Houston Paramedic and Emergency Stroke Treatment and Outcomes Study (HoPSTO)

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Background and Purpose—Establishment of stroke centers, combined with accurate paramedic diagnosis and rapid transport, is essential to deliver acute stroke therapy. We wanted to measure and improve paramedic and hospital performance through implementation of the Brain Attack Coalition and American Stroke Association guidelines.

Methods—Pre-intervention and active-intervention phases with parallel data measurement points were used. The study involved six hospitals comprising the majority of acute-stroke admissions in Houston, Tex. Hospital, paramedic, and patient data were collected prospectively pre-intervention and during the active-intervention phase on all suspected acute-stroke patients admitted by Houston Fire Department–Emergency Medical Services. A multilevel educational intervention included paramedic, hospital, and community education. Paramedic diagnostic accuracy, hospital-performance efficiency, and thrombolytic treatment rates were the main outcome measures of the study.

Results—Four hundred forty-six patients (74 per month) were transported in the pre-intervention phase to participating hospitals (59.8% of all suspected stroke patients transported city wide by Houston Fire Department–Emergency Medical Services), compared with 1072 patients (89 per month, or 68.7%) transported in the active-intervention phase ($P<0.001). Accuracy of paramedic diagnosis of stroke increased from 61% to 79%. Admission within 2 hours of symptom onset increased from 58% to 62% ($P=0.002). Thrombolysis rates increased in 4 of 6 centers, with 1 post–tissue plasminogen activator hemorrhage (3.7%) reported.

Conclusions—A multilevel educational program improves rapid hospitalization and paramedic diagnostic accuracy and increases the number of patients presenting for evaluation within the 3-hour tissue plasminogen activator window. Stroke center development supports safe thrombolytic practice in community settings. (Stroke. 2005;36:1512-1518.)

Key Words: community health services ■ education ■ paramedics ■ stroke, acute ■ thrombolytic therapy

Stroke represents a significant medical problem in the United States, with annual estimates of new cases approximating 700 000, of which 160 000 result in death.1,2 As the leading cause of adult disability, stroke produces significant burden for individuals and communities, carrying lifetime costs averaging $90 000 per patient for ischemic stroke, $124 000 per patient for intracranial hemorrhage, and $225 000 per patient in the case of subarachnoid hemorrhage.3

In 1997, a national consensus conference identified the need to establish designated stroke centers where patients with suspected stroke could receive emergent, comprehensive care.4 The Brain Attack Coalition5 (BAC) furthered this recommendation with a framework for stroke center development adopted by the American Stroke Association (ASA), along with published performance indicators for stroke centers to support program development and ongoing practice improvement.6 The set of ASA guidelines Get with the Guidelines—Stroke7 was recently developed to promote stroke center development, and, most recently, the Joint Commission on Accreditation of Health Care Organizations launched a certification program for Primary Stroke Centers supported by the BAC and ASA guidelines.8 It is expected that formal stroke center recognition will consolidate resources such as diagnostic capabilities and personnel trained to assess and implement evidenced-based practices, as well as make evident to the public the location of centers able to support the needs of stroke victims.

Developing cooperation among competing hospitals to facilitate stroke center development is complex, and effecting improvement in public recognition of stroke warning signs has been shown to be difficult, yet essential.9–11 Similarly, facilitating change in paramedic prehospital care and transport practices is challenging, although these factors have been identified as significant contributors to timely emergency department (ED) arrival,12,13 ultimately effecting thrombolysis candidacy. In this study, we sought to develop citywide stroke centers and improve prehospital paramedic performance to increase the number of patients receiving acute stroke treatment.
Subjects and Methods

The research goal of the study was to determine whether parallel programs of paramedic, hospital, and community education improved stroke care in Houston. The study was approved by the Committee for Protection of Human Subjects at all sites and the Houston Fire Department (HFD) and took place from September 1999 to March 2001.

Houston, Tex, is a multiethnic city of approximately 5 million. Data from operating year 1998 indicated that HFD paramedics transported a total of 2382 suspected stroke patients; ~75% of these cases were transported to 1 of 9 Houston hospitals, 4 of which are centrally located in the Texas Medical Center, whereas the remaining 5 hospitals are located within the greater Houston community. All 9 top-admitting hospitals were approached to participate in the study, and 6 hospitals agreed to participate in the project. Of the 3 hospitals declining participation, rationale included lack of administrative and medical professional incentive because of low stroke reimbursement and disinterest in thrombolysis (2 centers) and no ability to assign a staff person to assume the role of hospital study coordinator/stroke registrar because of nurse staffing shortage (1 center).

Characteristics describing the 6 participating hospitals are presented in Table 1. Hospital 1 had served as a stroke center since 1988, and Hospital 5 became a stroke center in 1997. The remaining 5 hospitals are located within the greater Houston community. All 9 top-admitting hospitals were approached to participate in the study, and 6 hospitals agreed to participate in the project. Of the 3 hospitals declining participation, rationale included lack of administrative and medical professional incentive because of low stroke reimbursement and disinterest in thrombolysis (2 centers) and no ability to assign a staff person to assume the role of hospital study coordinator/stroke registrar because of nurse staffing shortage (1 center).

Pre-intervention and active-intervention data were collected from paramedic run sheets and hospital charts. Paramedic cases were identified by paramedic diagnosis of stroke documented, and study variables included time from dispatch to arrival on scene, scene time, time associated with transport to a study hospital, and time from symptom onset to arrival in the ED. Hospital data were collected prospectively and reviewed again when the medical record was closed; variables included door to brain computed tomography (CT) interpretation times and treatment with intravenous tissue plasminogen activator (tPA), as identified by physician order and documentation of infusion. Final discharge diagnoses were collected to determine paramedic diagnostic accuracy. Patients transported to Hospital 1 by HFD that were not diagnosed by paramedics with stroke were screened during the last 3 months of the pre- and active-intervention phases to determine final ED diagnoses for use in sensitivity and specificity calculations. Two data collectors were used, with one assuming entry of all data into a project registry; a 10% random sample of project registry cases was used monthly to determine inter- and intrarater reliability, consistently revealing 100% agreement. Data were entered and analyzed using SPSS (Version 11; SPSS); dichotomous variables were analyzed for differences by χ², whereas continuous variables were analyzed for differences by Student t test for independent samples or 1-way ANOVA.

Results

A total of 446 suspected stroke patients (on average 74 patients per month) were transported by HFD paramedics to one of the 6 hospitals during the 6-month pre-intervention period, representing 59.8% of the total cases of HFD-EMS diagnosed stroke patients transported within the city of Houston during this period. During the active-intervention phase, 1072 suspected stroke patients (on average 89 patients per month) were transported by HFD-EMS to the same hospitals, accounting for 68.7% of stroke cases transported in Houston (P<0.001). Overall, 852 (56%) patients were female, the mean age was 69 years (SD=30; median=71), and ethnicity was 2% Asian, 14% Hispanic, 40% black, and 44% white; these characteristics were similar in both study phases (P=not significant [NS]).

Symptom Onset to Emergency Department Arrival

During the pre-intervention period, time from suspected stroke onset to arrival at a study hospital was documented in 359 (80.5%) cases from patient and/or witness interview by the ED medical team; in this sample, time from onset of symptoms to arrival in a study site ED ranged from 14 to 4320 minutes, with an interquartile range of 177 minutes (mean=226 minutes; SD=347; median=95 minutes). In the active-intervention phase, time from suspected stroke onset to arrival at a study site was documented by the ED medical team in 680 cases (63%) and ranged from 10 to 20160 minutes, with an interquartile range of 156 minutes (mean=358; SD=1486; median=89 minutes; P=NS). Excluding outliers arriving beyond 24 hours of symptom onset, a decrease in time from symptom onset to arrival in the ED that approached statistical significance was noted in the active-intervention phase (mean=180 minutes; t=1.97; P=0.054), compared with the pre-intervention phase (mean=214 minutes). Arrival at <120 minutes from symptom onset was analyzed for differences because of implications for intravenous tPA treatment; with equal variances assumed (Levene test, P=0.09), 210 (38%) pre-intervention compared with 418 (62%) active-intervention suspected stroke patients arrived within 120 minutes (t=3.09; P=0.002; mean difference, 6.37; 95% CI=2.3 to 10.4). No differences in symptom onset to arrival time by gender, age, or ethnicity were identified.

Paramedic Diagnostic Accuracy

Definitive medical diagnosis, determined by neurologist diagnosis of stroke, was verified in 323 (72%) charts during the
pre-intervention phase and 895 (84%) charts in the active-intervention phase. During the pre-intervention phase, paramedic diagnosis of stroke was accurate in 61% (n=1198; positive predictive value =0.61) of cases, compared with 79% (n=709; positive predictive value =0.79) accuracy in the active-intervention phase. Of the cases misdiagnosed by paramedics as stroke in both phases, the most common definitive diagnoses were seizure disorders, altered mental status, headache, and syncope. Review of 10,564 HFD-EMS patients transported to Hospital 1 identified 32 (0.3%) cases of stroke that were missed by paramedics during the pre-intervention phase; in the active-intervention phase, 11,296 reviewed cases transported to Hospital 1 revealed 39 (0.3%) stroke cases missed by HFD-EMS. For patients transferred by HFD-EMS to Hospital 1 during the pre-intervention period, sensitivity for paramedic diagnosis of stroke was 86% with a specificity of 99%, compared with 95% sensitivity in the active-intervention phase with a specificity of 98%.

**Paramedic Transport Times**
Transport time data were available in 445 (99.8%) of pre-intervention cases and 1063 (99.2%) of active-intervention cases (Figure 1). Time from dispatch to arrival on the scene of a suspected stroke case remained unchanged by the intervention; however, the average time paramedics spent on the scene preparing for hospital transport significantly increased following the intervention (P<0.001), as did total time from dispatch to arrival at a hospital study site (P<0.001). In both the pre-intervention and active-intervention phases, community-based hospitals located outside the Texas Medical Center averaged significantly shorter (P<0.001 both phases) total dispatch to hospital arrival times compared with those sites within the Texas Medical Center (Table 2). Figure 2 illustrates HFD-EMS patient distribution by hospital and study phase. Hospital 1 received the majority of cases in both phases.

**Emergency Department Arrival to CT Interpretation Time**
During the pre-intervention phase, door to CT interpretation times were documented in 261 (59%) cases, of which 180 were medically confirmed strokes; in the active-intervention phase, 600 (56%) cases had door to CT interpretation times documented, of which 450 were medically confirmed strokes (Table 3). In both “suspected” and medically confirmed strokes, door to CT times were significantly better in both the pre-intervention and active-intervention phases at the 2 pre-existing stroke centers when compared with average combined times for newly established stroke centers. Hospitals 1, 2, and 3 tended to improve (P=NS) their door to CT interpretation times, whereas Hospital 5 showed significant improvement (P=0.045) in times for suspected stroke patients. Hospitals 4 and 6 increased their door to CT interpretation times in the active-intervention phase; the increase at Hospital 6 coincided with implementation of a new billing practice by the Neurology section that ensured all stroke CTs were read and billed for by admitting neurologists. No differences in door to CT interpretation times by gender, age, or ethnicity were noted.

**Treatment with Intravenous tPA**
All 198 (pre-intervention) and 709 (active-intervention) medically confirmed stroke cases were reviewed for intravenous tPA administration. In the pre-intervention phase, Hospitals 1, 2, 4, and 5 exhibited tPA treatment rates ranging from 4.7% to 19.4% of all strokes admitted, whereas Hospitals 3 and 6 did not treat any strokes with tPA (Figure 3). In the active-intervention phase, all sites administered tPA with treatment rates ranging from 6.8% to 17.2% of all stroke admissions. Hospital 2 achieved a significantly higher rate of tPA treatment in the active-intervention phase with treatments increasing from 2 (4.7%) to 15 (17.3%; $\chi^2=3.9; P=0.047$). Hospitals 1 and 4 experienced a reduction in the number of tPA treatments during the active-intervention phase, whereas all
other centers experienced an increase in tPA treatments. No differences in tPA treatment by gender, age, or ethnicity were noted. Intracranial and/or other systemic hemorrhages were not documented in any patients receiving tPA during the pre-intervention phase. During the active-intervention phase, Hospital 1 documented 1 post-tPA intracranial hemorrhage (1 of 27 treated patients [3.7%]).

Discussion

Our study showed that implementation of the BAC and ASA Guidelines through paramedic, health professional, and community education may decrease time from patients’ symptom onset to hospital arrival, improve paramedic diagnostic capabilities, and promote safe administration of intravenous tPA among community hospitals. Conduct of this study within Houston was challenged by a preexisting commitment to the treatment of acute stroke demonstrated by 2 academic stroke centers; this may have contributed to an overall reduction in the effect of the intervention, as baseline symptom response times and treatment rates were already well above the national average.

Others have shown the need for significant community education using multilevel strategies to effect a change in awareness of stroke prevention, risk factors, and warning

### TABLE 2. Total Dispatch to Emergency Department Arrival Times: Community-Based and Inner-City Hospitals

<table>
<thead>
<tr>
<th>Hospital Type</th>
<th>Mean (min)</th>
<th>$t$</th>
<th>$P$</th>
<th>Mean Difference</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-intervention phase</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inner-city hospitals</td>
<td>44 (sd=13; median=42)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Community Hospitals</td>
<td>39 (sd=13; median=37)</td>
<td>3.9</td>
<td>&lt;0.001</td>
<td>4.96</td>
<td>2.4–7.5</td>
</tr>
<tr>
<td>Active-intervention phase</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inner-city hospitals</td>
<td>47 (sd=15; median=47)</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Community hospitals</td>
<td>43 (sd=13; median=42)</td>
<td>4.5</td>
<td>&lt;0.001</td>
<td>3.98</td>
<td>2.2–5.7</td>
</tr>
</tbody>
</table>

Figure 2. Patient distribution by hospital and study phase. Pre-intervention stroke for Hospital 6 was n=6. Pre-I indicates pre-intervention phase; Active, active-intervention phase; All, all patients transferred to each hospital by HFD-EMS with “suspected” stroke; stroke, all medically confirmed stroke cases.

Note: Pre-I = pre-intervention phase; Active = active intervention phase. “All” denotes all patients transferred to each hospital by HFD-EMS with “suspected” stroke; “stroke” denotes all medically confirmed stroke cases; Hospital 6 pre-intervention stroke n=6.
signs to impact early treatment. In our study, 62% of patients in the active-intervention phase arrived within 2 hours of symptom onset, providing time for evaluation and treatment within the 3-hour intravenous tPA window. Precise measurement of community education impact was not conducted, limiting our ability to credit this outcome to the educational intervention; additional measurement strategies should be encouraged in future studies to gauge the impact of education more precisely.

Paramedic accuracy in diagnosing stroke improved to 79% during the active-intervention phase and was likely tied to use of the age-modified LAPSS instrument combined with ongoing stroke education. Interestingly, paramedic transport times for suspected stroke cases were lengthened during the active-intervention phase with significant increases measured for the time spent on scene for initial paramedic assessment and diagnosis. Whereas others have shown a decrease in the time spent on scene following education, our findings may have been associated with use of competitive benchmarking that likely fostered a heightened degree of vigilance in assessment and diagnosis.

A significant reduction in transport times associated with transports to suburban-based stroke centers, as compared with intercity centers, was measured in both phases of the study.

### TABLE 3. Door to CT Times Among Hospital Study Sites

<table>
<thead>
<tr>
<th>Hospital study sites</th>
<th>Pre-intervention (min)</th>
<th>Active Intervention (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Suspected Strokes</td>
<td>Confirmed Strokes</td>
</tr>
<tr>
<td>Hospital 1, preexisting</td>
<td>41 ± 35 (median = 27)</td>
<td>38 ± 29 (median = 27)</td>
</tr>
<tr>
<td>Hospital 2</td>
<td>66 ± 60 (median = 55)</td>
<td>66 ± 68 (median = 45)</td>
</tr>
<tr>
<td>Hospital 3</td>
<td>95 ± 82 (median = 75)</td>
<td>85 ± 73 (median = 75)</td>
</tr>
<tr>
<td>Hospital 4</td>
<td>73 ± 50 (median = 58.5)</td>
<td>56 ± 35 (median = 50)</td>
</tr>
<tr>
<td>Hospital 5, preexisting</td>
<td>54 ± 59* (median = 37)</td>
<td>34 ± 19 (median = 30)</td>
</tr>
<tr>
<td>Hospital 6</td>
<td>58 ± 62 (median = 33.5)</td>
<td>42 ± 26 (median = 33.5)</td>
</tr>
</tbody>
</table>

Differences between preexisting and new stroke centers

<table>
<thead>
<tr>
<th></th>
<th>Preexisting stroke centers, combined</th>
<th>Active Intervention</th>
<th>Preexisting stroke centers, combined</th>
<th>Active Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>46 ± 46 (median = 31; t = 3.9; P &lt; 0.001; mean difference = 27; 95% CI = 13–40)</td>
<td>t = 4.0; P &lt; 0.001; mean difference = 30; 95% CI = 14–42)</td>
<td>36 ± 26 (median = 29; t = 4.5; P &lt; 0.001; mean difference = 26; 95% CI = 14–35)</td>
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New stroke centers, combined

|                      | 72 ± 63 (median = 55) | 74 ± 74 (median = 56) | 65 ± 60 (median = 49) | 63 ± 63 (median = 50) |

*P ≤ 0.05.
Although others have shown benefit to the use of helicopter and ground transport services\textsuperscript{16–21} to support movement of patients to comprehensive stroke centers, dependence on aeromedical transport may increase acute-care costs at a time when hospital reimbursement for stroke services is minimal. Although improvement in quality-of-life years may offset the increased cost of helicopter transport,\textsuperscript{22,23} hospital reimbursement currently does not offer incentive pay for improved patient outcomes recognized within the post-acute healthcare sector. Additionally, transport-time differences in our study were most likely the result of traffic congestion, making dependence on intercity ground transportation an unrealistic option. We suggest, instead, expansion of the number of suburban stroke centers to ensure diagnostic and treatment efficiency at the point of stroke occurrence in the community.

According to the BAC\textsuperscript{5} and ASA\textsuperscript{6} guidelines, stroke center hospitals must be able to complete a CT scan within 25 minutes of ED admission and have it read by a physician within 20 minutes of scan completion. Significant differences in door to CT interpretation times between preexisting stroke centers and newly designated centers were noted in both the pre-intervention and active-intervention phases. These findings underscore difficulties associated with orchestrating change within complex hospital systems and medical practices, although 4 of 6 centers did demonstrate some degree of improvement in times. Of interest is the time increase at Hospital 6 associated with the change in CT interpretation and billing procedures. Similarly, the increase in door to CT times at Hospital 4, coupled with the decrease in acute treatments, may have been predictive of a lapsing commitment to acute-stroke treatment; at the time of this writing, Hospital 4 has discontinued its commitment to serve as a stroke center, claiming significant financial loss and unrewarded financial support for their neurologists as rationale.

Since its approval by the US Food and Drug Administration, several studies have shown significant benefit to use of tPA in the treatment of acute ischemic stroke.\textsuperscript{24,25} At baseline, the majority of tPA-treated cases were managed by Hospital 1, which greatly exceeded the national average\textsuperscript{3} at 19.4\%. As paramedics were provided with more stroke center options, a redistribution of tPA-treatment sites became evident. Although others have identified differences in treatment rates by payer status, gender, ethnicity, and age,\textsuperscript{26–29} our study did not have similar findings. Difference in treatment rates may be accounted for by the sample, but they may also represent findings similar to those identified by others suggesting an inconsistent commitment among medical providers to the level of care identified by the BAC and ASA guidelines\textsuperscript{27,30} and high rates of unwarranted treatment exclusions.\textsuperscript{10,27,30}

In our study, hemorrhage rates were within the limits of those incurred in the National Institute of Neurological Disorders and Stroke trial.\textsuperscript{4} Investigators have questioned the safety of tPA administration at community settings because of high hemorrhage rates.\textsuperscript{31,32} Others have shown that lowering of hemorrhage rates can be achieved with significant educational support, quality monitoring, and experience.\textsuperscript{16,33–36} Our study suggests that tPA administration is safe in community settings, although efficacy and outcome postthrombolysis were not measured.

Effecting change in paramedic, community, and practitioner response to stroke care is challenging because of a combination of factors, such as internal hospital and medical staff politics, financial disincentives, chaotic prehospital and emergency care environments, and the complexity of communicating with diverse communities. Our findings support that of others, suggesting that a combination of interventions are necessary to improve stroke care. Lastly, increasingly rates of expensive acute stroke treatment are not supported by current hospital reimbursement, and stroke center development may be stifled by lack of financial incentives, as seen in our study. Similar to the experience heralded by cardiologists for improved reimbursement for acute myocardial infarction, improved pay for aggressive treatment of stroke must occur to ensure commitment to standard of care.

Acknowledgments

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References


