Organization of a United States County System for Comprehensive Acute Stroke Care

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Background and Purpose—Organized systems of care have the potential to improve acute stroke care delivery. The current report describes the experience of implementing a county-wide system of spoke-and-hub stroke neurology receiving centers (SNRC) that incorporated several comprehensive stroke center recommendations.

Methods—Observational study of patients with suspected stroke of <5 hours duration transported by emergency medical system personnel to an SNRC during the first year of this system.

Results—A total of 1360 patients with suspected stroke were evaluated at 9 hub SNRC, of which 553 (40.7%) had a discharge diagnosis of ischemic stroke. Of these 553, intravenous tissue-type plasminogen activator was administered to 110 patients (19.9% of ischemic strokes). Care at the 6 neurointerventional-ready SNRC was a major focus in which 25.1% (99/395) of the patients with ischemic stroke received acute intravenous or intra-arterial reperfusion therapy, and in which provision of such therapies was less common with milder stroke, older age, and Hispanic origin. The door-to-needle time for intravenous tissue-type plasminogen activator met the 60-minute target in only 25% of patients and was 37% longer (P = 0.0001) when SNRC were neurointerventional-ready.

Conclusions—A stroke system that incorporates features of comprehensive stroke centers can be effectively implemented with substantial rates of acute reperfusion therapy administration. Experiences potentially useful to broader implementation of comprehensive stroke centers are considered. (Stroke. 2012;43:1089-1093.)

Key Words: acute care ■ prehospital systems ■ stroke centers

The rates of stroke and of hospitalization from stroke have been increasing in the United States each year.1,2 In parallel, systems of stroke care delivery have received greater attention. In 2000, the Brain Attack Coalition suggested 2 types of stroke centers, primary and comprehensive,3 and in 2005 described recommendations for comprehensive stroke centers.2 In California, emergency medical systems are managed at the county level. In response to the 2005 updated Brain Attack Coalition recommendations, providers of acute stroke care from the hospitals of Orange County, California (the nation’s fifth most populous county, population >3 million4) met with county emergency medical system (EMS) personnel and hospital administrative representatives in a grass roots effort to define a stroke neurology receiving center (SNRC) system. In May 2009, local EMS policy was enacted, defining a plan for a county-wide spoke-and-hub system that had specialized SNRC as hubs and community hospitals as spokes. The SNRC hubs adopted features of comprehensive stroke centers, as practical.

A key goal for the SNRC system was to maximize use of acute reperfusion therapies for ischemic stroke. The current report describes initial experience, rate of acute therapy administration, and factors related to this rate. Areas of achievement and those requiring greater attention when implementing comprehensive stroke centers more broadly are highlighted.

Materials and Methods
Orange County EMS regulates, monitors, plans, and coordinates prehospital emergency medical services, hospital emergency pro-
The criteria for an Orange County SNRC hub incorporated several of the Brain Attack Coalitions recommendations for comprehensive stroke centers and approximated others. Criteria for a hub SNRC include: a neurologist on-call and available to consult within 30 minutes; a neurosurgeon on-call and available to consult within 30 minutes; an emergency medicine specialist available in-house at all times; a radiologist experienced in neuroradiology on-call and available to consult within 30 minutes (with teleradiology deemed acceptable); access to rehabilitation that is either in-house or via a documented referral protocol; a multidisciplinary institutional quality-assurance committee that meets on a regular basis to monitor quality benchmarks and reviews complications; and provision of stroke education to hospital staff, other regional hospital staffs, EMS personnel, and the public. Credentialing for the radiologist experienced in neuroradiology was determined by medical staff at each hospital. An endovascular neurointerventionalist who is available around the clock was deemed a preferred, although not a required, feature.

Endovascular neurointerventionalists were not assigned any spoke hospitals (Figure 1). Three SNRC hubs did not have an endovascular neurointerventionalist and were not assigned any spoke hospitals (Figure 1). Six of these hubs had an endovascular neurointerventionalist available and were assigned spoke hospitals based on EMS call volumes (1 spoke in 1 case, 2 spokes in 2 cases, and 3 spokes in 3 cases). Three SNRC hubs did not have an endovascular neurointerventionalist and were not assigned any spoke hospitals (Figure 1).

Countyle EMS units were required to transport patients suspected of stroke <5 hours in duration to the nearest hub SNRC. Spoke SNRC transferred such patients to hubs as appropriate. Suspected ischemic stroke was operationally defined by EMS as a patient with weakness (hemiplegia, hemiparesis, pronator drift, or facial paresis), capillary glucose ≥80 mg/dL, no seizure before or during EMS arrival, and Glasgow Coma Scale score ≥10. Suspected hemorrhagic stroke was operationally defined by EMS as a patient with sudden severe headache in the past 5 hours plus ≥1 of the following: (1) repeated vomiting; (2) neurological deficit (hemiparesis or weakness, gaze to 1 side, or asymmetrical pupils without previous eye surgery); (3) altered mental status; and (4) marked blood pressure elevation (diastolic >100 mm Hg).

A standardized data collection sheet (online-only Appendix; http://stroke.ahajournals.org) was completed for each patient triaged into the system by field EMS units or spokes, and then submitted to Orange County EMS for inclusion into a central database. Before initiation of the SNRC system, this data collection sheet was developed by EMS (derivation phase) with particular attention to definition and collection of each data element. After implementation of the SNRC system, the first 100 data collection sheets were reviewed (validation phase) for consistency in data element definitions. Reliability of data collected from different SNRC was assessed with the first 100 data collection sheets, as well as periodically thereafter. At each hub SNRC, this form was completed by the stroke coordinator after being trained to do so by county EMS. A limited data set was extracted from this database for the current study. Discharge diagnosis was based on International Classification of Diseases version 9 codes and was confirmed from a separate county-wide master EMS database. Note that all patients who were treated with intravenous (IV) tissue-type plasminogen activator (tPA) were coded as having an ischemic stroke regardless of symptom duration.

The current report examines the experience from the first 12 months of SNRC operation. Missing data were not imputed. Statistical analyses used parametric methods except for National Institutes of Health Stroke Scale scores, which were analyzed using nonparametric statistical methods. Analysis of this limited data set was approved by the University of California Irvine Institutional Review Board.

**Results**

**System Implementation**

No major impediments were identified in the implementation of this system. Eight of the 9 hub SNRC were either Joint Commission-certified primary stroke centers or were compliant with American Heart Association “Get With The Guidelines” at time of hub SNRC designation. Note that before the initiation of this system, all 6 neurointerventional-ready hub SNRC already had an emergency department physician in-house as well as 30-minute access to a neurologist, neurosurgeon, and neuroradiologist. In 2009, 4 of the 6 hub SNRC were neurointerventional-ready all day every day, and over time all 6 were. Several case report form fields were not consistently completed by SNRC; in particular, discharge National Institutes of Health Stroke Scale score was not provided in 49.8%, mortality was not described in 21.3%, and discharge diagnosis was not recorded on the case report form.
in 18.6% of patients and could only be identified from the master EMS database.

**Subjects**

From April 2009 to April 2010, 1360 EMS-transported patients with suspected stroke were evaluated at the 9 hub SNRC. Primary discharge diagnosis was ischemic stroke in 553 (40.7%), hemorrhagic stroke in 210 (15.4%), transient ischemic attack in 142 (10.4%), and a nonstroke diagnosis in 443 (32.6%; most often seizure, toxic metabolic state, and sepsis), with no diagnosis provided in 12 (0.1%). Of the hemorrhagic strokes, 185 were attributable to intracerebral hemorrhage (including 5 attributable to ruptured arteriovenous malformation) and 25 were attributable to aneurysmal subarachnoid hemorrhage. Age was 74 ± 15 years (mean ± SD; range, 8–103). Gender was 55% female and 45% male. The proportion of patients routed past a spoke hospital to a hub hospital was 18.1%. Only a small number (n = 28; 2.1%) of patients were first routed to a spoke hospital and later transferred to a hub SNRC. Of these 28, 12 received IV tPA at the first facility, before transfer, and 22 received endovascular treatment at the second facility.

**Use of IV tPA Across All SNRC**

IV tPA was administered to 110 patients (19.9% of ischemic strokes) as the sole reperfusion therapy. Indirect evidence suggests that this is substantially higher than the rate from the year previously, because a survey performed by EMS and required of all prospective SNRC found that only 3.4% of EMS-transported cases that were coded by EMS as acute stroke <5 hours old received acute thrombolytic therapy in 2008, nearly all of which being IV tPA. The time from emergency department arrival to IV tPA initiation (door-to-needle time) across all 9 SNRC, available in 96.4% of patients, averaged 86.4 ± 37.4 minutes and was 37% longer at the 6 neurointerventional-ready SNRC (100 ± 38 minutes; n = 54) compared to the 3 SNRC that were not neurointerventional-ready (73 ± 32 minutes; n = 52; P = 0.0001). The proportion of patients with door-to-needle time <60 minutes was 25%, which was also lower in neurointerventional-ready SNRC (11%) compared to SNRC not offering neurointerventional therapy (40%; P = 0.0004).

**Acute Reperfusion Therapy at Neurointerventional-Ready SNRC**

Acute care for the 938 patients taken to 1 of the 6 neurointerventional-ready SNRC was a major focus. Discharge diagnosis was ischemic stroke in 395, hemorrhagic stroke in 153, transient ischemic attack in 88, another diagnosis in 292, and no diagnosis provided in 10. Among the 395 EMS-transported patients with ischemic stroke diagnosed, age averaged 76 ± 14 years. Ethnicity was 67% white, 14% Asian, 11% Hispanic, 1.5% black, 4.5% other, and 2.5% not stated. The time of day during which these 395 patients arrived was unevenly distributed (P < 0.0001), eg, 26% arrived from 12:00 PM to 4:00 PM, whereas only 5% arrived from 12:00 AM to 4:00 AM (Figure 2). Median baseline National Institutes of Health Stroke Scale score, available in 90% of subjects, was 10 points. Among these 395 EMS-transported patients identified as having an ischemic stroke at a neurointerventional-ready SNRC, acute reperfusion therapy consisted of IV tPA alone in 57 (14.4%), an intra-arterial procedure alone in 32 (8.1%, includes intra-arterial tPA, MERCI, Penumbra, or any combination), and IV tPA followed by an intra-arterial procedure in 10 (2.5%), for a total of 99 (25.1%) receiving acute reperfusion therapy.

Provision of acute reperfusion therapy at a neurointerventional-ready SNRC varied in relation to baseline National Institutes of Health Stroke Scale score (median for those receiving acute reperfusion therapy is 14 versus 7 for those not receiving such therapy; P < 0.0001), age (73 ± 16 years in those receiving therapy versus 77 ± 14 years in those not; P = 0.027), and ethnicity (P = 0.046; lowest in Hispanic patients, highest in white and black patients), but not gender. A nominal logistic model predicting whether acute reperfusion therapy was provided found that all 3 of these measures (baseline National Institutes of Health Stroke Scale score, age, and ethnicity) remained significant.

**Discussion**

This report describes the experience of developing and implementing a system for comprehensive acute stroke care in a populous U.S. county that captured some, but not all, of the innovations proposed for comprehensive stroke centers. Among EMS-transported patients with ischemic stroke taken to a neurointerventional-ready hub SNRC, 25.1% received acute reperfusion therapy. Patients receiving such therapy tended to have a more severe stroke, a younger age, and were less likely to be Hispanic. The door-to-needle time for IV tPA met the <60-minute target in only 25% of patients and was longer when sites were neurointerventional-ready.

The Brain Attack Coalition has recommended both primary and comprehensive stroke centers. Primary stroke centers are designed to stabilize and treat most acute stroke patients. Core elements include formation of an acute stroke team, integration of EMS with stroke center operations, use
of an organized stroke unit, and access to neurosurgical care within 2 hours of need. A previous report from our group described the experience of becoming a primary stroke center. Comprehensive stroke centers build on this and are designed to have the “necessary personnel, infrastructure, expertise, and programs to diagnose and treat stroke patients who require a high intensity of medical and surgical care, specialized tests, or interventional therapies.” Key components of comprehensive stroke centers include: neurologists, neurosurgeons, emergency department personnel, as well as physicians with expertise in interventional endovascular neuroradiology procedures; a full intensive care unit staffed by properly trained personnel; the ability to have urgent neuroimaging studies interpreted within 20 minutes of acquisition; access to neurosurgical personnel within 30 minutes; door-to-needle time ≤60 minutes for IV tPA; and availability of rehabilitation services. The Orange County SNRC hubs that were neurointerventional-ready exceeded the requirements of a primary center and also captured some, but not all, of the innovations proposed for comprehensive stroke centers.

Implementation of the Orange County system went smoothly. This might be partly because of broad consensus developed before the start. Once there was medical consensus for the system, it was presented to the governing body for the county (the Orange County Board of Supervisors) to gain political support for the program. Several meetings with political leaders were held to inform them of the intent of the program and to obtain governmental support and, concurrently, local media and community interest groups were approached. Implementation of this system might also have been aided by the phased development of data collection methods or by the fact that all but 1 SNRC was either a Joint Commission-certified primary stroke center or compliant with American Heart Association “Get With The Guidelines” at the time the system was initiated. As such, the experience of initiating such a system might differ in communities whose hospitals do not have such previous certifications. IV tPA was administered to 19.9% of patients with an acute ischemic stroke, a rate that is 5-fold higher than the rate estimated in the United States and, furthermore, is specifically more that thrombolytic therapy usage has been increasing over time in this region for the year preceding initiation of this stroke system; system performance might differ in settings where this is not the case at baseline. Other data of interest, such as time from EMS departure from scene to emergency department arrival, were not recorded as part of this study.

Despite these limitations, some aspects of this experience might be instructive to broader implementation of comprehensive stroke centers. Although time of patient arrival to the emergency department clustered around normal working hours (Figure 2), 13% of EMS-transported patients arrived between 10:00 PM and 6:00 AM, emphasizing the importance of around-the-clock coverage. The door-to-needle time for subjects receiving IV tPA was within the target window of 60 minutes in only 25% of patients, a rate that, although low, is consistent with the value of 26.6% reported by Fonarow et al in a recent study of 25,504 U.S. patients with ischemic stroke. Review of this result with SNRC personnel disclosed 3 issues in particular that might have contributed: a need to educate some emergency department staff and physicians about this goal; a need for greater efficiency in obtaining baseline laboratory test results; and a need to strategically time performance of additional imaging when indicated. Furthermore, the door-to-needle time was significantly longer when an SNRC offered acute neurointerventional therapies. This might reflect a preference for a more detailed diagnostic evaluation before therapeutic evaluation in such a setting, a possibility that requires further study.

In conclusion, a county-wide stroke system that uses several of the core features of a comprehensive stroke center can provide effective acute stroke care with high rates of acute reperfusion therapy. The current report emphasizes some areas that might be of particular focus in assessing comprehensive stroke centers, such as assessing performance across age and ethnic groups and monitoring door-to-needle time for IV tPA.

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Disclosures
Drs Miller and Stratton are employed by Orange County Emergency Medical Services.

References


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Stroke-Neurology Receiving Center (SNRC) Report

Submit this form for all patients triaged from the field or transferred from another hospital as a OCEMS Stroke-Neurology Triage case.

Hospital:______________________________________________________________

Person completing form: ___________________________ Telephone #: ___________________________

1. OCEMS Identification (Sequence) #_________________ Date:__________________

2. Time: __________________

3. Patient Age: ___________ Patient Sex: □ Male □ Female

4. Ethnicity: Hispanic □ African American □ Asian □ Caucasian □ Other □

5. Time of onset of stroke symptoms: ________________________________

6. Time of patient arrival in Emergency Department: ________________________________

7. Copy of Prehospital Care Report (field documentation) Yes □ No □

8. Primary diagnosis at hospital discharge: Ischemic CVA □ Hemorrhagic CVA □ Other □ (note diagnosis below):

__________________________________________________________

9. Comments (vessel or area of stroke): ________________________________

10. Immediate outcome: Lived □ Died □

11. NIH Stroke Scale (GCS acceptable for hemorrhagic stroke):

Hospital admission ___________ Hospital discharge ___________

12. For acute stroke victims receiving thrombolytic or mechanical therapy :

   a) Type of therapy: ________________________________

   b) Time from Emergency Department arrival to initiation of treatment: ________________________________

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