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**Paul Coverdell National Acute
Stroke Registry Surveillance –
Four States, 2005–2007**

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Paul Coverdell National Acute Stroke Registry Surveillance – Four States, 2005–2007

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Abstract

Problem/Condition: Each year, approximately 795,000 persons in the United States experience a new or recurrent stroke. Data from the prototype phase (2001–2004) of the Paul Coverdell National Acute Stroke Registry (PCNASR) suggested that numerous acute stroke patients did not receive treatment according to established guidelines.

Reporting Period: This report summarizes PCNASR data collected during 2005–2007 from Georgia, Illinois, Massachusetts, and North Carolina, the first states to have PCNASRs implemented in and led by state health departments.

Description of System: PCNASR was established by CDC in 2001 to track and improve the quality of hospital-based acute stroke care. The prototype phase (2001–2004) registries were led by CDC-funded clinical investigators in academic and medical institutions, whereas the full implementation of the 2005–2007 statewide registries was led by CDC-funded state health departments. Health departments in each state recruit hospitals to collect data. To be included in PCNASR, patients must be aged ≥ 18 years and have a clinical diagnosis of acute ischemic stroke, intracerebral hemorrhage, subarachnoid hemorrhage, or transient ischemic attack (TIA) or an *International Classification of Diseases, Ninth Revision, Clinical Modification* (ICD-9-CM) code indicative of a stroke or TIA. Data for patients who are already hospitalized at the time of stroke are not included. The following 10 performance measures of care, based on established guidelines for care of acute stroke patients, were developed by CDC in partnership with neurologists who specialize in stroke care: 1) received deep venous thrombosis prophylaxis, 2) received antithrombotic therapy at discharge, 3) received anticoagulation therapy for atrial fibrillation, 4) received tissue plasminogen activator (among eligible patients), 5) received antithrombotic therapy within 48 hours of admission or by the end of the second hospital day, 6) received lipid level testing, 7) received dysphagia screening, 8) received stroke education, 9) received smoking cessation counseling, and 10) received assessment for rehabilitation services. Adherence to these performance measures of care was calculated using predefined inclusion and exclusion criteria.

Results: A total of 195 hospitals from Georgia, Illinois, Massachusetts, and North Carolina contributed data to PCNASR during 2005–2007, representing 56,969 patients. Approximately half (53.3%) the cases of stroke in the registry occurred among females. A total of 2.5% of cases were among Hispanics; however, the proportion varied significantly by state. Cases among black patients ranged from 5.6% in Massachusetts to 35.8% in Georgia. The age at which patients experienced stroke varied significantly by state. On average, patients were oldest in Massachusetts (median age: 77 years) and youngest in Georgia (median age: 67 years). Overall, the clinical diagnosis for registry stroke cases was hemorrhagic stroke (13.8% of cases), ischemic stroke (56.2%), ill-defined stroke (i.e., medical record did not specify ischemic or hemorrhagic stroke; 7.3%), and TIA (21.6%). A total of 18.5% of patients with stroke symptoms arrived at the hospital within 2 hours

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of symptom onset; however, the time from onset of symptoms to hospital arrival was not recorded or was not known for the majority (57.8%) of patients. Of the 56,969 patients, 47.6% were transported by emergency medical services (EMS) from the scene of symptom onset, 11.1% were transferred by EMS from another hospital, and 39.4% used private or other transportation. Adherence to acute stroke care measures defined by PCNASR were as follows: received antithrombotic therapy at discharge (97.6%), received antithrombotic therapy within 48 hours of admission or by the end of the second hospital day (94.6%), assessed for rehabilitation services (90.1%), received deep venous thrombosis prophylaxis (85.5%), received anticoagulation therapy for atrial fibrillation (82.5%), received smoking cessation counseling (78.6%), received lipid level testing (69.9%), received stroke education (58.8%), received dysphagia screening (56.7%), and received tissue plasminogen activator (among eligible patients) (39.8%).

Interpretation: Between 2001–2004 (prototype phase) and 2005–2007 (implementation by state health departments), substantial improvement occurred in dysphagia screening, lipid testing, smoking cessation counseling, and antithrombotic therapy prescribed at discharge. These initial improvements indicate that a surveillance system to track and improve the quality of hospital-based stroke care can be led successfully by state health departments, although further evaluations over time are needed. Despite these improvements, additional increases are needed in adherence to these and other performance measures. Nearly 40% of stroke patients did not use EMS services for transport to hospitals, and no change occurred in the proportion of patients who arrived at the hospital in time to receive thrombolytic therapy for ischemic stroke. Patients who are not promptly transported to hospitals after symptom onset are ineligible for thrombolytic therapy and other timely interventions for acute stroke.

Public Health Actions: Results from PCNASR indicate the need for additional public health measures to inform the public of the need for timely activation of EMS services for signs and symptoms of stroke. In addition, low rates of adherence to certain measures of stroke care underscore the need for continuing coordinated programs to improve stroke quality of care. Additional analyses are needed to assess improvements in adherence to guidelines over time.

Introduction

Each year, approximately 795,000 persons in the United States experience a stroke; approximately 610,000 of these are first-time strokes, and the remaining are recurrent strokes (1). In 2001, Congress provided funding to CDC to establish the Paul Coverdell National Acute Stroke Registry (PCNASR) to monitor and improve the quality of care for stroke patients through assessment of adherence to established performance measures for acute stroke care (2). PCNASR regularly monitors for racial/ethnic, sex, and geographic disparities in stroke care and works with states to eliminate these disparities in care, as well as to decrease the rate of premature death and disability from acute stroke through prevention of recurrent disease and increased public awareness of stroke treatment and prevention.

During 2001–2004 (the prototype phase), CDC funded eight PCNASR prototype registries, which were led by academic principal investigators and medical institutions, to collect data on the quality of care provided to stroke patients from the initial emergency response through hospital discharge. This prototype phase was used to determine how best to develop stroke quality improvement registries, identify which data elements could and should be collected, and identify challenges involved in data collection. Four registries began receiving funding in 2001 (implemented by clinical investigators in

Georgia, Massachusetts, Michigan, and Ohio), and four in 2002 (implemented by clinical investigators in California, Illinois, North Carolina, and Oregon).

Results from the prototype phase of PCNASR indicated that many acute stroke patients were not receiving treatments recommended in established guidelines (3). For example, one of the acute stroke care measures defined by PCNASR recommends that eligible patients with acute ischemic stroke who arrive at the hospital within 2 hours of onset of stroke signs and symptoms receive intravenous (IV) tissue plasminogen activator (tPA), a thrombolytic agent, within 3 hours of onset. Data from the North Carolina Stroke Care Collaborative, a CDC-funded PCNASR, indicated that among persons who either experienced or had a witnessed a stroke and knew the time of stroke onset, less than half (38%) arrived at the hospital within 2 hours of symptom onset; thus, few patients for whom tPA might have been indicated arrived in time to receive the treatment (4). Intravenous tPA is the only treatment approved by the Food and Drug Administration for use with ischemic stroke patients and is only approved for use within 3 hours of symptom onset (5). Patients treated with tPA are 30%–50% more likely to have good functional outcomes than those who do not receive tPA (6,7).

A CT scan is a crucial component of optimal stroke care for all stroke patients. The National Institutes of Neurological Disorders and Stroke recommends that stroke patients receive

an initial CT scan within 25 minutes of hospital arrival (8). A study of the North Carolina PCNASR program (the North Carolina Stroke Care Collaborative) indicated that 23% of stroke patients who arrived within 2 hours of symptom onset received a CT scan within 25 minutes (median: 42 minutes) (5). In that study, prehospital delays and mode of arrival were the strongest predictors of a longer time between hospital arrival and initial CT scan. Arriving at the hospital by emergency medical systems (EMS) was associated with a shorter time between hospital arrival and initial CT scan.

Timely receipt of appropriate treatments for stroke requires prompt recognition of stroke signs and symptoms and activation of EMS. The five major signs and symptoms of stroke include 1) sudden severe headache; 2) sudden loss of vision in one or both eyes; 3) sudden weakness in an arm, a leg, or the face; 4) sudden confusion, trouble speaking, or understanding; and 5) sudden trouble walking, dizziness, or loss of balance or coordination. Awareness of these signs and symptoms ranged from 34.4% to 55.7% among respondents to the 2005 Behavioral Risk Factor Surveillance System survey from 13 states and the District of Columbia (9).

Data from hospital-based registries that track quality of stroke care can be used by state health departments to guide hospital quality improvement interventions through partnerships with hospital staff members and state-based stroke councils. Based on results from the prototype phase, PCNASR data elements and performance measures were refined. In 2004, CDC provided initial funding to state health departments in Georgia, Illinois, Massachusetts, and North Carolina to implement PCNASRs and begin collecting data in 2005. This initial report summarizes 2005–2007 PCNASR data from these four state stroke registries, which are the first PCNASRs to be implemented and led by state health departments.

Methods

PCNASR is funded by CDC through a cooperative agreement between CDC and state health departments. Any state with a CDC-funded heart disease and stroke prevention program (which, in 2004, included 32 states and the District of Columbia) was eligible to apply for participation through a competitive application process. An objective review process based on criteria established in the PCNASR request for application was used to fund four states to collect data during 2005–2007 (Georgia, Illinois, Massachusetts, and North Carolina), in accordance with Department of Health and Human Services grants policy directives. CDC provides technical assistance to funded states for all aspects of PCNASR, and state health departments provide technical assistance to PCNASR hospitals (i.e., provide educational programs for

stroke care teams and assist with improving data quality and with quality improvement challenges).

Hospital Recruitment and Selection

Each state developed a strategy to recruit hospitals for the registry. Participation in the registry is voluntary; therefore, not all selected hospitals participated. In addition, all hospitals that were not specifically recruited or selected as part of a random sample but that individually volunteered to participate also were included in the registry (i.e., nonsample hospitals). Hospitals that collected data but subsequently withdrew from the registry were included in the analysis.

Georgia

To maintain registry continuity, the Georgia Division of Public Health chose the same hospitals that participated in the prototype phase to participate in the 2005–2007 registry. For the prototype phase, of the 151 non-Veterans Affairs (non-VA) acute care or critical-access hospitals* with at least one admission for acute stroke in Georgia during 2000, a total of 60 hospitals were selected to participate; 52 hospitals were selected from a random sample, and eight additional hospitals were selected from the county with the most annual acute stroke admissions. Of the 60 hospitals that participated in the prototype phase, three hospitals had gone out of business or merged with other hospitals. In November 2005, 19 (33%) of the random sample hospitals and seven nonsample hospitals were participating in the registry. In September 2006, an additional 20 sample hospitals and five nonsample hospitals began participating. Two additional nonsample hospitals volunteered to participate in December 2006 and March 2007, for a total of 53 hospitals (39 sample hospitals [68% of sample] and 14 nonsample hospitals) participating in the registry. Admission for stroke to these hospitals represented approximately 57% of stroke admissions in the state based on 2005 hospital discharge data (*International Classification of Diseases, Ninth Revision, Clinical Modification* [ICD-9-CM] codes 430–438). During April 2007–December 2007, 11 sample hospitals withdrew from the registry at various times. No nonsample hospitals withdrew.

Illinois

Illinois developed a sampling design based on experience gained with the PCNASR prototype registry. For the prototype, a stratified random sample design was used to identify potential hospitals for registry participation. Before selection, all Illinois

*Critical-access hospitals are acute care hospitals located in rural areas, at least 35 miles from another acute care hospital or at least 15 miles from another acute care hospital in mountainous terrain (Balanced Budget Act of 1997, H.R.2015. ENR Sect 4201 [January 7, 1997]).

hospitals were stratified by Illinois Department of Public Health (IDPH) regions (Champaign, Chicago, Edwardsville, Marion, Peoria, Rockford, and West Chicago) and by size based on the annual number of stroke admissions in 2001 (small, 50–200 stroke admissions; medium, 200–400 stroke admissions; large, >400 stroke admissions). IDPH attempted to choose equal numbers of small, medium, and large hospitals; hospitals were randomly selected within size strata from each region. Nineteen hospitals that participated in the PCNASR prototype registry also were invited to participate. In 2005, 22 hospitals (18 sample hospitals and four nonsample hospitals from the prototype registry) were recruited (group 1). The same sample design was used to identify additional hospitals in the following years. Twenty hospitals were recruited from a random sample in 2006 (group 2), and three hospitals were recruited in 2007 (group 3). Of the total 142 non-VA acute-care eligible hospitals in Illinois, 45 hospitals participated in the registry at various points during 2005–2007. Two hospitals in group 1 withdrew at various times after 1 year of participation; eight hospitals in group 1 withdrew at the end of May 2007. Admission for stroke to the 45 registry hospitals represented approximately 40% of stroke admissions in the state based on 2004 hospital discharge data (ICD-9-CM codes 430–438).

Massachusetts

In 2004, the Massachusetts Department of Public Health issued licensure regulations for hospital designation as a primary stroke service (PSS) hospital. PSS hospitals must have written, guideline-based protocols for acute stroke care; the ability to meet time goals for assessment, management, and treatment of acute stroke for patients who arrive within 3 hours of symptom onset; and the capacity to provide thrombolytic therapy, brain imaging (i.e., computed tomography [CT] and magnetic resonance imaging [MRI]), laboratory services, and neurologic services at all times. In Massachusetts, only PSS hospitals (69 of Massachusetts' 72 hospitals) are allowed to treat acute stroke patients; therefore, the Massachusetts Department of Public Health only recruited PSS hospitals to participate in the registry; no VA hospitals participated. Hospitals joined the registry in three groups: 36 hospitals (group 1) in June 2005, 16 hospitals (group 2) in January 2006, and five hospitals (group 3) in January 2007. One hospital withdrew in 2007. As of December 2007, 56 of the 69 PSS hospitals were participating in the Massachusetts PCNASR. Admission for stroke to the 56 participating hospitals represented 83% of stroke admissions in the state based on 2005 hospital discharge data (ICD-9-CM codes 430–438).

North Carolina

In North Carolina, hospitals eligible for participation in the registry included all non-VA hospitals that had a dedicated emergency department (ED) as defined by the Centers for Medicare & Medicaid Services (CMS). Critical-access hospitals were eligible to participate if they had a dedicated ED. A total of 110 hospitals met the eligibility criteria. The North Carolina registry program did not limit the number of hospitals that could submit a request to participate, which increased the likelihood of establishing registries at hospitals in all geographic regions of the state. In May 2005, 13 hospitals began participating. Additional hospitals joined the registry during May 2005–December 2007; 33 hospitals were participating by January 2006, 46 by January 2007, and 53 by December 2007 (of 110 hospitals eligible to participate). Admission for stroke to the 53 participating hospitals accounted for approximately 69% of the total stroke admissions for North Carolina based on 2006 hospital discharge data (ICD-9-CM codes 430–438).

Case Definition

PCNASR includes patients aged ≥ 18 years with a clinical diagnosis of acute ischemic stroke, intracerebral hemorrhage, subarachnoid hemorrhage, or transient ischemic attack (TIA)[†] or an ICD-9-CM code indicative of a stroke or TIA.[§] Patients who were already hospitalized at the time of stroke or TIA occurrence were not included in the PCNASR case definition and therefore not counted in the registry.

PCNASR program guidelines during 2004–2007 required hospitals to collect data for a minimum of 6 of every 12 consecutive months. Georgia and Massachusetts required hospitals to enter data every month.

PCNASR does not require states to include in the registry patients who were admitted to an ED but who were not admitted to the hospital. However, Massachusetts hospitals are legally required to enter into a registry all stroke cases in persons who arrive at a hospital (including an ED) within 3 hours of symptom onset and who still have symptoms when they arrive at the hospital.

[†] An ischemic stroke occurs when an artery to the brain is blocked. An intracerebral hemorrhage occurs when a blood vessel in the brain bursts, allowing blood to leak into the brain tissue. A subarachnoid hemorrhage occurs when a blood vessel just outside the brain bursts and blood escapes into the subarachnoid space around the brain, as occurs with a ruptured aneurysm in the brain. A TIA is the occurrence of stroke-like symptoms that fully resolve without treatment, typically within 24 hours, and do not result in evidence of an infarct on brain imaging.

[§] ICD-9-CM codes 430, 431, 432.9, 433.01, 433.10, 433.11, 433.21, 433.31, 433.81, 433.91, 434.00, 434.01, 434.10, 434.11, 434.90, 434.91, 435.0, 435.1, 435.2, 435.3, 435.8, 435.9, and 436.

Case Ascertainment

Hospitals were encouraged to identify stroke cases in the ED or at the time of hospital admission (prospective case ascertainment) and to collect data concurrently with hospital care. However, case ascertainment methods varied. Some hospitals prospectively identified cases, and some hospitals retrospectively identified cases based on ICD-9-CM codes and were asked to verify that these cases met the clinical case definition. Data collection tools used in Illinois and North Carolina contained questions regarding prospective and retrospective case ascertainment. The percentage of prospective case ascertainment compared with retrospective case ascertainment varied based on hospital personnel resources and use of electronic medical records.

Data Collection

State registry programs collected data for the registry using a uniform set of PCNASR data elements and definitions (Box 1). States were required to submit state registry data to CDC at the end of each calendar quarter. Data CDs from each state were mailed overnight to CDC as password-protected transport files; passwords were sent separately through a different carrier.

Methods for data collection varied among states. Georgia and Massachusetts used a modified version of an online patient management tool from Get With The Guidelines—Stroke, an American Heart Association program designed to improve stroke care for patients by measuring and increasing adherence to evidence-based guidelines.⁴ The patient management tool was modified to include PCNASR data elements.

The Illinois and North Carolina registries used custom-designed data collection tools. The Illinois registry program developed an online tool to collect data, which were submitted electronically to the Center for Stroke Research at the University of Illinois at Chicago, the agency that managed the data for the Illinois registry. The North Carolina registry program also developed an online data collection tool, which included all required PCNASR data elements and optional data elements. The tool was designed to follow the typical flow of patient care to encourage prospective collection of data. In Illinois and North Carolina, hospitals have access to their own data and to aggregate data on performance measures combined from all participating hospitals in their respective state.

The specific strategies for training hospital staff members (e.g., how to abstract information from medical records, enter data, and understand and interpret data elements identified in

BOX 1. Paul Coverdell National Acute Stroke Registry data categories

- Demographics
- Prehospital and emergency medical services
- Hospital arrival
- Imaging
- Onset of signs and symptoms
- National Institutes of Health Stroke Scale (NIHSS) score*
- Thrombolytic treatment
- Reasons thrombolytic therapy was not administered
- Medical history
- In-hospital diagnostic procedures and treatment
- In-hospital complications
- Discharge

*The NIHSS is a standardized measure of stroke severity. The NIHSS score is an optional data element.

the medical record) varied among states. However, most strategies included initial training sessions when a hospital began participating and varying levels of ongoing data abstraction training and support. Registry staff members performed the training sessions.

Completeness of Case Ascertainment and Data Validation

Case Ascertainment

All states determined the percentage of stroke patients admitted to the hospital for whom data were entered into the registry (i.e., completeness of case ascertainment). The registries in Georgia and Massachusetts monitored completeness of case ascertainment by comparing the number of cases entered by each hospital into the registry with the number of cases expected based on previous hospital discharge data, using ICD-9-CM codes to identify cases. The Georgia registry hospitals submitted monthly lists of discharged patients with selected primary stroke-related ICD-9-CM codes, and the number of cases on these lists was compared with the number of cases entered into the registry. The Illinois registry hospitals submitted reports at least annually of the number of discharged patients with a principal diagnosis of stroke or TIA, and the number of cases on these lists was compared with the actual number of abstracted cases entered into the registry (i.e., both retrospectively and prospectively identified cases). Hospitals that entered fewer cases in the registry than expected during the relevant time frame were provided assistance from registry

⁴Information on the Get With the Guidelines—Stroke patient management tool is available at <http://www.americanheart.org/presenter.jhtml?identifier=3045578>.

staff members to identify barriers to case ascertainment and increase the number of cases entered into the registry.

In North Carolina, after 6 months of participation, hospitals were asked to compile hospital discharge data. The North Carolina registry program then provided participating hospitals a list of all stroke cases that had been entered into the registry during their seventh month of participation and requested that these cases be compared with the hospital discharge data for the same month. The hospitals were asked to verify that the registry cases were in the discharge data and compile a list of any recorded stroke-related cases that were missed, including information such as admission date and time, whether the patient had been admitted directly to the hospital or through the ED, and whether the stroke onset occurred while the patient was hospitalized. The proportion of stroke cases entered into the registry was calculated every 6 months based on the date the hospital began abstracting data.

Data Validation

All state registry programs monitored data accuracy. The tools used to collect registry data included internal checks to highlight and prevent the entry of implausible values. PCNASR required at least 5% of charts be reabstracted to assess the accuracy of data abstraction.

Georgia

Registry staff members in Georgia monitored data entered by hospitals for errors such as implausible values and asked hospitals to correct identified errors. Registry staff members also asked hospitals to submit to the Georgia Medical Care Foundation photocopies of clinical charts for a random sample of 10% of cases entered into the registry; statistical software was used to select the sample of cases. The medical information for these cases was reabstracted at the foundation by trained abstractors to assess the interrater reliability of the data using kappa statistics and whether entered cases met the clinical case definition. Data from the reabstractions were compared with data from the original chart abstractions, and results of the interrater reliability testing were provided to hospitals in a year-end report. Information from the chart reabstractions was used for subsequent data abstraction training sessions.

Illinois

Registry staff members in Illinois monitored data entered by hospitals by reabstracting cases soon after the original hospital abstraction. After abstractors at a hospital had entered data for at least 10 cases, two registry staff members visited the hospital to reabstract random samples of charts to monitor the accuracy of the initial abstraction. During this data monitoring visit, data abstracted by hospital staff members and then reabstracted

by registry staff members were compared. Discrepancies were addressed, additional training was provided, and the hospital plan for concurrent case identification, chart abstraction, and data entry was reviewed.

Massachusetts

Registry staff members in Massachusetts monitored data entered by Massachusetts hospitals for errors, and hospitals were asked to correct identified errors. John Snow, Inc. (JSI) was hired to reabstract a random sample of approximately 10% of cases entered into the registry; charts were reabstracted at the hospitals by trained JSI abstractors and assessed for accuracy and reproducibility. Because few patients were eligible to receive thrombolytics and adherence to thrombolytic guidelines was poor in the prototype registries, cases for reabstraction were oversampled for patients who were eligible to receive thrombolytics. Immediate feedback was given to hospital staff members involved in the registry program, and the reabstractions results were used to develop future data quality training sessions.

North Carolina

The North Carolina registry developed a computer program to identify possible data errors. The program was run weekly and used to generate queries for hospitals to use while reviewing data. Hospitals were encouraged to use these queries to investigate and correct incomplete and inaccurate data. A random sample of 5% of cases entered at each hospital was reabstracted by hospital staff members and entered into the registry website, which allowed prospectively collected registry data to be compared with data in the medical records. The North Carolina registry program website links registry entries with the original records, which facilitates comparisons between original data and the data from reabstractions.

Data Quality

PCNASR continually monitors data to improve the quality and accuracy of data entered into state registries. After each quarterly data submission by state registry programs to CDC, CDC provides state registry programs with individual reports on missing, invalid, and questionable data. State registry programs use this information to work with hospitals to correct data (if possible). State registry programs help hospitals improve data abstraction by providing regular training sessions for new abstractors, conducting regular conference calls, and creating lists of responses to frequently asked questions about abstraction guidelines.

Hospital Inventory

State registry programs collect self-reported baseline hospital information, including annual numbers of stroke cases, number of hospital beds, and information on hospital resources for stroke care. Any information that identifies the hospitals is removed, and the inventory information is transmitted to CDC annually.

Quality Improvement

In addition to monitoring hospital care provided to stroke patients, PCNASR was created to improve the quality of stroke care. Hospitals have access to their own data and state-level aggregate data from other sites for use in developing quality improvement strategies; hospitals do not have access to patient-level data from other hospitals. PCNASR quality improvement occurs in two stages. First, the state registry program recruits hospitals (as discussed in a previous section) to participate in a hospital-based, patient-level quality improvement program for acute stroke care. Second, state registry programs are required to develop a quality improvement plan for hospitals and for the state registry. Registry staff members provide quality improvement assistance to hospitals in various ways, including evaluation of stroke-related quality improvement activities, hospital visits to consult with hospital staff members caring for stroke patients (i.e., the stroke team), training (in person or through conference calls), and workshops with participating hospitals.

During 2005–2007, PCNASR assessed 10 major performance measures of care for stroke patients (Box 2). Data also were collected on selected additional measures, including time between hospital arrival and receipt of brain imaging (a measure of optimal stroke care), time between hospital arrival and receipt of tPA, and time between hospital arrival and receipt of brain imaging by method of arrival (e.g., EMS versus private transportation). The 10 performance measures, which were developed by CDC in partnership with neurologists who specialize in stroke care, are based on established guidelines for care of acute stroke patients (10–18). Not all performance measures are applicable to every type of stroke for which information is collected in PCNASR. The performance measures are reported as the proportion of patients who received the intervention or treatment (numerator) among the proportion of patients eligible to receive the intervention or treatment (denominator). Patients who were discharged to another acute care hospital and patients who left the hospital against medical advice were excluded. In addition, each performance measure has specific inclusion and exclusion criteria based on stroke type and other factors (Box 2).

Hospital-based quality improvement programs also address implementation of stroke care processes recommended by the Brain Attack Coalition (BAC) to improve adherence to guidelines for acute stroke care. BAC recommendations include use of standardized stroke orders and protocols, establishment of acute stroke care protocols, hospital notification by EMS of incoming potential stroke patients, and establishment of stroke units within hospitals (19).

State registry programs used conference calls and in-person meetings to implement educational programs for participating hospital stroke quality improvement teams. These meetings allowed stroke team members to discuss successes and challenges and included topics such as how to improve adherence to the stroke performance measures, how to implement evidence-based guidelines such as those recommended by BAC, and how to address barriers to implementation. In-person meetings with registry staff members and hospital stroke teams took place at least annually in all states.

Analytic Methods

Adherence to performance measures was calculated using predefined inclusion and exclusion criteria; hemorrhagic stroke, ischemic stroke, ill-defined stroke, and TIA cases were included (Table 1 and Box 2). To eliminate invalid values, data on time intervals (i.e., time from hospital arrival to receipt of brain imaging) were reported based on a range of 0–240 hours (except for length of hospital stay, which was reported based on a range of 1–120 days). The chi-square test was used to examine differences between categorical variables; the Wilcoxon-Mann-Whitney rank test or the Kruskal-Wallis test was used to examine differences between continuous variables. All statistical analyses were conducted using unweighted aggregate data.

Results

Characteristics of Participating Hospitals

Of 208 hospitals recruited during 2005–2007, a total of 195 contributed data to the registry; hospital inventory information was available for 190 of these 195 hospitals (Table 2). Twenty percent of the hospitals had <100 beds, and 22.1% had ≥400 beds. The annual number of stroke and TIA cases per hospital ranged from 12 to 1,532 per year, with 5.8% of hospitals reporting ≤25 cases per year and 10.5% of hospitals reporting ≥750 stroke cases per year. A total of 66.3% of the hospitals were nonteaching hospitals (i.e., did not have residency programs). Nearly all (91.1%) hospitals had physical

BOX 2. Inclusion and exclusion criteria for Paul Coverdell National Acute Stroke Registry performance measures of care

Performance measure 1. Patients with acute ischemic stroke or acute hemorrhagic stroke who were nonambulatory and who began receiving deep venous thrombosis (DVT) prophylaxis within 48 hours of admission were included in the numerator of this performance measure.

Patients who were discharged or transferred to another short-term facility, left against medical advice, or died within 48 hours of admission were excluded. However, patients who were discharged within 48 hours but received DVT prophylaxis were included.

Performance measure 2. Patients with acute ischemic stroke or transient ischemic attack (TIA) who were discharged on antithrombotic therapy unless contraindicated were included in the numerator of this performance measure. Contraindications had to be documented in the medical record for exclusion from the measure. Patients who were transferred to another acute care facility, left against medical advice, were transferred to hospice, or died were excluded.

Performance measure 3. Patients with acute ischemic stroke or TIA who had atrial fibrillation during this hospitalization who were discharged on anticoagulation therapy unless contraindicated were included in the numerator of this performance measure. Contraindications had to be documented in the medical record for exclusion from the measure. Patients who were transferred to another acute care facility, left against medical advice, were transferred to hospice, or died were excluded.

Performance measure 4. Patients with acute ischemic stroke who arrived at the hospital within 2 hours of onset of stroke signs and symptoms and received intravenous (IV) tissue plasminogen activator (tPA) within 3 hours of onset unless contraindicated were included in the numerator of this performance measure. Patients who received IV tPA at a hospital before being transferred to the current hospital were excluded, as were patients undergoing thrombolytic experimental protocols and patients receiving intraarterial (IA) tPA, unless the IA tPA was given after IV tPA. If patients did not receive IV tPA because of in-hospital delays, they were included in the denominator.

Performance measure 5. Patients with acute ischemic stroke or TIA who received antithrombotic medication within 48 hours of admission or by the end of the second hospital day unless contraindicated were included in the numerator of this performance measure. Contraindications to antithrombotic therapy had to be documented in the medical record for exclusion from the measure. Patients discharged within 48 hours but who received antithrombotic medication were included.

Performance measure 6. Acute ischemic stroke or TIA patients who had a lipid profile performed during their hospital admission or had documentation in the medical record that a lipid profile was performed in the 30 days before the event, with results also recorded in the medical record, were included in the numerator of this performance measure. Patients were included in the analysis if they had a low-density lipoprotein level recorded or if they had all three of the following recorded: total cholesterol, high-density lipoprotein, and triglycerides.

Performance measure 7. Patients with acute ischemic stroke or acute hemorrhagic stroke who received dysphagia screening (swallow screening) before being given anything by mouth, including food, fluid, or medication were included in the numerator of this performance measure. In the registry, patients who were on NPO orders (i.e., no food, fluid, or medication by mouth) throughout the entire hospitalization were excluded from the measure. If dysphagia screening was not documented or the status was unknown, performed, then the screening was assumed not to have been performed.

Performance measure 8. Patients with acute ischemic stroke, hemorrhagic stroke, or TIA who were given stroke education before discharge were included in the numerator of this performance measure. Patients who were transferred to another acute care facility, left against medical advice, were transferred to hospice, or died were excluded.

Performance measure 9. Patients with acute ischemic stroke, hemorrhagic stroke, or TIA who had smoked ≥ 1 cigarettes in the past year and who were given smoking cessation counseling before discharge were included in the numerator of this performance measure. Patients who were transferred to another acute care facility, left against medical advice, were transferred to hospice, or died were excluded.

Performance measure 10. Patients with acute ischemic stroke or hemorrhagic stroke who were assessed for rehabilitation services or who received rehabilitation services were included in the numerator of this performance measure. Patients who were transferred to a rehabilitation facility at discharge were assumed to have been assessed for or to have received rehabilitation services. Patients who were transferred to another acute care facility, left against medical advice, were transferred to hospice, or died were excluded.

therapy available in the hospital; 86.8% had occupational therapy, and 83.7% had speech therapy. A total of 12.6% of hospitals were categorized as rural,** and many of these were critical-access hospitals.

Patient Demographics

Sex and Race/Ethnicity Overall and by State

Approximately half (53.3%) the stroke cases recorded in the registry occurred among females, a proportion that varied little by state (Table 3). Overall, 2.5% of cases were among Hispanics; however, the proportion of Hispanics varied significantly by state (chi-square test, $p < 0.001$). In addition, race varied significantly by state (chi-square test, $p < 0.001$). The proportion of cases among black stroke patients ranged from 5.6% in Massachusetts to 35.8% in Georgia.

Age

The age at which patients experienced stroke varied significantly among states (comparison of mean age among the four states, $p < 0.001$). On average, patients were oldest in Massachusetts (median age: 77 years) and youngest in Georgia (median age: 67 years) (Table 3). Compared with men, women were significantly older (median age for women: 75 years, median age for men, 68 years [$p < 0.001$]) (Table 4). The age at which strokes occurred also varied significantly by race. Whites who had strokes were significantly older than other racial groups ($p < 0.001$). Black male stroke patients were significantly younger than white male stroke patients ($p < 0.001$), and black females were significantly younger than white females ($p < 0.001$). The median age among Hispanic stroke patients was 62 years (range: 18–97 years), compared with 72 years (range: 18–108 years) among non-Hispanics ($p < 0.001$).

Diagnoses

Among stroke cases entered in the registry, the clinical diagnosis for 13.8% of cases was hemorrhagic stroke (unspecified cranial hemorrhage or combined intracerebral hemorrhage and intracranial hemorrhage), for 56.2% was ischemic stroke, for 7.3% was ill-defined stroke (i.e., medical record did not specify ischemic or hemorrhagic stroke), and for 21.6% was TIA (Table 5). Because more than one stroke type could be entered into the registry for a single stroke case (e.g., a case of hemorrhagic stroke that converted to an ischemic stroke, which could be categorized as both ischemic and hemorrhagic), determining a single type was not possible in a small propor-

tion (1.1%) of cases. Stroke type varied substantially by state. Twenty percent of stroke cases in Georgia were hemorrhagic strokes, compared with 5.3% in Massachusetts. Because the Massachusetts PSS regulations do not address hemorrhagic stroke, caution should be used in interpreting the variability in stroke type for Massachusetts.

EMS, Prehospital, and ED Care

Of the 56,969 patients, 47.6% were transported by EMS from the scene of symptom onset, 11.1% were transferred by EMS from another hospital, and 39.4% used private or other transportation (Table 6). Mode of transportation was unknown or missing for 1.9% of patients. Most patients (90.4%) arrived at the ED for assessment; 8.4% were directly admitted to the hospital and did not use the ED. Of the 33,488 patients who were transported by EMS, the time from symptom onset to EMS call was missing or unknown in 81% of cases; two thirds of these were a result of unknown time of symptom onset (e.g., patients who woke from sleep to realize they had experienced a stroke). For patients who arrived within 10 days (i.e., 240 hours) of symptom onset, the median time from symptom onset to EMS call was 1 hour, 12 minutes (mean: 4 hours, 24 minutes). The time from symptom onset to arrival at the ED was missing or unknown in 58% of cases. For patients arriving within 10 days of symptom onset and with known time of symptom onset, the median time from onset to ED arrival was 2 hours, 30 minutes (mean: 6 hours, 12 minutes).

Initial Treatment and Receipt of Brain Imaging

A total of 18.5% of patients with stroke symptoms arrived at the hospital within 2 hours of symptom onset, 21.7% arrived in 2–24 hours, and 2.0% arrived >24 hours after symptom onset (Table 7). For the majority (57.8%) of patients, the time from onset of symptoms to hospital arrival was not recorded or was unknown. The time from hospital arrival to receipt of brain imaging was known for 82% of patients. The median time from hospital arrival to brain imaging among all patients was 1 hour, 12 minutes (mean: 2 hours, 36 minutes). However, among patients who arrived at the hospital within 2 hours of symptom onset, the median time from hospital arrival to receipt of brain imaging was 42 minutes (mean: 1 hour, 18 minutes). The initial brain image indicated hemorrhagic stroke in 13.9% of cases; imaging results were not available or were missing in 1.7% of cases. Fourteen percent of all hemorrhagic stroke patients had a National Institutes of Health Stroke Scale (NIHSS) score recorded (median score: 8), and 34% of ischemic stroke patients had an NIHSS score recorded

** Per U.S. Department of Agriculture rural urban commuting area codes (available at <http://www.ers.usda.gov/Data/RuralUrbanCommutingAreaCodes>).

(median score: 4).^{††} A neurologist was involved in the care of 62.1% of stroke patients.

Receipt of tPA

Among patients who experienced an ischemic stroke, 17.3% arrived within 2 hours of symptom onset. An additional 4.3% arrived 2–3 hours after symptom onset (Figure 1). The remaining 78.4% of patients either arrived >3 hours after symptom onset or did not know when their symptoms began or were not asked when symptoms began. To calculate the number of patients who were eligible for tPA, only patients who arrived within 2 hours of symptom onset and had no contraindications for tPA were considered. Of those 5,545 patients that arrived within 2 hours of symptom onset, 2,875 were eligible for tPA (9% of all ischemic stroke patients).

Patients identified by a health-care provider as having contraindications for tPA and who had documentation of the contraindication in the medical record were considered ineligible for tPA (Table 8). For patients who arrived within 2 hours of onset of stroke symptoms, the most common reasons for being ineligible for tPA were rapid improvement or mild stroke (46.6%) or any of the following contraindications: uncontrolled hypertension; recent surgery; recent trauma; recent stroke; active internal bleeding; suspicion of subarachnoid hemorrhage; platelets <100,000, partial thromboplastin time >40 seconds after heparin use, prothrombin time >15 seconds, or an international normalized ratio >1.7, or known bleeding diathesis; history of intracranial hemorrhage, brain aneurysm, vascular malformation, or brain tumor (22.6%); findings on brain imaging (7.7%); patient or family refusal (7.4%); and age (5.3%).

Lipid Levels

Lipid levels were measured after hospital admission, or previous lipid levels were recorded if the levels had been measured within 30 days before the stroke and were available in the medical record. Median total cholesterol and low-density lipoprotein cholesterol levels did not differ between hemorrhagic stroke and ischemic stroke patients (170 mg/dL and 171 mg/dL, 101 mg/dL and 102 mg/dL, respectively) (Table 9). The median high-density lipoprotein cholesterol level was significantly higher in hemorrhagic stroke patients compared with ischemic stroke patients (45 mg/dL and 41 mg/dL, respectively). The median triglyceride level was significantly lower in hemorrhagic stroke

patients compared with ischemic stroke patients (99 mg/dL and 110 mg/dL, respectively).

Stroke Risk Factors

PCNASR includes medical history information for each patient, including 10 risk factors for stroke: previous stroke or TIA, history of ischemic heart disease, history of atrial fibrillation, history of hypertension, history of hyperlipidemia, history of diabetes, cigarette smoking during the preceding year, history of peripheral arterial disease, presence of a heart valve prosthesis, and history of carotid stenosis. Seventy percent of patients had more than one risk factor for stroke, and 8.6% had no risk factors (Figure 2).

The most common risk factors were history of hypertension (72.7%), history of hyperlipidemia (33.8%), previous stroke or TIA (30.9%), history of diabetes (28.2%), previous myocardial infarction or history of coronary artery disease (24.7%), cigarette smoking (17.7%), and history of atrial fibrillation (15.1%) (Figure 3). A history of peripheral arterial disease, history of carotid stenosis, or presence of a valve prosthesis were recorded for <5% of patients. The prevalence of all risk factors differed significantly between white and black patients, with blacks having a higher prevalence of history of hypertension, diabetes, smoking, and previous stroke or TIA. The most common combinations of risk factors were hypertension and dyslipidemia (28.5%), hypertension and diabetes (23.8%), hypertension and previous stroke or TIA (24.4%), and hypertension and previous myocardial infarction or history of coronary artery disease (20.0%). The combination of hypertension, diabetes, and dyslipidemia, three components of metabolic syndrome, occurred in 11.0% of patients.

Risk factor prevalence varied by stroke type. Patients with hemorrhagic stroke had a lower prevalence of each risk factor than patients with ischemic stroke for all risk factors except cigarette smoking (Table 10).

Discharge Information

Median length of hospital stay varied by type of stroke: hemorrhagic stroke, 7 days; ischemic stroke, 4 days; and TIA, 2 days (Table 11). A total of 86.6% of ischemic stroke patients received rehabilitation services or were assessed for the need for rehabilitation services, compared with 68% of hemorrhagic stroke patients. Discharge status varied by diagnosis: 30.3% of hemorrhagic stroke patients were discharged home, compared with 45.8% of ischemic stroke patients; 22.7% of hemorrhagic stroke patients died, compared with 5.7% of ischemic stroke patients; 3.5% of hemorrhagic stroke patients were discharged to a hospice setting, compared with 2.5% of ischemic stroke patients. Hemorrhagic stroke and ischemic stroke patients

^{††} NIHSS is a standardized measure of stroke severity and level of stroke impairment. NIHSS scores range from 0 to 42, with increasing scores indicating increasing stroke severity or resulting impairment. Current guidelines for acute stroke care recommend the use of a standard stroke scale, such as NIHSS, to document the results of the neurological examination.

were equally likely to be discharged to chronic care facilities (43.0% and 45.5%, respectively).

Ambulation Status

Approximately half (51.1%) of hemorrhagic, ischemic, or ill-defined stroke patients were able to ambulate independently before and after the stroke (Table 12). Among all stroke patients, 26.9% were able to ambulate independently before the stroke but only with assistance after the stroke, 12.9% were able to ambulate independently before the stroke but unable to ambulate after the stroke, and 2.2% were able to ambulate with assistance before the stroke but unable to ambulate after the stroke.

Adherence to Performance Measures

Ten measures of acute stroke care were developed for PCNASR by CDC in partnership with neurologists who specialize in stroke care. In this report, these measures are not used to assess improvement over time but rather to assess total performance for the entire 36-month reporting period. Receipt of antithrombotic therapy within 48 hours of admission or by the end of the second hospital day, antithrombotic therapy at discharge, and assessment for rehabilitation services were >90% for the reporting period. Receipt of tPA by eligible patients averaged 39.8% during 2005–2007 (Table 13).

Discussion

PCNASR provides information on the quality of care provided to stroke patients by collecting data on specific stroke performance measures. PCNASR assesses these data to identify areas of stroke care in need of improvement and to develop and implement quality improvement interventions in participating hospitals. A total of 195 hospitals contributed data in PCNASR during 2005–2007, representing 56,969 patients. PCNASR is based within and led by state health departments, indicating that a state-based registry is feasible. Rates of adherence to measures of quality of care improved between the 2001–2004 prototype phase and the 2005–2007 phase of the PCNASR. Substantial improvement occurred in dysphagia screening (56.7% versus 45.4%), lipid testing (69.9% versus 33.6%), smoking cessation counseling (78.6% versus 21.4%), and antithrombotic therapy prescribed at discharge (97.6% versus 91.5%) (3).

Despite these improvements, no change occurred in the proportion of patients who arrived at the hospital in time to receive thrombolytic therapy for ischemic stroke. Only 9%

of all ischemic stroke patients were determined to be eligible to receive tPA, and only 3.6% of all ischemic stroke patients received tPA. Approximately half of ischemic stroke patients lacked documented information on time of symptom onset, and an additional 25% arrived too late to receive tPA. A total of 39.8% of acute ischemic stroke patients who were eligible for tPA received tPA within 3 hours of symptom onset. Stroke patients might have their stroke while sleeping and therefore will not know the time of onset; however, many others are unaware of the signs and symptoms of stroke. In addition, nearly 40% of stroke patients did not use EMS services for transport to hospitals, which might have contributed to pre-hospital delays and increased the number of ischemic stroke patients who were ineligible to receive thrombolytic therapy. This finding highlights the need for ongoing public health measures to inform the public about signs and symptoms of stroke and the need to activate EMS for suspected stroke. Timely recognition of stroke and hospital transport are necessary for patients to be eligible to receive tPA.

Three of the 10 acute stroke performance measures were met for >90% of patients: 1) treating patients with antithrombotic therapy within 48 hours of admission or by the end of the second hospital day, 2) prescribing antithrombotic therapy at discharge, and 3) assessing the need for rehabilitation. A total of 90.1% of stroke patients were assessed for the need for rehabilitation services. Forty-four percent of stroke patients who could ambulate independently before the stroke could not ambulate independently after the stroke, highlighting the need for access to rehabilitation.

Demographic data from PCNASR indicated high rates of hypertension among both white (71%) and black (81%) stroke patients, highlighting the substantial relationship between stroke and hypertension and the need for prevention of this important risk factor. PCNASR data also indicate that the mean age of black stroke patients is 10 years younger than that of whites (62 years versus 72 years). The younger age of stroke patients in Georgia (mean: 66 years) likely reflects the higher proportion of black patients in the Georgia (36%) registry; Massachusetts, which has a much lower proportion of black stroke patients (5.6%) in the registry, had the oldest stroke patients of the four states (mean: 73 years). Stroke is a leading cause of disability and affects a greater proportion of blacks during their productive work years.

The United States has approximately four neurologists per 100,000 persons. U.S. neurologists treat approximately 700,000 acute strokes per year; however, patients in many parts of the United States have no access to acute stroke services (20). PCNASR data indicate that neurologists were involved in the care of 62.1% of stroke patients. Most rural hospital staffs do not include neurologists. Telemedicine might increase

neurologist participation in acute stroke care and improve geographic disparities in access to quality stroke care. In the Veteran's Administration Acute Stroke Study, care of stroke patients by a neurologist was associated with increased testing, improved outcomes, and decreased mortality in acute stroke patients (21).

The ultimate goal of programs such as PCNASR and Get With the Guidelines—Stroke (GWTG—S) is to improve care provided to stroke patients. GWTG—S reported improvements in stroke care in 99 participating hospitals (22). In a CMS review of another program to improve stroke care in the United States (the Medicare Quality Improvement Organization program), the median performance among all states in three performance measures related to stroke care improved between 1998–1999 and 2000–2001 (23). Additional analyses are needed to assess improvements in adherence to guidelines over time.

Although PCNASR focuses primarily on the 10 described acute stroke care performance measures, data on selected hospital outcomes also were collected, including in-hospital deaths by type of stroke. In-hospital deaths occurred among 22.7% of patients who experienced hemorrhagic stroke, 5.7% of patients who experienced ischemic stroke, and 4.3% of patients who experienced ill-defined strokes. These rates are similar to those reported in a study that involved 857 hospitals and 365,186 patients. In that study, in-hospital mortality for hemorrhagic and ischemic strokes was 25.9% and 5.5%, respectively (24). A recent report from the Registry of the Canadian Stroke Network found that the level of organized hospital stroke care, as determined by the presence or absence of occupational therapy, physical therapy, stroke team assessment, and admission to a stroke unit, was related to the risk-adjusted 7-day stroke mortality (25). Additional studies of outcomes associated with acute stroke performance measures in hospitals are needed to assess other outcomes (e.g., disability, postacute care, and quality of life), as are better methods of calculating risk-adjusted stroke mortality (26).

Arriving at the hospital by EMS was associated with a shorter time between hospital arrival and initial CT scan, a finding that is consistent with previous reports (27,28). This finding highlights the need for persons who are experiencing stroke signs and symptoms to be transported to the hospital by EMS rather than other forms of transportation. Combined PCNASR data from all four states indicated a median time of 42 minutes from hospital arrival to initial CT scan among patients who arrived within 2 hours of symptom onset, the same time as in North Carolina, suggesting that the combined data are consistent with data from a single state.

The findings in this report are subject to at least four limitations. First, methods for hospital selection and data validation

varied among states. PCNASR data are not intended to be used for population estimates but rather to reflect care provided by hospitals participating in PCNASR. Second, the number of Hispanic cases is limited; therefore, statistical comparison of data on Hispanics should be interpreted with caution. Third, certain data were missing or excluded. For example, EMS date and times of service were missing from 81% of medical records because EMS trip sheets are not part of the hospital medical record; time of stroke was unknown in 57% of cases. Ambulation status was missing in 30% of stroke cases, lipid levels were missing in 38% of cases, and NIHSS scores were missing in 66% of ischemic stroke cases. In addition, because TIA patients often are not admitted to the hospital or are admitted to an observation unit only, not all TIA patients were included in the registry. Inclusion of patients admitted for short-term ED observation is optional, and ED cases that do not result in hospital admission are not typically included. (Massachusetts is the only state that requires inclusion of all stroke patients who arrive at the ED within 3 hours of symptom onset and still have symptoms on arrival.) Finally, although states reabstract at least 5% of cases to assess data accuracy, and CDC works with state registry programs to improve the accuracy of abstracted data, the overall accuracy of data likely varies among states and hospitals. Determining the completeness of data abstraction is difficult because the case definition is based on clinical diagnosis and retrospective comparisons with hospital case records based on ICD-9-CM codes. State registry programs report that they include approximately 57% of stroke discharges at registry hospitals based on ICD-9-CM codes. Because only a subset of these ICD-9-CM codes (430–438) represent acute stroke or TIA, the actual percentage of cases abstracted is thought to be >57%. The limitations of using ICD-9-CM codes to identify acute stroke patients have been described previously (29,30). State-reported estimates on case ascertainment based on hospital discharge records ranged from 54% to 97%.

Conclusion

Data from the 2005–2007, the first 3 years of PCNASR, provide a useful marker from which future trends can be evaluated, including acute stroke patient characteristics, hospital diagnostic and treatment performance measures, discharge status, and estimates of time from stroke onset to treatment. The focus on recruiting diverse types of hospitals within each state allows for identification of geographic and demographic variations in stroke care. The quality improvement component of the registry allows state health departments to work with hospitals to improve the stroke care and reduce disparities in care, including disparities by geographic area, race, and sex .

Implementing PCNASR within state health departments has several advantages, including 1) broadening stroke care to include linking secondary and primary stroke prevention activities; 2) capitalizing on established relationships with the various hospitals in the state; 3) engaging local health departments, state regulators, and regional health coordinators in the recruitment and retention of registry sites; 4) local monitoring of data quality; and 5) customizing quality improvement initiatives to meet local needs. PCNASR is implementing various quality improvement initiatives in funded states, including regional collaborations with hospital stroke quality improvement teams, data feedback to hospitals in the form of grand rounds presentations to a wide hospital staff audience, use of small tests of change to improve hospital care processes and pathways, identifying physicians willing to promote stroke quality of care initiatives, engaging hospital administration, and focused discussions on barriers and opportunities to implement best practices. This collaborative, state- and hospital-based quality improvement registry can be used to develop comprehensive stroke care protocols and to identify disparities in care by race/ethnicity, geographic region, and sex, which can be used to improve access to higher quality care for stroke patients in every state.

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TABLE 1. Paul Coverdell National Acute Stroke Registry performance measures of care for stroke patients, by type of stroke

Measure number	Measure name	Ischemic stroke	Transient ischemic attack	Hemorrhagic stroke*	Ill-defined stroke†
1	Received deep venous thrombosis prophylaxis	●		●	●
2	Prescribed antithrombotic therapy when discharged	●	●		
3	Received anticoagulation medication for atrial fibrillation	●	●		
4	Received tissue plasminogen activator	●			
5	Received antithrombotic therapy within 48 hrs of admission or by the end of the second hospital day	●	●		
6	Received lipid level measurement	●	●		
7	Received dysphagia screening	●		●	●
8	Received stroke education	●	●	●	●
9	Received smoking cessation counseling	●	●	●	●
10	Assessed for rehabilitation services	●		●	●

* Includes both subarachnoid hemorrhage and intracerebral hemorrhage.

† Stroke that is not defined as hemorrhagic or ischemic in the medical record.

TABLE 2. Selected characteristics of hospitals (N = 190*) participating in the Paul Coverdell National Acute Stroke Registry — Georgia, Illinois, Massachusetts, and North Carolina, 2005–2007

Characteristic	No. of hospitals	(%)
Hospital size (by number of hospital beds)		
<100	38	(20.0)
100–199	55	(28.9)
200–399	55	(28.9)
≥400	42	(22.1)
Number of admissions for stroke and transient ischemic attack per year		
1–25	11	(5.8)
26–99	33	(17.4)
100–199	37	(19.5)
200–299	31	(16.3)
300–499	37	(19.5)
500–749	21	(11.1)
≥750	20	(10.5)
Teaching hospital		
Yes	64	(33.7)
No	126	(66.3)
Hospital with speech therapy		
Yes	159	(83.7)
No	18	(9.5)
Missing	13	(6.8)
Hospital with occupational therapy		
Yes	165	(86.8)
No	11	(5.8)
Missing	14	(7.4)
Hospital with physical therapy		
Yes	173	(91.1)
No	3	(1.6)
Missing	14	(7.4)
Hospital RUCA codes†		
Metropolitan or micropolitan§	166	(87.4)
Small town or rural¶	24	(12.6)

* Of a total of 195 hospitals, hospital characteristic information was available for 190.

† U.S. Department of Agriculture rural-urban commuting area.

§ Metropolitan: an urban core population area with a population of ≥50,000; micropolitan: an urban core population area with a population of 10,000 to <50,000.

¶ An urban core population area with a population of <10,000.

TABLE 3. Age, sex, and race/ethnicity of adult stroke patients, overall and by state — Paul Coverdell National Acute Stroke Registry, Georgia, Illinois, Massachusetts, and North Carolina, 2005–2007

Characteristic	Total (N = 56,969)	Georgia (N = 13,047)	Illinois (N = 10,257)	Massachusetts (N = 16,984)	North Carolina (N = 16,681)
Age at admission, yrs					
Median	72	67	72	77	70
Range	18–108	18–105	18–104	18–107	18–108
Mean (SE*)	69.6 (0.1)	66.4 (0.1)	69.9 (0.2)	73.4 (0.1)	68.2 (0.1)
Sex, no. (%)					
Male	26,583 (46.7)	6,184 (47.4)	4,735 (46.2)	7,820 (46.0)	7,844 (47.0)
Female	30,386 (53.3)	6,863 (52.6)	5,522 (53.8)	9,164 (54.0)	8,837 (53.0)
Race, no. (%)					
White	42,398 (74.4)	7,729 (59.2)	7,762 (75.7)	15,093 (88.9)	11,814 (70.8)
Black	11,893 (20.9)	4,670 (35.8)	1,842 (18.0)	951 (5.6)	4,430 (26.6)
Asian	765 (1.3)	181 (1.4)	184 (1.8)	261 (1.5)	139 (0.8)
Native Hawaiian/Other Pacific Islander	28 (0.0)	11 (0.1)	5 (0.0)	5 (0.0)	7 (0.0)
American Indian/Alaska Native	86 (0.2)	9 (0.1)	12 (0.1)	5 (0.0)	60 (0.4)
Other	329 (0.6)	61 (0.5)	71 (0.7)	51 (0.3)	146 (0.9)
Unknown	1,470 (2.6)	386 (3.0)	381 (3.7)	618 (3.6)	85 (0.5)
Ethnicity, no. (%)					
Hispanic	1,400 (2.5)	216 (1.7)	504 (4.9)	478 (2.8)	202 (1.2)
Non-Hispanic	55,569 (97.5)	12,831 (98.3)	9,753 (95.1)	16,506 (97.2)	16,479 (98.8)

* Standard error.

TABLE 4. Age of adult stroke patients at hospital admission, by sex and race/ethnicity — Paul Coverdell National Acute Stroke Registry, Georgia, Illinois, Massachusetts, and North Carolina, 2005–2007

Characteristic	No.	Age at hospital admission (yrs)	
		Mean (SE*)	Median (Range)
Sex			
Male	26,583	67.0 (0.1)	68 (18–106)
Female	30,386	71.8 (0.1)	75 (18–108)
Race			
White	42,398	72.0 (0.1)	75 (18–107)
Male	19,927	69.2 (0.1)	71 (18–106)
Female	22,471	74.5 (0.1)	78 (18–107)
Black	11,893	62.2 (0.1)	61 (18–108)
Male	5,274	60.1 (0.2)	59 (18–102)
Female	6,619	63.8 (0.2)	63 (19–108)
Asian	765	66.9 (0.5)	68 (21–100)
Male	402	65.1 (0.7)	65 (22–97)
Female	363	68.8 (0.7)	69 (21–100)
Other	1,913	62.9 (0.4)	64 (18–103)
Male	980	60.9 (0.5)	61 (18–94)
Female	933	65.0 (0.6)	67 (18–103)
Ethnicity			
Hispanic	1,400	60.7 (0.4)	62 (18–97)
Non-Hispanic	55,569	69.8 (0.1)	72 (18–108)

* Standard error.

TABLE 5. Stroke type among adult stroke patients, overall and by state — Paul Coverdell National Acute Stroke Registry, Georgia, Illinois, Massachusetts, and North Carolina, 2005–2007

Stroke type	Total (N = 56,969)		Georgia (N = 13,047)		Illinois (N = 10,257)		Massachusetts (N = 16,984)		North Carolina (N = 16,681)	
	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)
Hemorrhagic	7,839	(13.8)	2,615	(20.0)	1,620	(15.8)	894	(5.3)	2,710	(16.2)
Ischemic	32,014	(56.2)	7,884	(60.4)	4,228	(41.2)	11,873	(69.9)	8,029	(48.1)
Ill defined	4,158	(7.3)	162	(1.2)	1,749	(17.1)	250	(1.5)	1,997	(12.0)
Transient ischemic attack	12,320	(21.6)	2,289	(17.5)	2,511	(24.5)	3,760	(22.1)	3,760	(22.5)
Unable to classify*	638	(1.1)	97	(0.8)	149	(1.4)	207	(1.2)	185	(1.2)

* Because more than one stroke type could be entered into the registry for a single stroke case (e.g., a case of hemorrhagic stroke that converted to an ischemic stroke, which could be categorized as both ischemic and hemorrhagic), determining a single type was not possible in a certain number of cases.

TABLE 6. Mode and location of hospital arrival, time from symptom onset to emergency medical services (EMS) call, and time from symptom onset to emergency department (ED) arrival among adult stroke patients (N = 56,969) — Paul Coverdell National Acute Stroke Registry, Georgia, Illinois, Massachusetts, and North Carolina, 2005–2007

Characteristic	No.	(%*)
Arrival mode		
EMS transport from scene of symptom onset	27,145	(47.6)
EMS transfer from another hospital	6,343	(11.1)
Private or other	22,419	(39.4)
Missing or not documented	1,062	(1.9)
Location of arrival in hospital		
ED or urgent care	51,518	(90.4)
Direct admission	4,802	(8.4)
Not documented	499	(0.9)
Missing	150	(0.3)
Time from symptom onset to EMS call†		
No. of patients	6,483	—
Median, hrs	1.2	—
Range, hrs	0.02–240.0	—
Mean (SE§), hrs	4.4	(0.1)
Missing	27,005¶	(81¶)
Time from symptom onset to ED arrival†		
No. of patients	24,042	—
Median, hrs	2.5	—
Range, hrs	0.02–240.0	—
Mean (SE), hrs	6.2	(0.1)
Missing	32,927	(58)

* Values are reported as number (percentage) unless otherwise indicated.

† Times <0 or >240 hrs were calculated as missing in this analysis.

§ Standard error.

¶ A total of 66% of the missing data were a result of missing or unknown time of symptom onset.

TABLE 7. Receipt of brain imaging services and other selected treatment characteristics among adult stroke patients (N = 56,969) — Paul Coverdell National Acute Stroke Registry, Georgia, Illinois, Massachusetts, and North Carolina, 2005–2007

Characteristic	No.	(%*)
Hours from symptom onset to arrival		
≤2	10,567	(18.5)
>2–8	8,517	(15.0)
>8–24	3,829	(6.7)
>24	1,129	(2.0)
Missing	32,927	(57.8)
Time from hospital arrival until receipt of brain imaging†		
No. of patients	46,961	—
Median, hrs	1.2	—
Range, hrs	0.02–238.4	—
Mean (SE‡), hrs	2.6	(0.04)
Missing	10,008	(18)
Time from hospital arrival until receipt of brain imaging among patients who arrived within 2 hrs of symptom onset†		
No. of patients	10,004	—
Median, hrs	0.7 hr	—
Range, hrs	0.02–193.5	—
Mean (SE), hrs	1.3	(0.05)
Missing	563	(5)
Initial imaging results		
No hemorrhage	48,052	(84.3)
Hemorrhage	7,910	(13.9)
Not available	582	(1.0)
Missing	425	(0.7)
NIHSS‡ score: hemorrhagic stroke patients		
No. of patients	1,100	—
Median	8.0	—
Range	0–42.0	—
Mean (SE)	10.4	(0.3)
Missing	6,739	(86)
NIHSS score: ischemic stroke patients		
No. of patients	10,989	—
Median	4.0	—
Range	0–42.0	—
Mean (SE)	7.1	(0.1)
Missing	21,025	(66)
Neurologist involved in patient care**		
Yes	35,377	(62.1)
No/not documented	4,769	(8.4)
Missing	16,823	(29.5)

* Values are reported as number (percentage) unless otherwise indicated.

† Times <0 or >240 hrs were calculated as missing in this analysis.

‡ Standard error.

§ National Institutes of Health Stroke Scale.

** Optional question (data not collected by all states).

TABLE 8. Receipt of tissue plasminogen activator (tPA) therapy and reasons for lack of tPA therapy among adult ischemic stroke patients (N = 32,014) — Paul Coverdell National Acute Stroke Registry, Georgia, Illinois, Massachusetts, and North Carolina, 2005–2007

Characteristic	No.	(%)
Hours from symptom onset to hospital arrival		
≤2	5,545	(17.3)
>2–3	1,365	(4.3)
>3 or unknown	25,104	(78.4)
tPA therapy administered to eligible ischemic stroke patients (i.e., patients who arrived within 2 hrs of symptom onset and had no contraindications) (N = 2,875)		
Yes	1,144	(39.8)
No	1,731	(60.2)
Reasons for patients being deemed ineligible for tPA (N = 2,670)		
Delay in patient arrival*	200	(7.5)
Delay in obtaining brain imaging, other time delays	58	(2.2)
Rapid improvement or stroke too mild to warrant treatment*	1,243	(46.6)
Stroke too severe to provide tPA*	113	(4.2)
Certain brain imaging findings* (e.g., intracranial hemorrhage and massive stroke)	206	(7.7)
Patient or family refused*	197	(7.4)
Age*	142	(5.3)
Seizure at onset*	70	(2.6)
Unable to determine eligibility*	84	(3.1)
Patient transferred to another hospital*	9	(0.3)
tPA not available	7	(0.3)
Risk of bleeding, not otherwise specified*	25	(0.9)
Patient not a candidate, per physician, not otherwise specified*	24	(0.9)
Investigative therapy or other treatment*	31	(1.2)
Contraindications* (e.g., history of intracranial hemorrhage, brain aneurysm, vascular malformation, or brain tumor)	604	(22.6)
Patient condition that might lead to unfavorable outcome* (e.g., increased risk of bleeding because of recent pericarditis, subacute bacterial endocarditis, hemostatic defects from renal or hepatic failure, pregnancy, diabetic retinopathy, septic thrombophlebitis, or taking oral anticoagulation medication)	129	(4.8)
Unable to make current diagnosis	64	(2.4)

* Resulted in exclusion from the tPA performance measure.

TABLE 9. Lipid levels among adult stroke patients, by type of stroke — Paul Coverdell National Acute Stroke Registry, Georgia, Illinois, Massachusetts, and North Carolina, 2005–2007

Lipid level	Stroke type					
	Total (N = 56,969)	Hemorrhagic (N = 7,839)	Ischemic (N = 32,014)	Ill defined (N = 4,158)	Transient ischemic attack (N = 12,320)	Other (N = 638)
Total cholesterol						
No. of patients	36,186	2,141	23,266	2,523	7,856	400
Median, mg/dL	172	170	171	175	172	174
Range, mg/dL	9–990	9–359	9–917	21–427	9–990	82–399
Mean (SE)*, mg/dL	176.3 (0.3)	172.9 (1.0)	176.4 (0.3)	179.3 (1.0)	175.9 (0.5)	177.1 (2.4)
Missing, no. (%)	20,783 (36)	—	—	—	—	—
Low-density lipoprotein						
No. of patients	35,138	2,044	22,639	2,377	7,691	387
Median, mg/dL	102	101	102	105	100	103
Range, mg/dL	1–1,784	1–279	1–1,784	4–860	1–926	24–288
Mean (SE), mg/dL	106.9 (0.2)	105.4 (0.9)	107.5 (0.3)	110.8 (0.9)	104.1 (0.5)	108.6 (2.1)
Missing, no. (%)	21,831 (38)	—	—	—	—	—
High-density lipoprotein						
No. of patients	35,588	2,029	23,004	2,422	7,742	391
Median, mg/dL	42	45	41	41	43	42
Range, mg/dL	2–998	5–998	3–941	5–600	2–438	15–150
Mean (SE), mg/dL	45.2 (0.1)	48.5 (0.6)	44.5 (0.1)	44.9 (0.5)	46.7 (0.2)	45.0 (0.9)
Missing, no. (%)	21,381 (38)	—	—	—	—	—
Triglyceride						
No. of patients	35,763	2,137	23,026	2,451	7,755	394
Median, mg/dL	111	99	110	114	113	109
Range, mg/dL	1–6,331	15–1,999	9–6,331	9–2,018	1–4,700	29–816
Geometric mean (SE), mg/dL	114.9 (0.4)	162.7 (6.1)	137.6 (0.9)	142.2 (2.3)	141.3 (1.4)	113.4 (3.0)
Missing, no. (%)	21,206 (37)	—	—	—	—	—

* Standard error.

TABLE 10. Prevalence of risk factors for stroke among adult stroke patients, by type of stroke — Paul Coverdell National Acute Stroke Registry, Georgia, Illinois, Massachusetts, and North Carolina, 2005–2007

Risk factor	Stroke type									
	Hemorrhagic (N = 7,839)		Ischemic (N = 32,014)		Ill defined (N = 4,158)		Transient ischemic attack (TIA) (N = 12,320)		Other (N = 638)	
	No.	(%)	No.	(%)	No.	(%)	No.	(%)	No.	(%)
Previous stroke or TIA	1,590	(20.3)	9,836	(30.7)	1,466	(35.3)	4,440	(36.0)	243	(38.1)
Previous myocardial infarction or history of coronary artery disease	1,220	(15.6)	8,468	(26.5)	1,075	(25.9)	3,158	(25.6)	174	(27.3)
History of atrial fibrillation	864	(11.0)	5,554	(17.3)	539	(13.0)	1,505	(12.2)	125	(19.6)
History of hypertension	5,250	(67.0)	23,860	(74.5)	3,040	(73.1)	8,815	(71.6)	458	(71.8)
History of hyperlipidemia	1,515	(19.3)	11,390	(35.6)	1,237	(29.7)	4,908	(39.8)	203	(31.8)
History of diabetes	1,524	(19.4)	9,714	(30.3)	1,317	(31.7)	3,329	(27.0)	186	(29.2)
History of cigarette smoking during the preceding year	1,614	(20.6)	5,927	(18.5)	740	(17.8)	1,722	(14.0)	104	(16.3)
History of peripheral arterial disease	154	(2.0)	1,479	(4.6)	96	(2.3)	519	(4.2)	33	(5.2)
Presence of valve prosthesis	90	(1.1)	426	(1.3)	50	(1.2)	210	(1.7)	13	(2.0)
History of carotid stenosis	116	(1.5)	1,389	(4.3)	134	(3.2)	584	(4.7)	30	(4.7)

TABLE 11. Length of hospital stay, receipt of rehabilitation services, and discharge status among adult stroke patients, by type of stroke — Paul Coverdell National Acute Stroke Registry, Georgia, Illinois, Massachusetts, and North Carolina, 2005–2007

Variable	Stroke type					
	Total (N = 56,969)	Hemorrhagic (N = 7,839)	Ischemic (N = 32,014)	Ill defined (N = 4,158)	Transient ischemic attack (N = 12,320)	Other (N = 638)
Length of stay*						
No.	54,381	7,132	31,067	4,010	11,553	619
Median, days	4	7	4	4	2	4
Range, days	1–120	1–120	1–119	1–91	1–94	1–73
Mean (SE†), days	5.5 (0.03)	9.8 (0.1)	5.6 (0.03)	5.1 (0.1)	2.83 (0.03)	6.3 (0.3)
Missing	2,588 (5)	—	—	—	—	—
Assessed for or received rehabilitation services, no. (%)						
Yes	44,405 (77.9)	5,331 (68.0)	27,711 (86.6)	3,487 (83.9)	7,357 (59.7)	519 (81.3)
No	10,033 (17.6)	1,949 (24.9)	3,415 (10.7)	514 (12.4)	4,070 (33.0)	85 (13.3)
Not documented	2,498 (4.4)	550 (7.0)	868 (2.7)	157 (3.8)	889 (7.2)	34 (5.3)
Missing	33 (0.1)	9 (0.1)	20 (0.1)	—	4 (0.0)	—
Discharge status, no. (%)						
Discharged home	29,854 (52.4)	2,379 (30.3)	14,656 (45.8)	1,979 (47.6)	10,535 (85.5)	305 (47.8)
Left against medical advice	328 (0.6)	32 (0.4)	150 (0.5)	23 (0.6)	122 (1.0)	1 (0.2)
Died	3,856 (6.8)	1,781 (22.7)	1,815 (5.7)	178 (4.3)	30 (0.2)	52 (8.2)
Entered hospice	1,231 (2.2)	272 (3.5)	796 (2.5)	116 (2.8)	36 (0.3)	11 (1.7)
Entered an another institution	21,648 (38.0)	3,369 (43.0)	14,567 (45.5)	1,860 (44.7)	1,585 (12.9)	267 (41.8)
Missing	52 (0.1)	6 (0.1)	30 (0.1)	2 (0.0)	12 (0.1)	2 (0.3)

* Lengths of stay <1 or >120 days were calculated as missing for this analysis.

† Standard error.

TABLE 12. Change in ambulation status among adult stroke patients (N = 25,923*) before and after stroke†— Paul Coverdell National Acute Stroke Registry, Georgia, Illinois, Massachusetts, and North Carolina, 2005–2007

Ambulation status before stroke	Ambulation status after stroke	No.	(%)
Independent	Independent	13,259	(51.1)
Independent	Only with assistance	6,976	(26.9)
Independent	Unable to ambulate	3,335	(12.9)
Only with assistance	Unable to ambulate	572	(2.2)
Other combinations	Other combinations	1,781	(6.9)

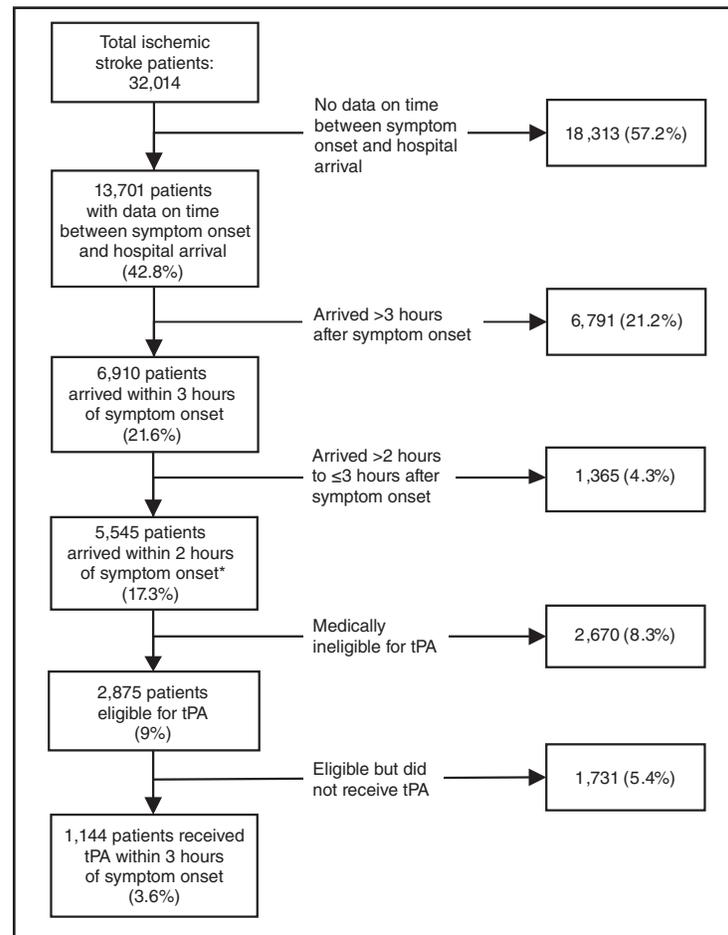
* Does not include 3,774 patients who died and 14,314 patients whose ambulation status information was missing.

† Among patients with hemorrhagic, ischemic, and ill-defined strokes.

TABLE 13. Adherence to stroke performance measures of care — Paul Coverdell National Acute Stroke Registry, Georgia, Illinois, Massachusetts, and North Carolina, 2005–2007

Performance measure	Total eligible patient population	Patients receiving intervention or treatment	
		No.	(%)
Received deep venous thrombosis prophylaxis	25,400	21,709	(85.5)
Received antithrombotic therapy when discharged	38,746	37,821	(97.6)
Received anticoagulation for atrial fibrillation	4,206	3,470	(82.5)
Received tissue plasminogen activator (among eligible patients)	2,875	1,144	(39.8)
Received antithrombotic therapy within 48 hrs of admission or by the end of the second hospital day	32,219	30,469	(94.6)
Received lipid level testing	44,317	30,965	(69.9)
Screened for dysphagia (i.e., swallow screening)	38,516	21,834	(56.7)
Received stroke education	48,850	28,748	(58.8)
Received smoking cessation counseling	8,929	7,016	(78.6)
Assessed for rehabilitation services	36,943	33,292	(90.1)

FIGURE 1. Percentage of ischemic stroke patients who received tissue plasminogen activator (tPA) therapy — Paul Coverdell National Acute Stroke Registry, Georgia, Illinois, Massachusetts, and North Carolina, 2005–2007



* Only patients who arrived within 2 hours of symptom onset and had no contraindications for tPA were considered eligible for tPA.

FIGURE 2. Number of risk factors for stroke among adult stroke patients (N = 56,969) and percentage of patients with risk factors — Paul Coverdell National Acute Stroke Registry, Georgia, Illinois, Massachusetts, and North Carolina, 2005–2007

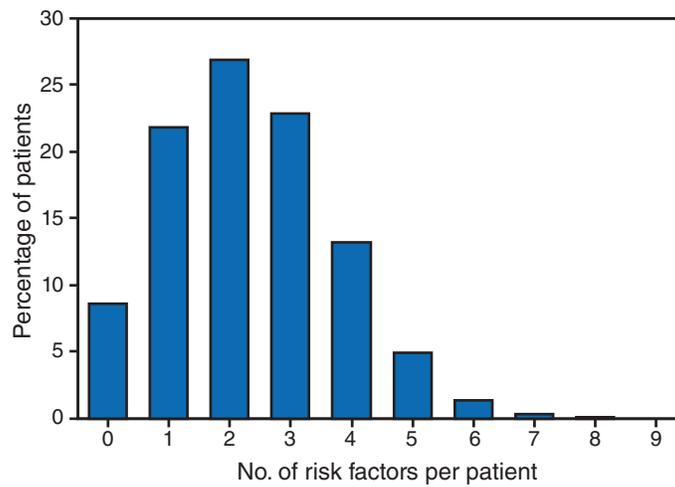
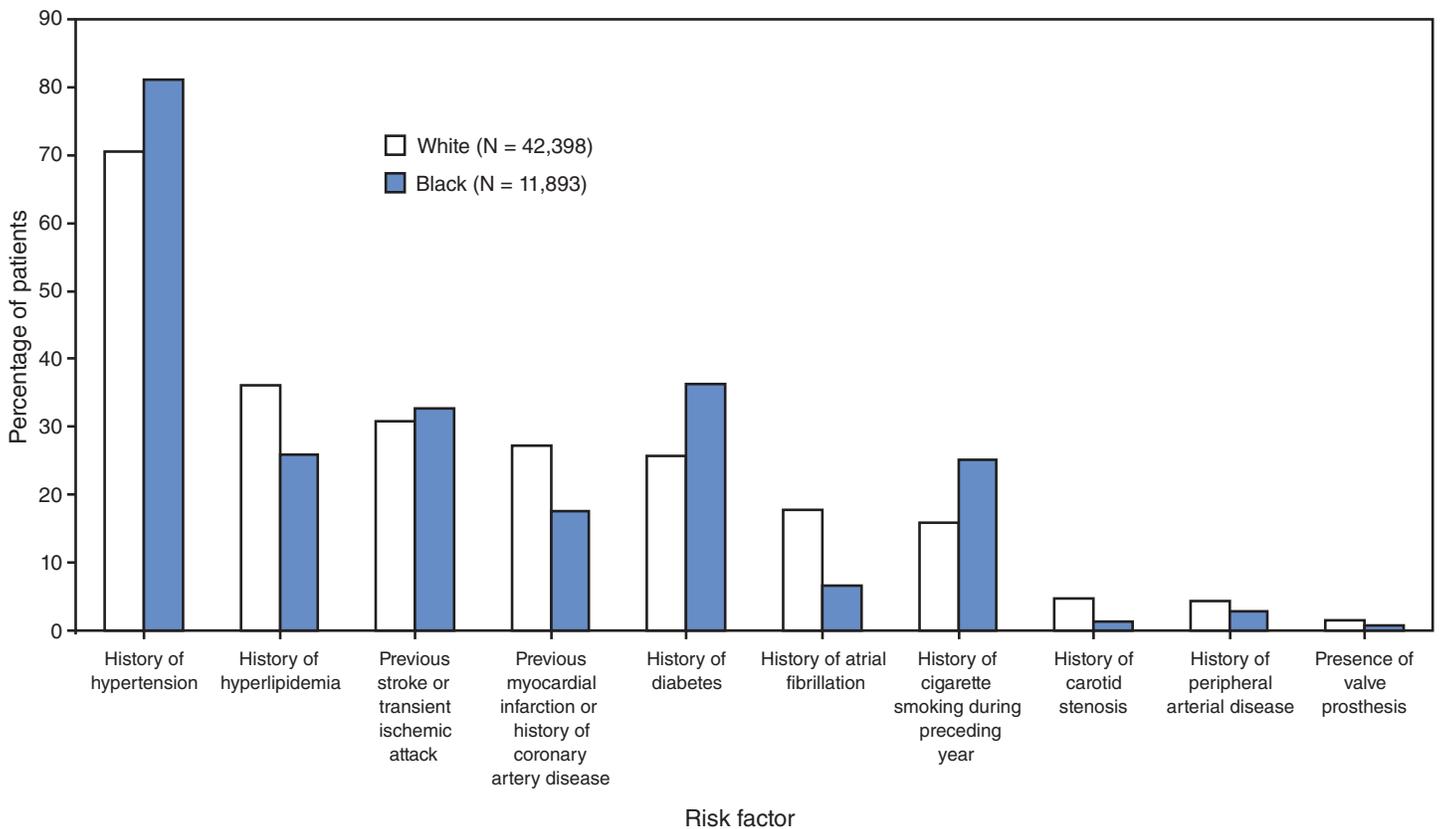


FIGURE 3. Prevalence of risk factors for stroke among adult stroke patients, by race — Paul Coverdell National Acute Stroke Registry, Georgia, Illinois, Massachusetts, and North Carolina, 2005–2007



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