis, 7 questions regarding acute stroke care, and 4 items regarding stroke pathophysiology.

The sole inclusion criterion for entry into the study was transport by a paramedic vehicle involved in the study during the enrollment period. These patients constitute the “all runs” population.

A “target stroke” population was predefined as noncomatose, nontrauma patients with symptom duration under 24 hours with either ischemic stroke, intracerebral hemorrhage, or transient ischemic attack (TIA) if the patient was still symptomatic at the time of initial paramedic examination. These patients constitute the population the LAPSS was designed to identify.

In the 2-stage LAPSS screening process, paramedics were asked (1) to identify all noncomatose, nontrauma patients having neurological complaints, ie, potential stroke or stroke mimics patients, and then (2) to complete LAPSS forms on this subset of patients. LAFD regulations require that paramedics complete a run sheet that includes a medical history field with a checklist of 28 symptom categories on every patient transported. A panel of prehospital care and stroke experts identified 6 categories as being potentially relevant for neurological disorders and stroke. These included (1) altered level of consciousness, (2) local neurological signs, (3) seizure, (4) syncope, (5) head pain, and (6) the cluster category of weakness/dizzy/sick. Examples of categories that were not neurologically relevant included chest pain, allergic reaction, abdominal pain, and shortness of breath. Accordingly, criteria for LAPSS form completion were as follows: (1) age ≥18 years, (2) neurologically relevant complaint, (3) absence of coma, and (4) nontraumatic presentation. We tracked compliance levels for completion of the LAPSS form on the indicated runs and provided feedback to the paramedics on a monthly basis.

For all runs, 1 blinded author (K.W.) reviewed emergency department department charts, recorded final emergency department discharge diagnoses, and confirmed absence or presence of potential stroke symptoms. During the study period, all hospitalized patients with final diagnoses of stroke were identified by review of the UCLA stroke service patient logs (the UCLA Stroke Service is routinely consulted on every emergency department stroke patient).

On all potential target stroke runs (patients meeting LAPSS form completion criteria), 1 blinded author (C.S.K.) additionally examined all inpatient medical records to confirm hospital discharge diagnoses of ischemic stroke, intracerebral hemorrhage, and TIA by review of reports from imaging studies and attending physician notes. For patients with the diagnosis of TIA, a consensus on final diagnosis was reached after complete medical record review and case discussion with a second stroke neurologist (J.L.S.). In all cerebral infarct and intracerebral hemorrhage patients, the diagnosis of the blinded reviewer agreed with the chart diagnosis of the attending neurologist. For ischemic stroke patients, National Institute of Health Stroke Scale (NIHSS) scores were calculated on the basis of the emergency physician’s or admitting neurologist’s examination.

Data were entered into a Microsoft Access database, and statistical analyses were performed with STATA software. We calculated sensitivity, specificity, positive predictive value, negative predictive value, and accuracy for LAPSS performance in identifying our prespecified target stroke population. These variables were calculated for runs in which an LAPSS form was completed (“LAPSS form completed runs”) and for the “all runs” population.

Our primary outcome measure was actual test performance as achieved by paramedics in the field (termed “rater performance”). Rater performance analyses were based on the paramedics’ response to final item No. 10 (LAPSS criteria for stroke met: Yes or No). However, on the basis of both our initial experience with the paramedics’ performance during video certification and that reported by others,19 we suspected that inadvertent documentation errors might occur. We therefore planned a secondary analysis to determine the LAPSS performance after correction for documentation errors as an overall efficacy measure (termed “instrument performance”). Instrument performance analyses corrected for any documentation errors made by the paramedics in completing the form, such as failing to follow form instructions, leaving blanks, or appearing to inadvertently check the wrong box at the end of the form.

Both positive and negative likelihood ratios were calculated for rater performance.20 CIs for the likelihood ratios were calculated by bootstrapping with the use of the “bstrap” command in STATA 6.0 with 1000 replicates. Because of the low frequency of false-positives, the upper limit of the CI may be somewhat underestimated. Analyses of individual LAPSS items were performed to determine the contribution of each item in identifying true strokes and excluding mimics. The study was approved by the UCLA Medical Center Institutional Review Board.

Results

Paramedic Training

Of the 18 paramedics who participated in the prospective validation study, 15 completed the initial training sessions (3 paramedics were initially unavailable but later completed training). Twelve of these 15 (80%) demonstrated 100% proficiency on the LAPSS certification tape on the first trial. The remaining 3 were certified on the second trial after a brief additional training session. Of a total of 75 video patient ratings, 72 were correctly identified on the initial trial as stroke versus nonstroke by LAPSS criteria, for an overall diagnostic accuracy rate of 96%. All 3 errors were false-positives occurring in the intoxicated, stroke mimic patient.

The mean score for the 15 paramedics on the 19-question stroke knowledge pretest was 63% (range, 9 to 17 correct answers), improving to 82% (range, 12 to 18 correct answers) on the posttest, for a mean absolute improvement of 19% (95% CI, 13% to 26%). Thirteen of the 15 paramedics improved their scores from the pretest to the posttest (P<0.0005, paired t test). The 2 others had high baseline scores of 89%.

Prospective Validation Study

Data were collected on all paramedic runs made between September 24, 1997, and April 30, 1998. During this period, paramedics from these 3 ALS vehicles transported 1298 patients to UCLA Medical Center. Of these, 446 (34%) met criteria for nontraumatic, noncomatose neurological runs. Four hundred six had 1 of the 6 neurologically relevant categories marked, and an additional 40 patients had 1 of these symptoms clearly evident in the paramedic’s written history.

Of the 1298 total runs, 49 patients had a final diagnosis of ischemic stroke, intracerebral hemorrhage, or TIA, and of these, 36 were target stroke patients. Of the 13 cerebrovascular patients not meeting target stroke criteria, 6 were comatose at the time of transport, 6 were TIA patients who were no longer symptomatic at the time of transport, and 1 patient presented beyond the 24-hour time window. LAPSS performance analyses were therefore based on the 36 target stroke cases, of which 21 had a final diagnosis of ischemic stroke, 8 intracerebral hemorrhage, and 7 TIA.

Of the 446 patients with a neurologically relevant symptom, LAPSS forms were completed on 206. For the 36 target stroke patients, LAPSS forms were completed on 34. Among
the 446 patients with a neurologically relevant symptom, mean age was 63.3 years (median, 70 years); 48% were female and 52% male. There was no difference in the proportion of men and women in the neurological patients with LAPSS forms completed versus those without LAPSS forms completed; however, the groups did differ in age (mean age, 67 versus 60 years; \( P = 0.001 \)). None of the patients who failed to meet LAPSS form completion criteria had a final diagnosis of target stroke.

Among the 36 target stroke patients, mean age was 77.7 years (median, 80 years); 18 were female and 18 male. Median duration from symptom onset to time of paramedic examination for the 36 target stroke patients was 1 hour and 15 minutes (mean, 4 hours and 13 minutes; range, 15 minutes to 19 hours and 30 minutes).

When performed in the field by trained paramedics in this population, the LAPSS demonstrated a high degree of sensitivity, specificity, positive predictive value, negative predictive value, and accuracy. These data are provided in Table 1 for rater performance for LAPSS form completed runs and for all runs. For instrument performance on LAPSS form completed runs, sensitivity was 91% (95% CI, 76% to 98%); specificity, 99% (95% CI, 97% to 99%); positive predictive value, 97% (95% CI, 84% to 99%); negative predictive value, 98% (95% CI, 96% to 99%); and accuracy, 98% (95% CI, 95% to 99%). For instrument performance on all runs, sensitivity was 89% (95% CI, 74% to 97%); specificity, 99.9% (95% CI, 99% to 100%); positive predictive value, 97% (95% CI, 84% to 99%); negative predictive value, 99.7% (95% CI, 99% to 100%); and accuracy, 99.6% (95% CI, 99% to 100%). The LAPSS also demonstrated very favorable likelihood ratio performance (Table 2).

Of the 5 rater false-positive cases, 4 were attributed to documentation errors. In 2 patients, the paramedics checked “Yes” for the final item “LAPSS criteria met” when, in fact, none of the criteria had been met; this error was attributed to inadvertently checking the wrong box. In 2 other cases, the paramedics did not follow the LAPSS form instructions, eg, checking “Yes” for “LAPSS criteria met” when they had previously documented at least 1 history exclusion criterion. There were 5 rater false-negative cases. LAPSS forms were not completed on 2 ischemic stroke patients, and these were counted as rater false-negatives. When we corrected for documentation errors, there were 4 instrument false-negative cases and 1 instrument false-positive case.

The mean presenting NIHSS score for the 21 ischemic stroke patients was 13 (range, 2 to 25). Seven patients were candidates for thrombolytic therapy (6 were actually treated), and all 7 were correctly identified by the LAPSS.

An analysis of the individual LAPSS items revealed that each of the LAPSS history, blood glucose, and examination items was valuable in identifying true strokes while excluding potential stroke mimics. Using the criterion of age <45 years did not eliminate any true strokes but did exclude 47 patients with neurological symptoms that were not related to stroke. No stroke patient was excluded because of history of seizure or epilepsy, while 22 potential stroke mimics were excluded. Symptom duration >24 hours eliminated 1 patient with intracerebral hemorrhage and 10 potential stroke mimics. Baseline wheelchair bound or bedridden criteria did not eliminate any true strokes but did eliminate 14 potential mimics with neurological symptoms. The blood glucose <60 and >400 mg/dL criterion did not exclude any true strokes but did exclude 4 potential mimics. The serum glucose measures were recorded on 61% of LAPSS completed forms. In the remaining patients, the initial emergency department serum glucose measure was within the range permitted by the LAPSS (60 to 400 mg/dL).

Each of the 3 examination items also proved valuable in identifying the target stroke patients. Including facial weakness as part of the LAPSS examination identified 2 TIA patients and 1 ischemic stroke patient not identified by grip or arm weakness alone. Three ischemic stroke patients were identified by grip weakness alone, and 1 ischemic stroke patient was identified by arm drift alone. Bilateral weakness excluded 6 potential stroke mimics while eliminating only 2 true stroke cases, both not candidates for aggressive intervention (these figures likely underestimate the number of poten-

**TABLE 1. LAPSS Rater Performance Characteristics for LAPSS Form Completed Runs and All Runs**

<table>
<thead>
<tr>
<th>LAPSS Form Completed Runs (n=206)</th>
<th>All Runs (n=1298)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TP</strong></td>
<td><strong>FP</strong></td>
</tr>
<tr>
<td>31</td>
<td>5</td>
</tr>
<tr>
<td><strong>FN</strong></td>
<td><strong>TN</strong></td>
</tr>
<tr>
<td>3</td>
<td>167</td>
</tr>
</tbody>
</table>

Sensitivity Specificity Accuracy Sensitivity Specificity Accuracy
91% (76–98) 97% (93–99) 96% (92–98) 86% (70–95) 99% (99–100) 99% (99–100)

*Values in parentheses are 95% CI. TP indicates true-positives; FP, false-positives; FN, false-negatives; TN, true-negatives; PPV, positive predictive value; and NPV, negative predictive value.*

**TABLE 2. LAPSS Likelihood Ratios: Rater Performance**

<table>
<thead>
<tr>
<th>LAPSS runs</th>
<th>All runs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive LR (95% CI)</td>
<td>0.09 (0–0.21)</td>
</tr>
<tr>
<td>Negative LR (95% CI)</td>
<td>0.14 (0.03–0.26)</td>
</tr>
</tbody>
</table>

*LR indicates likelihood ratio.*
tial stroke mimic patients with bilateral weakness since the examination was often completed only on patients without other exclusion criteria).

**Discussion**

The LAPSS was designed to allow prehospital personnel to rapidly identify the most frequent types of stroke patients while excluding common stroke mimics (e.g., seizure or hypoglycemia) or patients unlikely to qualify for, or benefit from, acute stroke interventions (e.g., those with symptom duration >24 hours or wheelchair bound or bedridden at baseline). Eliciting the time of onset for the LAPSS prompts prehospital personnel to document this critical decision-guiding data when events are most fresh in the minds of the patient and observers. The examination tests for unilateral face, arm, and/or grip weakness and emphasizes motor deficits for several reasons. Not only do 80% to 90% of all stroke patients have unilateral motor weakness, but additionally, motor weakness is a major determinant of long-term disability. Motor weakness is even more likely to be present in the type of stroke patients activating the 911 system. In addition, testing for motor weakness can be easily and reliably performed by medical personnel not specifically trained in neurology.

By collecting data on initial medical symptom categories and all final diagnoses, we found that prehospital personnel encounter a large number of patients with potentially neurologically relevant complaints (one third of patients during our study period), but of these, very few had a final diagnosis of acute cerebrovascular disease. The ratio of nonstroke, neurologically relevant patients to actual target stroke patients encountered by paramedics in the field was 11:1. The high rate of potential stroke mimics to true strokes emphasizes that a prehospital stroke identification instrument must have very high specificity. Potential stroke mimics must be identified and excluded to avoid overfrequent activation of stroke teams and exhaustion of cerebrovascular emergency response systems.

Patients with trauma were excluded from this study for 3 reasons. First, trauma patients will automatically be transported at an emergent level of priority under existing trauma protocols. Second, the great majority of neurological deficits in trauma patients are caused by traumatic brain injury rather than ischemic stroke. Third, major recent trauma is a contra-indication to thrombolytic stroke therapy. Similarly, comatose patients were excluded from this study because they will automatically be transported under existing coma protocols and often have etiologies other than focal cerebrovascular disease for the neurological deficit.

Using an LAPSS-based training session, we were able to educate paramedics in use of the LAPSS, confirm paramedic LAPSS proficiency employing a certification tape, and significantly improve overall paramedic stroke knowledge. Subsequently, when used in the field, paramedics employing the LAPSS demonstrated a high degree of sensitivity, specificity, and positive predictive value in identifying symptomatic cerebrovascular patients. Correcting for documentation errors further increased the positive predictive value. Most documentation errors appeared to reflect an understandable tendency of paramedics to overinclusiveness, most commonly a tendency to check “Yes” for “LAPSS criteria met” for patients found to have an explicit exclusion item on the LAPSS form. Further training would likely ameliorate such documentation errors. In addition, this type of error could easily be screened for and identified by the base station or receiving hospital at the time of radio notification.

One limitation of this study is the overall modest completion rate of LAPSS forms by paramedics of nonstroke neurological runs. This reflects paramedic disinclination to complete forms solely for study purposes when stroke is not a likely possibility. This modest completion rate is not a threat to the validity of the study because we performed analyses of all runs made by paramedics whether or not forms were completed. These analyses still demonstrated an excellent performance of the overall 2-stage LAPSS screening process.

It is instructive to consider the few patients misidentified by the LAPSS (instrument false-positives and false-negatives). The 1 instrument false-positive involved a patient with a prior left hemiparesis and new syncopal events. Distinguishing new strokes from exacerbations of old strokes is a difficult diagnostic challenge in the hospital as well as the prehospital setting. Of the 4 instrument false-negatives, 1 involved a patient with dementia and an old left hemiparesis who developed a new right hemiparesis, with resulting bilateral weakness on examination. A second involved a patient with a new right hemiparesis and simultaneously an acute myocardial infarction and an acute gastrointestinal bleed with a hematocrit of 20%, who demonstrated bilateral weakness on paramedic examination. A third case involved a patient with mild, isolated left lower extremity weakness due to small anterior cerebral artery stroke. The fourth case involved a patient with a midline cerebellar hemorrhage and no focal findings.

As illustrated, these false-negative patients generally fell in the very mild or very severe extremes of acute neurological/medical insult, beyond the wide central range of deficits that are optimal targets for emergent interventions with thrombolysis or experimental neuroprotective agents. Exceptional patients with isolated field cuts, patients with isolated aphasias, and some patients with brain stem and cerebellar strokes will be missed when the LAPSS criteria are used. Broadening the LAPSS criteria to detect these rare cases, however, would likely not yield many additional candidates for acute interventional stroke therapy but would surely compromise instrument specificity, ease, and simplicity.

Several groups have begun to design education programs and instruments to aid prehospital personnel in stroke identification. Other approaches besides the LAPSS include the Cincinnati Prehospital Stroke Screen, NIHSS-based curricula, and the Tele-BAT ambulance remote-video system. The LAPSS is the first prehospital stroke identification tool to be prospectively validated in an actual in-the-field study.

The LAPSS could be immediately applied to reduce delays to treatment and improve delivery of conventional intravenous thrombolytic therapy. Once paramedics identify a patient meeting LAPSS stroke criteria in the field, rapid
transport could be initiated and the receiving hospital immediately notified by radio or cellular phone. Prearrival mobilization of the stroke team and CT could expedite in-hospital treatment to meet the recommended target of door-to-needle time of 60 minutes.28 An emerging potential use of the LAPSS is identification of appropriate stroke patients for transportation to designated “stroke critical care centers,” for example, to receive intra-arterial thrombolytic therapy.29 A possible future application of the LAPSS is to guide paramedics in initiating neuroprotective drug therapy in the field, employing agents of likely benefit for both ischemic and hemorrhagic stroke.30–32

In conclusion, paramedic training and certification in use of the LAPSS was achieved with a short LAPSS-based training session during which paramedics demonstrated improved general stroke care knowledge. In a prospective, in-the-field trial, trained prehospital personnel were able to identify acute stroke patients with a high degree of accuracy using the LAPSS. Use of the LAPSS has the potential to lead to earlier stroke treatment and better patient outcome.

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References
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