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Revised and Updated Recommendations for the Establishment of Primary Stroke Centers

A Summary Statement From the Brain Attack Coalition

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Background and Purpose—The formation and certification of Primary Stroke Centers has progressed rapidly since the Brain Attack Coalition's original recommendations in 2000. The purpose of this article is to revise and update our recommendations for Primary Stroke Centers to reflect the latest data and experience.

Methods—We conducted a literature review using MEDLINE and PubMed from March 2000 to January 2011. The review focused on studies that were relevant for acute stroke diagnosis, treatment, and care. Original references as well as meta-analyses and other care guidelines were also reviewed and included if found to be valid and relevant. Levels of evidence were added to reflect current guideline development practices.

Results—Based on the literature review and experience at Primary Stroke Centers, the importance of some elements has been further strengthened, and several new areas have been added. These include (1) the importance of acute stroke teams; (2) the importance of Stroke Units with telemetry monitoring; (3) performance of brain imaging with MRI and diffusion-weighted sequences; (4) assessment of cerebral vasculature with MR angiography or CT angiography; (5) cardiac imaging; (6) early initiation of rehabilitation therapies; and (7) certification by an independent body, including a site visit and disease performance measures.

Conclusions—Based on the evidence, several elements of Primary Stroke Centers are particularly important for improving the care of patients with an acute stroke. Additional elements focus on imaging of the brain, the cerebral vasculature, and the heart. These new elements may improve the care and outcomes for patients with stroke cared for at a Primary Stroke Center. (*Stroke*. 2011;42:2651-2665.)

Key Words: cerebrovascular disease ■ disease management ■ stroke centers ■ stroke units

Stroke is a common and serious disorder. Each year in the United States, approximately 795 000 people will have a new or recurrent stroke.¹ It is the fourth leading cause of death in the United States and a major cause of adult disability.² Stroke is also a costly disease with lifetime costs in excess of \$140 000 for ischemic stroke and >\$225 000 for subarachnoid hemorrhage.^{3,4} Annual costs for stroke in the United States exceed \$73 billion.¹ Improved care of patients with an acute stroke may reduce the high morbidity and mortality from this disorder and have significant public health and financial implications.

Prior studies have shown that many patients with stroke are not treated according to contemporary guidelines.^{5,6} One

approach to improving stroke care is the development of Stroke Centers.^{7,8} These hospitals would act as focal points for the care of patients with an acute stroke. The fact that 77% of US counties lack a hospital with neurological services further highlights the need for more organized and centralized stroke care.¹ Two levels of Stroke Centers have been delineated in the literature: (1) a Primary Stroke Center (PSC)⁹; and (2) a Comprehensive Stroke Center (CSC).¹⁰ A PSC would provide acute care to most patients with stroke, be able to use some acute therapies, and admit the patient if it had a Stroke Unit.⁹ A CSC would provide care to those patients with large or complex strokes, hemorrhagic strokes, patients who required specialized treatments (endovascular, surgery),

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or those with multisystem involvement.¹⁰ A third type of facility, the Acute Stroke Ready Hospital, is currently under development. The Acute Stroke Ready Hospital would have fewer capabilities than a PSC but be able to diagnose, stabilize, treat, and transfer most patients with stroke. An Acute Stroke Ready Hospital would typically be a smaller facility in a small community or rural setting with limited resources.

Since The Joint Commission (TJC) and other entities/organizations (ie, state health departments, the Healthcare Facilities Accreditation Program) have begun to formally certify and recognize certain hospitals as PSCs, the number of such hospitals has increased dramatically.¹¹ To date, there are >800 PSCs certified by TJC and perhaps another 200 to 250 certified by various state-based agencies, the Healthcare Facilities Accreditation Program, and other organizations. On average a typical PSC admits approximately 400 to 440 patients with stroke per year, has an average of 400 beds, and is in an urban area. Most are not major teaching hospitals.¹²

Since the initial publication of the PSC recommendations in 2000, there have been substantive modifications and changes in how patients with stroke are diagnosed and treated.^{13–16} These relate to the efficacy and importance of stroke teams, Stroke Units, the use of intravenous tissue plasminogen activator (tPA), and imaging advances, among others. Some other important advances such as endovascular therapies and acute surgery are more germane to a CSC and are not reviewed here. This revision will re-examine the key elements for a PSC, performance measures, and options for certification in an effort to update them and provide levels of evidence.

Methods

A comprehensive review of the English language literature using MEDLINE and PubMed was conducted to identify articles dealing with the formation, function, and outcomes of Stroke Centers; the use of acute imaging techniques; and related treatments and outcomes related to acute stroke care. Key words and terms used included Stroke Centers, stroke teams, Stroke Units, stroke guidelines, brain imaging, acute treatment, and other specific terms that might reflect care elements at a PSC. These publications deal with the diagnosis and treatment of all types of strokes (ischemic and hemorrhagic). We focused on articles published between March 2000 and January 2011, but also cited older literature if it contained relevant information. We reviewed randomized clinical trials as well as large case series, care guidelines, consensus publications, and appropriate observational studies. These data and subsequent recommendations were then reviewed and analyzed by the members of the Brain Attack Coalition (BAC) to help develop recommendations for this revision of the PSC recommendations.

Most recommendations were graded using a slightly modified form of the American Heart Association evidence-based grading system.¹⁷ Other grading criteria relevant to therapies and diagnostic imaging were used as appropriate.¹⁸ A summary of these criteria is in Table 1. The modifications were made to accommodate the diverse care aspects that are integral parts of a PSC. In some cases, recommendations from other care guidelines and scientific statements from organizations such as the American Heart Association and the American Academy of Neurology were reviewed and included or modified based on a review by the BAC (and were referenced as appropriate). The inclusion of specific grading criteria is an improvement over the prior recommendations, because levels of evidence were not included in that publication.⁹ Individual articles were graded based on their study design, methodology, number of

Table 1. Grading Criteria Used for Recommendations*

| | Explanation | Comment |
|--------------------------------|--|---|
| Class of recommendation | | |
| I | Benefits of treatment, test, intervention, or personnel clearly outweigh any risks | This treatment, test, intervention, or personnel should be used |
| IIa | Benefits of treatment, test, intervention, or personnel likely outweigh any risks | It is reasonable to use treatment, test, intervention, or personnel |
| IIb | Benefits of treatment, test, intervention, or personnel is possibly greater than the risks | It is reasonable to consider this treatment, test, intervention, or personnel in some cases |
| III | Risks may be equal to or greater than any benefits | Treatment, test, intervention, or personnel should not be used |
| Level of evidence | | |
| A | Treatment or test validated in multiple studies/populations, meta-analyses, or circumstances | Very consistent treatment effects or test sensitivity and specificity |
| B | Treatment or test studied in studies/populations or circumstances with some limitations | Treatment effects promising but somewhat limited; testing results less robust |
| C | Treatment or test examined in few or very limited studies/populations or clinical circumstances; case series, expert opinion | Treatment or test recommendation based largely on expert opinion or is standard of care; may be a need for further studies/data |

*This grading system has been adapted and modified from other publications (see references 14–18) to reflect the unique components of Primary Stroke Centers.

patients, and general applicability of the results to a broad stroke population. The BAC also considered other aspects of its recommendations such as logistical issues, feasibility, applicability, and costs. In cases of disagreement about the inclusion about a specific care element or recommendation, the BAC membership would vote on its inclusion or modification, with a two thirds majority needed for final approval and inclusion.

Results

A thorough literature review provided high levels of support for many of the initial key elements of a PSC. In addition, there was support for several additional elements of a PSC, mostly dealing with imaging of the brain, the cerebral vasculature, and the heart (Table 2). These recommendations are organized around 13 major aspects of stroke care. The focus is clearly on acute aspects of stroke care, because this is the logical place to begin and such acute care can often

Table 2. Major Elements of a Primary Stroke Center

| Patient Care Elements | Administrative/Support Elements |
|--|---|
| Acute stroke team | Institutional commitment and support |
| Written care protocols | PSC director, reimbursement for call |
| Emergency medical services | Stroke registry with outcomes and QI components |
| Emergency department | Educational programs: public and professional |
| Stroke Unit | Support certification process |
| Neurosurgical services | Participation in stroke system of care |
| Imaging services: brain, cerebral vasculature, cardiac | |
| Laboratory services | |
| Rehabilitation services | |

PSC indicates Primary Stroke Center; QI, quality improvement.

significantly influence subsequent care decisions and outcomes. Early rehabilitation is also included as an important aspect of care at a PSC. Important revisions and additions are summarized in Table 3. For each specific area, we have included ≥ 2 methods by which the recommendation can be met or documented. These elements apply to patients with all types of acute strokes (ischemic, intracerebral hemorrhage [ICH], subarachnoid hemorrhage [SAH]) regardless of underlying etiology. Although we recognize that some or most patients with intracerebral hemorrhage and subarachnoid hemorrhage may be cared for at a CSC,¹⁰ some may also

Table 3. Key Revisions to Primary Stroke Center Recommendations

| Service/Element | Recommendation/Revision | Comment |
|------------------------|--|---|
| Acute stroke team | At least 2 members | At bedside within 15 min |
| EMS | Transport patient to nearest PSC | Class 1, Level B recommendation |
| ED | Monitoring protocol for patients | Vital signs and neurologic status |
| Stroke Unit | Multichannel telemetry; clinical monitoring protocol | Includes who to call and when to call for deterioration |
| Imaging | MRI, MRA or CTA, and cardiac imaging available | May not apply to all patients; Not required in acute setting; performed within 6 h; read within 2 h of completion (for MRI/MRA/CTA) |
| Laboratory | HIV testing for admitted patients; Toxicology screen | CDC recommendation (HIV) |
| Rehabilitation | Early assessment and initiation | If patient clinically stable |
| Administrative support | Call pay consideration | May improve acute response |
| Center certification | Independent organization; performance measures | Self-certification not recommended |

EMS indicates emergency medical services; ED, emergency department; PSC, Primary Stroke Center; MRA, MR angiography; CTA, CT angiography; CDC, Centers for Disease Control and Prevention.

receive care at a PSC; therefore, they are included in our recommendations.

Patient Care Areas

Acute Stroke Teams

The formation of an acute stroke team (AST) is an important step for organizing and delivering emergent stroke care. As used in this setting, the AST is responsible for responding to patients with an acute stroke and initiating diagnostic testing and immediate care (not ongoing in-hospital care). There is a growing literature supporting the formation and use of such teams.^{19,20} Recent studies have shown that the AST is a key element in the screening and delivery of acute therapies (such as intravenous tPA) to patients with acute stroke.^{21–23} Such teams also improve overall outcomes for patients with stroke.^{21,22,24,25} The AST may be staffed by a variety of healthcare personnel depending on the resources available at a particular facility. Different members may rotate on the team depending on staffing levels and patient needs. Although the AST does not have to be led by or include a neurologist or neurosurgeon, it is recommended that the AST include personnel with experience and expertise dealing with cerebrovascular disease. At a minimum, the AST should include 1 physician and 1 other healthcare provider (ie, nurse, physician’s assistant, nurse practitioner) who are available on a 2-hours/day, 7 days/week (24/7) basis. A member of the AST should be at the patient’s bedside within 15 minutes of being called.^{9,26,27} Although it is preferred that members of the AST be in-house on a continual basis, a rapid response from outside the hospital may be reasonable in specific situations as long as the response time remains ≤ 15 minutes.

It is recommended that the AST respond to patients with acute stroke in the emergency department (ED), in other hospital wards, or in a clinic within or immediately adjacent to the hospital (if logistically feasible and legally allowable). There must be a specific and well-organized system for rapidly notifying and activating the AST to evaluate patients presenting with symptoms suggestive of an acute stroke (ie, pager, cell phone, overhead calling). The precise organization of the AST will vary by institution but should include the key elements outlined here.

In some cases, members of the AST will assist and advise personnel at outside hospitals about acute measures than can be used to stabilize and treat patients before transfer to the PSC. Examples might include beginning intravenous tPA therapy (drip and ship method), reversal of anticoagulation, stabilization of vital signs, etc. There is abundant literature supporting the safety and efficacy of “drip and ship” protocols for the use of intravenous tPA.^{28–31}

Members of the AST must have familiarity and expertise with the recognition, diagnosis, stabilization, and acute care of all types of patients with stroke. Evidence-based protocols should be used by the AST members to guide acute care and determine which patients should be transferred to other facilities. The protocols should apply to all major stroke types.

The existence and operations of the AST should be supported by a written document that provides information about administrative support, staffing, notification plans, and care protocols. A log should be kept that documents call

times, response times, patient diagnoses, treatments, and outcomes. This log could be kept by the AST leader or a designee and be used for quality improvement projects.

The AST is supported by a Class I, Level A recommendation. Although the inclusion of the AST as a key element in a PSC has not changed since the original publication, its specific elements and operations have been better defined to reflect current experience and knowledge about the importance of the AST to improve the rapid diagnosis and treatment of patients with stroke at a PSC.

Written Care Protocols

The use of written care protocols has expanded greatly in the past 10 years for all aspects of medical care. The availability of such protocols for the use of intravenous tPA in acute stroke has been shown to be a key step in enhancing the administration and reducing complications of this therapy.^{27,32–35} Numerous studies have shown the efficacy of written care protocols for general patients with stroke.^{36–38} Such protocols can be implemented across a multihospital system to reflect individual diagnostic capabilities and treatment preferences.^{31,39} For a PSC, such protocols should include the emergent care of patients with ischemic and hemorrhagic strokes, including stabilization of vital functions, initial diagnostic tests, and the use of various medications. These protocols could be based on previously published ones or could be developed by a multidisciplinary team organized by the Stroke Center. For hospitals using electronic medical records, these protocols should be included in admission orders to ensure their consistent use. The use of electronic medical records also enhances the ability of such care protocols to exclude certain orders (eg, prohibition of anticoagulants immediately after intravenous tPA administration) or mandate certain activities (eg, a swallow evaluation before feeding, deep vein thrombosis prophylaxis) that affect care and outcomes.^{40,41}

Documentation should include written care protocols for acute stroke that are available in the ED and other areas likely to treat such patients. These protocols should be reviewed and updated at least once per year by a multidisciplinary team using evidence-based medical guidelines. It is understood that individual physicians and patients may not follow a particular protocol due to variations in the clinical situation and preferences of the patient and/or physician. Adherence to ≥ 1 components of a stroke protocol could be one component of a quality improvement project. Examples of such protocols can be found at the following web sites: www2.massgeneral.org/stopstroke/treatmentProtocols.aspx, www.stroke-site.org/pathways/pathways.html, and www.innovations.ahrq.gov/content.aspx?id=2782.

The use of written care protocols is supported by a Class I, Level A recommendation.

Emergency Medical Services

There is abundant evidence supporting the key role of the emergency medical services (EMS) in providing timely identification, care, and transportation for patients with acute stroke.⁴² Patients with stroke who activate the EMS system by calling 911 and are transported by EMS clearly demonstrate

shorter delay times and more rapid assessment and treatment.^{23,42–49} Notification of EMS of a call for a patient with a possible stroke should be assigned a high priority to ensure rapid transportation.⁴³ A significant challenge is that the EMS system is not nationally regulated in the United States, which makes it difficult to design and mandate specific educational programs and care protocols. This also leads to considerable variability in organization and training in each city, state, and region.^{50,51}

It is recommended that each EMS system demonstrate proficiency in basic emergency stroke care, including (1) the recognition of patients with acute stroke; (2) their assessment using a validated scale (ie, Los Angeles Prehospital Stroke Screen, Cincinnati Prehospital Stroke Scale); (3) stabilization and treatment of such patients onsite and during transportation; (4) assistance with establishing time of onset; (5) transporting a patient's medications with them to the hospital; and (6) effective and accurate communications with the receiving facility.⁵²

Although rapid EMS transportation may be easily achievable in urban settings, can similar expectations hold for patients with stroke in a rural setting? Prior studies of stroke presentation times have failed to identify living in a rural setting as an independent predictor of a delayed hospital presentation.⁵³ Numerous studies of transportation practices of trauma patients have been conducted in rural settings, and all have shown that rapid access to EMS is both possible and beneficial.^{54,55} Although we appreciate that the use of EMS for the rapid transportation of patients with acute stroke in a rural setting may present some logistical challenges, the experience with trauma patients suggests that these obstacles can be overcome. A recent study showed using a "pay-for-performance" system could improve EMS responses to several medical emergencies, including stroke.⁵⁶ A geographic information system can also reduce response times.⁵⁷

The PSC staff should support and participate in educational activities involving EMS personnel. Prior studies have shown that such programs can improve response times and patient care.^{51,58} The cooperation between EMS and the PSC should be documented by written protocols for transporting patients with stroke by EMS to the PSC, a letter of cooperation between the PSC and EMS, and evidence of cooperative educational activities at least twice per year.^{46,51}

The issue of whether EMS personnel should take patients with acute stroke only to facilities with a Stroke Center has been addressed in recent guidelines. It is now a Class I, Level B recommendation that patients with acute strokes be transported initially to the nearest facility that can operate as a PSC.¹⁴ This should be the case unless there is another concomitant imminent life-threatening condition (cardiac arrest, severe hypotension) that would necessitate EMS transporting the patient to the nearest appropriate ED. Regional healthcare systems may also assist in directing patients with acute stroke to designated facilities, because this may improve their care and outcome.⁵⁹ In areas with laws or regulations that mandate the preferential transportation of patients with acute stroke to the nearest PSC, the EMS care providers should develop and implement such protocols

within 6 to 9 months of when the law was passed or the regulation was approved (Class I, Level B).^{14,23,34}

The use of telemedicine and air ambulances may be efficacious for treating and transporting patients in a rural setting remote from a PSC, thus allowing the expertise of the PSC to be “exported” to a remote facility and expediting transfer of the patient to a PSC.^{60,61} There are numerous reports and growing experience with telemedicine/telestroke being used successfully in many different healthcare settings (mostly hospital to hospital and physician to hospital links) to reduce time delays and increase the use of acute therapies in a timely manner.^{60,62–74} The ability to use an air ambulance transportation system may vary depending on local factors (ie, ability to land a helicopter). The use of telemedicine as a direct part of EMS transportation (ie, a link in the ambulance) is an emerging area with some technical and logistical challenges. At present, there are insufficient data for the BAC to make a recommendation about the usefulness of these technologies as part of acute EMS care (not care in the ED).⁷⁴

In some settings, a PSC might use telemedicine within its own facility to deal with acute stroke assessment and treatment for patients in the ED. However, this would not be a substitute for in-house neurological expertise or ongoing care beyond an emergency setting. More extensive use of telemedicine/telestroke and related technologies will be discussed in the Acute Stroke Ready Hospital guidelines as it relates to emergent care in the ED. There are some data to support the use of helicopter transportation/air ambulances in improving the care of patients with acute stroke and reducing transportation times.^{62,63,75–78}

The importance of including EMS in a PSC is supported by a Class I, Level A recommendation. The BAC supports the emergent triage of patients with stroke to the nearest Stroke Center that can provide appropriate care unless there is another life-threatening emergency that would necessitate taking the patient to the closest facility (Class I, Level B; new recommendation). The inclusion of air ambulances is a Class IIa, Level B recommendation (new recommendation). The use of technologies such as telemedicine/telestroke/teleradiology, although more germane to Acute Stroke Ready Hospitals, are useful components for PSCs that may serve as support hospitals for other facilities in need of such support (Class I, Level A; new recommendation).

Emergency Department

The ED is a key part of the PSC, because it is the point of first contact (in most cases) between the patient and the medical facility.⁷⁹ The ED should have well-established lines of communications with EMS personnel and be able to receive patients with stroke from the EMS system. ED personnel should be trained in the diagnosis and treatment of all types of acute stroke, including the use of intravenous tPA in acute ischemic stroke.⁸⁰ ED personnel should be familiar with the AST, how it is activated, and its functions.³⁴ It is possible that some ED personnel also will be members of the AST. It is recommended that a door-to-physician assessment time for patients with suspected stroke be no more than 15 minutes.

The ED staff should have written protocols for stroke triage and treatment, including the use of intravenous tPA as well as other acute therapies (ie, management of increased intracranial pressure, blood pressure management, reversal of coagulopathies).^{79,81,82} Such protocols should also delineate areas of responsibility between ED physicians/staff and other medical staff such as the AST, among others. The ED medical staff should have a clear protocol for monitoring patients with an acute stroke that includes frequent assessment of vital signs and neurological function.²⁷ The use of acute therapies in an ED setting should be supported by other needed personnel, including but not limited to neurologists, neurosurgeons, radiologists, and others. Proper monitoring protocols for the use of intravenous tPA and other acute therapies should be developed and in place with adequate in-service training of key personnel.^{35,83}

Key ED personnel should participate in educational activities related to stroke diagnosis and treatment at least 2 times per year.⁹ Written documents that detail the ED operations for managing patients with acute stroke should be provided. Such documentation should include clear statements about how the ED is integrated into the entire Stroke Center along with treatment protocols. A log of patients with stroke and a record of door-to-physician times should be maintained.

The existence of a well-trained and staffed ED is a Class I, Level B recommendation. The specific inclusion of monitoring protocols is seen as an enhancement of the overall ED function and not a separate recommendation.

Stroke Unit

There is abundant evidence from individual studies as well as several new and updated meta-analyses that support the efficacy of Stroke Units in the care of patients with acute stroke. Although the definition of a “Stroke Unit” can vary in different regions of the world, in this setting, we are referring to (typically) a defined group of beds, staff, and protocols that are used for the acute care of patients with a stroke. Compared with general medical wards, patients cared for in Stroke Units had a 17% to 28% reduction in death, a 7% increase in being able to live at home, and an 8% reduction in length of stay.^{84,85} Recent studies have further affirmed the importance of a Stroke Unit in improving outcomes with a 19% increase in good outcomes and a reduction in mortality.⁸⁶ PSCs that intend to provide care beyond the very acute period (ie, longer than an ED evaluation) should provide such care in a Stroke Unit setting. Stroke centers that do not intend to provide care beyond that very acute period do not require Stroke Units. An example would be a hospital that treats patients with stroke with intravenous tPA in the ED and then transfers the patients to another facility.

Although Stroke Units do not have to be geographically distinct hospital wards or units, in most settings they are distinct and operate better using this paradigm. In all cases, they should be staffed and directed by personnel (ie, nurses, physicians, speech therapists, physical therapists) with training and expertise in caring for patients with cerebrovascular disease.⁹ In general, most Stroke Units operate as a “step-down” unit and have nurse-to-patient ratios of approximately 1:3. It is now recommended that a Stroke Unit include

continuous multichannel telemetry (preferably computerized) capable of monitoring blood pressure, pulse, respirations, and oxygenation.⁸⁷ This is based on recent studies demonstrating the importance of such telemetry in detecting important rhythm disturbances and other changes in vital signs that might have significant clinical implications.⁸⁷⁻⁹⁰

Other aspects of a Stroke Unit such as written care protocols are also key components.²⁷ Nurses in the Stroke Unit should have experience and expertise in performing serial neurological assessments using the National Institutes of Health Stroke Scale or a similar validated tool.⁹¹ There should be a written protocol that details how changes in a patient's status are detected, how they are documented, and how medical staff are notified of such changes.⁹² For example, a standard protocol might include vital signs every 1 to 2 hours for 24 hours after admission and neurological checks (using the National Institutes of Health Stroke Scale or similar assessments) every 2 to 4 hours. These would vary depending on the patient's clinical status, but some minimum standard should be defined. Notification of the medical staff of any changes or worsening in vital signs and/or neurological status might include a protocol that defines who gets called initially (house officer, advanced practice nurse, attending) and when and how additional personnel are notified as well as expected response times.

In some cases, a Stroke Unit may have the capability to use arterial catheters and administer some vasoactive agents (ie, low-dose dopamine, intravenous nicardipine), although these interventions are typically performed in an intensive care unit (ICU). Stroke Units do not have to include all of the features of an ICU, although there may be some overlap. In some hospitals, the Stroke Unit could be a part of an established ICU. If this is the case, the ICU nurses should receive specific training about the care of patients with stroke (see previous details). The physicians caring for patients with stroke in an ICU should be intensivists and preferably neurointensivists, who can improve overall outcomes.⁹³ However, the vast majority of patients with stroke do not require the services of a typical ICU. The monitoring of stroke patients after treatment with intravenous tPA can be performed in a Stroke Unit or an ICU, depending on the staffing levels, nursing protocols, expertise, and telemetry available in that unit.

For PSCs with a Stroke Unit, documentation should be provided about the staffing and operations of the unit, including admission and discharge criteria, care protocols, patient census, and outcome data. All physicians, physician assistants, advanced practice nurses, and nurses on the Stroke Unit staff who provide direct patient care or supervise such care must receive at least 8 hours per year of medical education (continuing medical education or other types of education) related to cerebrovascular disease. This amount of education is 50% of the 16 hours per year recommended for healthcare professionals at Level I and Level II trauma centers.⁹⁴ These educational requirements can be met through a variety of means, including lectures, online courses, webcasts, journal continuing medical education activities, etc.

The importance of a Stroke Unit remains a Class I, Level A recommendation that is unchanged from the original publication. The specification of a notification

protocol is considered a modification to the overall Stroke Unit protocol. The addition of multichannel telemetry as a component of a Stroke Unit is a new Class I Level B recommendation.

Neurosurgical Services

Some patients with acute stroke will require a neurosurgical procedure or evaluation during their illness. Examples of such interventions include insertion of a ventricular drainage catheter, evacuation of a hematoma, and decompressive hemicraniectomy in cases of massive hemispheric infarction.^{14,82,95} There are compelling data about the improved survival and outcomes seen with decompressive hemicraniectomy in patients with large ischemic strokes and early signs of swelling who undergo early surgery.^{95,96} However, due to the limited number of neurosurgeons, it is appreciated that many hospitals do not have ready access to a neurosurgeon.

For the purposes of a PSC, it is suggested that neurosurgical care for the patient be available within 2 hours of the time it is deemed clinically necessary. This recommendation is based on a consensus from a national symposium on stroke and is also endorsed by the BAC.⁹⁷ This means that either the patient could be transferred to another facility with a neurosurgeon or the neurosurgeon could be on-call and able to see the patient within 2 hours. If the hospital will be providing such care, it must have an operating room staffed on a 24/7 basis with the necessary equipment and support personnel (ie, anesthesiology, radiology, pharmacy) to perform neurosurgical procedures that a patient with stroke might require on an urgent basis. These procedures, which may be life-saving in some circumstances, can typically only be performed by a neurosurgeon. (Treatment of patients with large intracerebral hemorrhages, subarachnoid hemorrhages, and those needing advanced neurovascular surgeries is discussed in more detail in the CSC recommendations.)¹⁰

Neurosurgical coverage should be documented in a written plan that is approved by the covering neurosurgeon(s), Stroke Center leaders, and involved facilities. A call schedule should be readily available in the ED and to PSC personnel. In cases in which such patients will be transferred to another facility for neurosurgical care, a written transfer agreement, plan, and protocol should be developed and readily available.

The availability of neurosurgical services is a Class 1, Level A recommendation.

Cerebral and Cerebrovascular Imaging

The ability to perform brain and vascular imaging studies on patients with acute stroke is vital for determining an accurate and timely diagnosis. Such studies can also provide information about the vascular abnormality and mechanism that has caused the stroke. PSCs must have the capability to perform a head CT within 25 minutes of the order being written.⁹⁷ This implies that such capabilities are available on a 24/7 basis. Also, physicians experienced in interpreting such images must be readily available so that the scans can be read within 20 minutes of their completion.⁹⁷ These physicians may include radiologists (or neuroradiologists) with experience interpreting head CTs as well as neurologists, neurosurgeons, and others with expertise and experience with these techniques. Such availability may be through remote access

(ie, teleradiology) or in-hospital.^{68,70,73} Brain MRI may be performed acutely, in lieu of a head CT, if the same time parameters can be met in the acute setting. Teleradiology links could be to radiologists (or other physicians) at home or to a remote site such as a CSC. Remote viewing sites and services must have the equipment and infrastructure to ensure that the quality of reviewed images meets appropriate standards.^{66,98–100} There should be written documentation that such scans were performed and read within the specified times and that such scans can be performed on a 24/7 basis. A log book that records such scans with time parameters and interpretation is 1 way to document this capability.

The timely performance of a head CT scan or brain MRI and its rapid interpretation is a Class I, Level A recommendation. The inclusion of MRI is a new recommendation.

It is well established in the literature and in recent guidelines that brain MRI is more sensitive than head CT for detecting small strokes, acute strokes, and many lesions and processes that could produce stroke-like symptoms (ie, demyelinating plaques, small tumors, areas of infection or inflammation).^{18,101,102} In many cases, the detection of such lesions could change significantly the evaluation and therapy for such patients. MRI is now widely available in the vast majority of US hospitals, particularly those that are currently PSCs. Although an MRI examination may not be needed for every patient with stroke, it should be available at a PSC for those patients who are admitted and might benefit from such testing. MRI does not have to be performed in the hyperacute setting, but if needed (as judged by the treatment team), it should be available at the PSC as part of the evaluation for admitted patients.

Imaging of the extracranial and intracranial vasculature is an important component of the assessment for admitted patients with a stroke. Two widely used techniques are MR angiography (MRA, often performed with contrast enhancement) and CT angiography (CTA, which must be done with contrast). MRA and CTA are capable of detecting abnormalities that can be missed by routine carotid Doppler such as stenotic lesions of the origins of the great vessels, intracranial stenoses, aneurysms, vasculitis, and some dissections.^{103–105} The detection of such lesions might alter patient management for acute care as well as secondary prevention.¹⁸ The inclusion of MRA and/or CTA reflects current standard imaging techniques widely available in the United States and is supported by numerous studies as well as imaging guidelines.¹⁸ They should be available at a PSC, although their performance on a hyperacute basis is not recommended at this time. Like with MRI, these techniques may not be needed or clinically indicated in some patients (ie, patients who have a terminal condition or would not benefit from further evaluation or therapies). These imaging tests (MRI, MRA, CTA) should be performed at a PSC within 6 hours of being ordered and they should be interpreted within 2 hours of test completion (during normal working hours) if they are thought to be needed to determine or guide treatment decisions.

The inclusion of brain MRI for admitted patients (Class I, Level A) and vascular imaging with an MRA or CTA

are new recommendations (Class I, Level B). Such imaging is not required for all patients and is not meant to be performed in the hyperacute setting but should be available at a PSC for those patients who might benefit from such testing.

Cardiac Imaging

A significant percentage of ischemic strokes are due to cardioembolic disease. Atrial fibrillation, myocardial infarction, valvular disease, aortic arch plaques, and other disorders are well-recognized etiologies for ischemic strokes. Cardiac imaging using transthoracic echocardiography, transesophageal echocardiography, or cardiac MRI often provides important information about underlying cardiac and aortic pathologies that may provide an etiology for a stroke and provide important information about further therapies.^{106–110} Due to the importance of cardiac imaging, it is recommended that a PSC have at least 1 modality (and preferably both transthoracic echocardiography and transesophageal echocardiography) to image the heart for all admitted patients with stroke. One or more of these imaging modalities are widely available at most acute care hospitals.⁶ Adequately trained echocardiography technicians or cardiac MRI technologists as well as physicians to interpret such images are also recommended.

The inclusion of transthoracic echocardiography, transesophageal echocardiography, or cardiac MRI is a new recommendation for a PSC (Class 1, Level A for transthoracic echocardiography and transesophageal echocardiography; Class Iib, Level C for cardiac MRI).

Laboratory Services

The efficient diagnosis and treatment of patients with stroke requires the availability of standard laboratory services on a 24/7 basis.⁹ These include the ability to rapidly perform and report complete blood counts, blood chemistries, coagulation studies, and a pregnancy test (as appropriate). Also, a PSC should be able to rapidly complete an electrocardiogram and chest x-ray. This is based on the high prevalence of cardiac disease in a typical stroke population as well as the high risk of lung and thoracic disease in these patients.^{111,112} It is recommended that the studies cited be completed within 45 minutes of being ordered.⁹⁷

Guidelines from the Centers for Disease Control and Prevention recommend that an HIV test be performed on most adults admitted to the hospital.¹¹³ We support HIV testing in accordance with the Centers for Disease Control and Prevention guidelines based on the high prevalence of HIV, its importance as a public health matter, and the relationship between HIV and cerebrovascular disease.^{114,115} A blood or urine test for drug toxicology is also suggested based on the high prevalence of drug abuse and the association between illicit drug use and stroke.^{116,117} A letter of support from the laboratory director(s) should be provided along with written documentation that the testing noted can be completed within the recommended time period.

The performance of laboratory tests in a timely fashion is a Class 1, Level A recommendation. The addition of an electrocardiogram, chest x-ray, HIV, pregnancy test, and drug toxicology test are new since the original publication (Class 1, Level A for electrocardiogram, Class 1, Level B

for HIV; Class IIa, level C for drug toxicology, chest x-ray, and pregnancy test).

Rehabilitation Services

The initiation of rehabilitation activities such as speech therapy, physical therapy, and occupational therapy can improve poststroke recovery and overall functional outcomes.^{118–120} The Joint Commission has now included rehabilitation consideration as a disease performance measure for PSCs. Various elements of rehabilitation are supported by recent guidelines, but the strength of the supporting evidence varies based on the type of rehabilitation service (ie, speech, physical therapy, occupational therapy).¹²¹ For patients admitted to a PSC, the early assessment of rehabilitation needs and initiation of rehabilitation therapy such as basic speech therapy and physical therapy/occupational therapy should be readily available for patients in need of such services. It is recognized that many PSCs may not have extensive inpatient rehabilitation services onsite nor is this the intended purpose of our recommendation. However, an assessment for rehabilitation potential and the early initiation of basic rehabilitation activities should be part of a PSC that admits patients with acute stroke.

The recommendation for rehabilitation assessment and early initiation of basic rehabilitation services is supported by multiple studies with different classes of evidence depending on the specific aspect of rehabilitation that is being considered.¹²¹ In general, most of the elements are supported by Class I to Class IIa, Level B to C evidence depending on the specific service (see previously). This is a new recommendation.

Support and Administrative Services

Commitment and Support of the Medical Organization

The delivery of high-quality and efficient care to patients with acute stroke is highly dependent on the degree of commitment of the facility, its administration, and personnel. Without such commitment, it is unlikely that the necessary training, organization, infrastructure, and funding will be available. Also, a PSC should have a designated director who has training and expertise in cerebrovascular disease. The director does not have to be a neurologist or neurosurgeon but should have sufficient knowledge of cerebrovascular disease to provide administrative leadership and clinical guidance and input to the program. Examples of such knowledge might include ≥ 2 of the following: (1) completion of a vascular neurology fellowship or board certification in vascular neurology; (2) participation (as an attendee or faculty) in at least 2 regional, national, or international stroke courses or conferences in the past 2 years; (3) ≥ 5 peer-reviewed publications in the area of clinical cerebrovascular disease; (4) ≥ 8 continuing medical education credits (or equivalent educational exposure) each year in the area of cerebrovascular disease; and (5) other criteria agreed on by local physicians and hospital administrators. Other physician staffing for a PSC should include staff with some training and expertise in cerebrovascular disease. Evidence of such training could include ≥ 1 of the criteria cited above.

The importance of having neurological expertise in caring for patients with stroke is supported by several studies. For example, a study of >38 000 Medicare patients with strokes found that patients cared for by a neurologist had a 90-day mortality rate of 16% compared with 23% for internists and 25% for family practitioners.¹²² Hospitals with neurologists or vascular neurologists had a $\geq 50\%$ reduction in mortality in a study of patients with ischemic strokes admitted to academic medical centers and Veterans Affairs hospitals.^{123–125} Similar findings were found for Stroke Units staffed by physicians and staff with neurological expertise.⁸⁶ These differences were statistically significant after controlling for differences in illness severity and other comorbid conditions.

Administrative support for a PSC might be enhanced if the center is shown to improve patient outcomes and be cost-effective. Several key elements of Stroke Centers have been shown to be cost-effective. These include the proper use of tPA to treat ischemic stroke, the use of Stroke Units, and aggressive measures to prevent subsequent strokes, particularly in high-risk patients.^{26,27,126–128} Patients at a PSC will have fewer peristroke complications and a reduced length of stay.¹²⁸ A recent study from Finland found that patients cared for at a PSC had reduced mortality and improved outcomes when compared with patients at a general hospital.¹²⁹

Based on these data, it is anticipated that many hospitals would benefit from becoming a PSC, particularly if they admit several hundred patients with stroke each year. However, even smaller hospitals can become PSCs and perhaps achieve improved patient outcomes.¹³⁰ Becoming a PSC might increase hospital admissions and increase stroke volumes, thereby improving the efficiency of overall care.¹³¹ Hospitals with an active cardiac program might consider becoming a PSC, because both diseases often coexist and share risk factors.

The issue of “call pay” for taking stroke call is one of growing importance in the United States. In some cases neurologists, neurosurgeons, and others are receiving extra compensation to take stroke call, which includes being available (during nights and weekends) by telephone for emergency consultation and being willing to come to the hospital to direct therapy in urgent situations. Such call pay might range from $\geq \$500$ for a 24-hour period and up to \$1500 for weekend or holiday coverage (based on an informal survey of neurologists in various care settings throughout the United States).

In some areas of the United States, neurologists are reluctant to leave their office-based practices to care for hospitalized patients. To address this issue, hospitals are employing neurohospitalists to provide coverage for hospitalized patients with various types of neurological conditions, including acute stroke.¹³² Neurohospitalists are typically neurologists who specialize in the care of in-hospital patients with a variety of neurological conditions (including stroke) and provide neurology consultations to other admitted patients.

Evidence of administrative support can be provided by written documents that include a statement of support from the administration, an organizational chart, a listing of available infrastructure for the Stroke Center, and a budget.

Budgetary support for the PSC medical director, other key personnel, and call pay would also be evidence of administrative support. The curriculum vitae of key personnel should be provided to demonstrate their training and expertise in cerebrovascular disease.

Anecdotal data suggest that administrative support is a key factor in establishing and operating a PSC. **Medical staff with neurological expertise improves outcomes and is an important element of a PSC (Class I, Level B). Having a PSC director with training and expertise in the area of cerebrovascular disease is also a key element for a PSC (Class IIa, Level C).** The concepts of call pay and neurohospitalists are new and require further data before formal recommendations can be made.

Outcomes and Quality Improvement

Stroke Centers should have a database or registry for tracking the number and type of patients with stroke seen, their treatments, timelines for receiving treatments, and some measurement of their outcomes.¹³³ A written system should be in place whereby such data can be systematically collected, reviewed, and acted on. Specific benchmarks for comparisons should be established. For example, published guidelines recommend that the door-to-needle time for the use of intravenous tPA in patients with stroke should be no more than 60 minutes.¹⁴ Past and recent studies have documented the usefulness of quality improvement programs for the care of patients with stroke such as the "Get With the Guidelines–Stroke" program^{134–136} and the Paul Coverdell National Acute Stroke Registry.¹³⁷ Such programs have high acceptance among hospital staff and clearly improve the attainment of treatment benchmarks.¹³ A German quality database has similar measures to Get With the Guidelines–Stroke but also includes early mobilization, hospital-acquired pneumonia, and 7-day in-hospital mortality.¹³⁸ The use of a validated scoring system (ie, National Institutes of Health Stroke Scale, Canadian Neurological Scale) is another useful project to ensure accurate assessment of initial stroke severity and provide a baseline on which to assess worsening or improvement in neurological status.^{139–141}

The PSC should select at least 2 relevant patient-care parameters for benchmarking each year. Prespecified committees should meet, review, and alter practice patterns (if needed) at least 2 times per year.⁹ Documentation should be provided about specific benchmarks, quality improvement areas, and minutes from at least biannual meetings of the appropriate committee(s).

The inclusion of a stroke registry, database, or similar monitoring program such as Get With the Guidelines–Stroke and Paul Coverdell National Acute Stroke Registry for quality improvement was not specifically addressed in the initial publication but in most cases is a key component for several types of quality improvement programs and is often used for PSC certification by TJC and other bodies. **The inclusion of such resources is a new Class 1, Level A recommendation. The inclusion of 2 relevant quality improvement projects is a new Class 1, Level A recommendation.**

Educational Programs

Due to the rapidly changing field of medicine, particularly as it relates to cerebrovascular disease, it is recommended that the professional staff of the Stroke Center receive at least 8 hours/year of educational credit (or an equivalent amount of nursing and allied health educational credits) in areas related to cerebrovascular disease. This is less than is recommended for trauma centers, but the BAC believes this is appropriate considering the scope of cerebrovascular disease.⁹⁴ Prior studies have shown the importance of such educational activities for improving the care of patients with stroke.²⁷ This will provide one mechanism to ensure that the Stroke Center staff is aware of new knowledge in this area.

There has been some confusion about which professional staff are required to meet the educational goals outlined above. The BAC recommends that all physicians, nurses, and advanced practice nurses involved in direct care of patients with stroke meet the educational goals. Although it would be optimal if all nurses and therapists also met these goals, we realize that this might not be feasible or practical in many cases because staffs rotate among many different patient populations. We also recommend that nurses in leadership roles (ie, nurse managers, head nurses, charge nurses) as well as program directors for allied health services attain the educational goals cited here. It is also suggested that the PSC staff engage in professional education of their peers and colleagues in an effort to raise the overall knowledge about the care of patients with stroke.^{51,58}

In addition to professional education, the PSC should have at least 2 annual programs to educate the public about stroke prevention, diagnosis, and/or the availability of acute therapies. Past studies have shown that much of the population lacks basic information about stroke, its risk factors, and treatments.^{137,142,143} Various public education programs have shown a positive effect in improving stroke recognition and reducing time delays of presentation.^{144–148} Although such educational programs that target the public are labor-intensive and may have to be repeated to be effective, they are a key component and mission of a PSC and public health policy.

Documentation of educational programs can be done by monitoring educational credit and attendance for the professional staff. The date, title, speaker, and duration of each talk should be recorded and filed. Evaluation questionnaires for the public educational programs should be reviewed and saved to document such programs. The estimated annual costs for such educational activities for the staff might be \$5000 to \$10 000 depending on the size of the program and the number of staff who participates. The costs for public educational programs might range from \$2500 to \$5000 per program depending on its size, content, and complexity.

The requirement for professional and public education has not changed from the original publication (Class I, Level B).

Stroke Center Certification

The original PSC recommendations did not address the issue of certification because it was unclear in 2000 if any group or

organization would certify PSCs nor was it clear if any hospitals would opt for a certification program. During the past 10 years, several groups have begun successful programs to certify PSCs; these include TJC, Healthcare Facilities Accreditation Program, and various state health departments and other organizations. The BAC strongly supports and endorses such certification programs as a means to (1) independently verify the components, protocols, level of care, and outcomes of a PSC; (2) provide patients and the public with assurances that a PSC provides the intended quality of care on an ongoing basis; and (3) ensure proper recognition of such facilities.^{8,11,15}

Any PSC certification program should fulfill several criteria to ensure the accuracy and rigor of such programs; these include (1) the certifying body should be administratively and financially independent of the hospital; (2) the program should include an assessment of infrastructure, personnel, protocols, and programs; (3) a site visit should be performed at least every 2 years; and (4) well-defined and quantifiable disease performance measures should be developed and assessed on a regular basis.¹⁵ Self-certification programs are discouraged based on prior studies showing that such efforts often produce unreliable results.^{14,9}

The inclusion of specific recommendations for certification is new and is supported by Class 1, Level B evidence.

Acute Stroke Ready Hospitals

In some states and regions, there has been a recent effort to define another level of Stroke Center, often referred to as “acute stroke-capable” or an “acute stroke-ready” facility. Such hospitals do not meet the definition of a PSC. The purpose would be to define a group of facilities that provide more complete acute stroke care than other surrounding hospitals and to help EMS route such patients in rural areas with significant distances between hospitals and with no nearby PSCs. The BAC supports any effort to provide improved care to patients with an acute stroke. However, the lack of data about the function of such facilities, outcomes, and how they would operate in a stroke system of care makes us cautious about making a recommendation until more data are available. We urge any such programs to collect performance and outcomes data on the “stroke-ready” hospitals. The BAC is developing formal criteria for such “acute stroke-ready” hospitals.

The possible designation of an “acute stroke-ready” hospital is a potentially important addition to a Stroke System of Care and might be a viable alternative in some areas of the country. However, the lack of data about the function, outcomes, and certification of such facilities precludes us from making any recommendations at this time.

Discussion

Since our original publication of recommendations for PSCs, the concept of using the Stroke Centers to improve care has been validated by several studies showing improved outcomes as well as surveys and expert opinion from stroke leaders throughout the world.^{129,150–152} There are now >800 PSCs certified by TJC and several hundred more recognized by other organizations in the United States ([mission.org\). Other nations have also adopted and promoted the Stroke Center concept.⁶ Preferential triage of patients with acute stroke occurs routinely in some major metropolitan areas and a growing number of cities and states. Protocols for the care of patients with an acute stroke combined with well-formulated disease performance measures are now commonplace in many hospitals, even if they are not a formally designated Stroke Center.^{152,153} All of these developments have improved the overall care for these patients with stroke throughout the United States and in many other countries.](http://www.jointcom-</p>
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As we have gained experience with organized stroke care, medical science has developed new tools to better diagnose and treat stroke. Some have been included in these revised guidelines to ensure that all patients cared for at a PSC receive optimal care. From all available data, it is clear that better imaging of the brain, cerebral vasculature, and the heart will lead to a better understanding of stroke etiology, mechanism, acute care, and secondary prevention. For example, a patient with an MRI that shows a shower of small infarcts in multiple vascular territories might lead to a search for a source of cardiac embolism, a central nervous system vasculitis, or a hypercoagulable state. These entities might require different therapies compared with an isolated ischemic stroke presumed to be caused by small-vessel atherosclerosis.

The addition of MRI and either MRA or CTA might incur additional costs for some hospitals. However, the vast majority of US hospitals have head CT and brain MRI readily available, and the addition of MRA or CTA accrues only modest additional costs for equipment and software. Therefore, almost all hospitals that are currently PSCs or might desire to become a PSC should not incur significant additional capital expenses due to these recommendations. There might be modest additional costs related to technical support, staffing, and training. These costs might be partially offset by changing billing practices.

Physician staffing at a PSC, particularly neurologists and neurosurgeons willing to take emergency call, has often been mentioned as a challenge for some hospitals and in some areas of the country. The use of call-pay and neurohospitalists are 2 important trends that may address some of these issues.¹⁵⁴ It will be important for hospital systems and national organizations to monitor these trends to see if coverage and response times improve. As healthcare reform is implemented, it will be interesting to track hospital and physician reimbursement and correlate such changes with specific patient outcomes and PSC performance measures.

As the number of PSCs has increased, some have asked if overall outcomes are improved. Doing rigorous pre- and postcomparisons is problematic now because some non-PSC facilities may have adopted protocols that improve patient outcomes and reduce peristroke complications (eg, dysphagia screening, deep vein thrombosis prophylaxis). Available published data have shown that care at a PSC does positively affect several key measures of stroke care such as the use of intravenous tPA, a decline in tPA protocol violations, reduced time delays in emergent evaluation, and an increase in the number of patients admitted to a Stroke Unit.^{27,127} Data from quality improvement programs such as Get With the Guidelines have also shown that a PSC is associated with improved

compliance with and achievement of many disease performance measures.^{131,155}

A large national study from Finland has shown that patients cared for at a PSC or CSC have reduced mortality and improved outcomes.¹²⁹ A similar study in New York state also found significantly reduced mortality for patients cared for in a PSC compared with a non-PSC facility.¹⁵⁰ This effect was specific for stroke care, because outcomes for gastrointestinal hemorrhage and myocardial infarction were not improved.¹⁵⁰ Thus, there are convincing data from many parts of the world that a PSC does improve a number of patient outcomes.

Several recent studies have shown that patient volume is an important factor in stroke outcomes in that hospitals with more patients with stroke tend to have improved outcomes, particularly stroke mortality, even if they are not Stroke Centers.^{156,157} Other studies cited have clearly shown that designated PSCs have improved outcomes also.^{129,150} These data support the concept of having patients with acute stroke concentrated at larger facilities with higher numbers of patients with stroke. However, there are some cases of smaller hospitals achieving PSC status and having excellent outcomes. The local and regional distribution of hospitals and patients are key factors in making these decisions.

The issue of PSC certification has always been a challenge due to diverse opinions and options for certification programs. TJC launched a PSC certification program in 2004 that includes several important components such as a review of the PSC staff, facilities, processes of care, and disease performance measures.¹¹ These are accomplished by data analysis as well as a 1-day site visit every other year. Some states use government entities such as health departments to conduct a similar type of review and certification process. In some cases, a hospital can 'attest' to meeting the criteria for being a PSC, although an external independent review and site visit are not mandated. Prior studies have shown that an independent external review is more rigorous and accurate than self-certification; hence, the BAC strongly endorses such independent certification programs.¹⁵

As has been noted in other publications, a PSC is one component of a large stroke system of care.^{15,145} Such systems include EMS, local/regional governments and agencies, PSCs, CSCs, and other healthcare facilities. All resources should be integrated and communicate at a citywide or regional level to ensure the most efficient care for patients with all types of stroke. Newer technologies such as telemedicine, teleradiology, telestroke, and robotic care should be used as appropriate to build a functional network of care for all patients with an acute stroke.⁷⁴ The staff and expertise at a PSC should serve as a resource to other facilities and healthcare providers for acute and ongoing care of patients with cerebrovascular disease.

Clinical research studies involving patients with acute stroke have often experienced very slow rates of patient enrollment due to a variety of reasons. The current network of >800 PSCs provides an excellent resource for such clinical trials, because these facilities will have the personnel, infrastructure, protocols, and expertise to efficiently identify, enroll, and treat patients with acute stroke.^{77,158}

In summary, the BAC has updated and modified our recommendations for the formation and operation of PSCs based on the past 10 years of experience and advances in medical care and technology. We anticipate the updated disease performance measures that mirror these recommendations will result in improved care for patients at a PSC. It is anticipated that if hospitals adopt and follow these recommendations, patients will achieve more accurate diagnoses, more timely therapies, and improved overall outcomes. Updated PSCs will be an important addition in any stroke system of care.

Appendix

The Brain Attack Coalition includes representatives from the following organizations. The authors listed have reviewed the content of the article and approved its publication (exceptions noted with an asterisk): National Institute of Neurological Disorders and Stroke*, Michael D. Walker, MD (BAC Chair), Marian Emr, Margo Warren; American Academy of Neurology, Lawrence R. Wechsler, MD; American Association of Neurological Surgeons, E. Sander Connolly, Jr, MD; American Association of Neuroscience Nurses, Barbara Mancini, RN; American College of Emergency Physicians,* Andy Jagoda, MD; American Society of Neuroradiology, Richard E. Latchaw, MD; American Stroke Association, Stephen Prudhomme; Centers for Disease Control and Prevention,* Mary G. George, MD, MSPH; Congress of Neurological Surgeons, LTC Rocco A. Armonda, MD; Department of Veterans Affairs, Robert Ruff, MD; National Association of Chronic Disease Directors, Kathy Foell, MS, RD; National Association of EMS Physicians, Todd J. Crocco, MD; National Association of State EMS Officials, Robert R. Bass, MD; National Stroke Association, James Baranski; Neurocritical Care Society, Daryl R. Gress, MD; Society of NeuroInterventional Surgery, Mary E. (Lee) Jensen, MD; and Stroke Belt Consortium, Mark J. Alberts, MD. *This manuscript represents the opinion of the authors and may not necessarily represent the official position of the American College of Emergency Physicians, the Centers for Disease Control and Prevention, and the National Institute of Neurological Disorders and Stroke.

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References

- Lloyd-Jones D, Adams RJ, Brown TM, Carnethon M, Dai S, De Simone G, et al. Executive summary: heart disease and stroke statistics—2010 update: a report from the American Heart Association. *Circulation*. 2010;121:948–954.
- Kochanek K, Xu J, Murphy SL, Minino AM, Kung H-C. Deaths: Preliminary data for 2009. *National Vital Statistics Report*. 2011;59:1–51.
- Prevalence of stroke—United States, 2005. *MMWR Morb Mortal Wkly Rep*. 2007;56:469–474.
- Taylor TN. The medical economics of stroke. *Drugs*. 1997;54(suppl 3):51–57; discussion 57–58.
- Reeves MJ, Arora S, Broderick JP, Frankel M, Heinrich JP, Hickenbottom S, et al. Acute stroke care in the US: results from 4 pilot prototypes of the Paul Coverdell National Acute Stroke Registry. *Stroke*. 2005;36:1232–1240.
- Ringelstein EB, Meckes-Ferber S, Hacke W, Kaste M, Brainin M, Leys D. European Stroke Facilities Survey: the German and Austrian perspective. *Cerebrovasc Dis*. 2009;27:138–145.

7. Alberts MJ. Stroke centers: proof of concept and the concept of proof. *Stroke*. 2010;41:1100–1101.
8. Mohammad YM, Divani AA, Jradi H, Hussein HM, Hoonjan A, Qureshi AI. Primary stroke center: basic components and recommendations. *South Med J*. 2006;99:749–752.
9. Alberts MJ, Hademenos G, Latchaw RE, Jagoda A, Marler JR, Mayberg MR, et al. Recommendations for the establishment of primary stroke centers. *JAMA*. 2000;283:3102–3109.
10. Alberts MJ, Latchaw RE, Selman WR, Shephard T, Hadley MN, Brass LM, et al. Recommendations for comprehensive stroke centers: a consensus statement from the Brain Attack Coalition. *Stroke*. 2005;36:1597–1616.
11. Joint Commission on Accreditation of Healthcare Organizations. Updated Primary Stroke Center Certification appendix for the disease-specific care manual. *Jt Comm Perspect*. 2005;25:3–6.
12. Alberts M, Hampel M, Range J. Primary Stroke Centers: characteristics and re-certification rates. *Neurology*. 2009;72:A102.
13. LaBresh KA. Quality of acute stroke care improvement framework for the Paul Coverdell National Acute Stroke Registry: facilitating policy and system change at the hospital level. *Am J Prev Med*. 2006;31:S246–S250.
14. Adams HP Jr, del Zoppo G, Alberts MJ, Bhatt DL, Brass L, Furlan A, et al. Guidelines for the early management of adults with ischemic stroke: a guideline from the American Heart Association/American Stroke Association Stroke Council, Clinical Cardiology Council, Cardiovascular Radiology and Intervention Council, and the Atherosclerotic Peripheral Vascular Disease and Quality of Care Outcomes in Research Interdisciplinary Working Groups: the American Academy of Neurology affirms the value of this guideline as an educational tool for neurologists. *Circulation*. 2007;115:e478–e534.
15. Adams R, Acker J, Alberts M, Andrews L, Atkinson R, Fenelon K, et al. Recommendations for improving the quality of care through stroke centers and systems: an examination of stroke center identification options: multidisciplinary consensus recommendations from the Advisory Working Group on Stroke Center Identification Options of the American Stroke Association. *Stroke*. 2002;33:e1–e7.
16. Adams RJ, Albers G, Alberts MJ, Benavente O, Furie K, Goldstein LB, et al. Update to the AHA/ASA recommendations for the prevention of stroke in patients with stroke and transient ischemic attack. *Stroke*. 2008;39:1647–1652.
17. American College of Cardiology Foundation (Bethesda, MD) and American Heart Association (Dallas, TX). *Methodology Manual and Policies From the ACCF/AHA Task Force on Practice Guidelines*. 2010.
18. Latchaw RE, Alberts MJ, Lev MH, Connors JJ, Harbaugh RE, Higashida RT, et al. Recommendations for imaging of acute ischemic stroke: a scientific statement from the American Heart Association. *Stroke*. 2009;40:3646–3678.
19. Hill MD, Barber PA, Demchuk AM, Sevick RJ, Newcommon NJ, Green T, et al. Building a 'brain attack' team to administer thrombolytic therapy for acute ischemic stroke. *CMAJ*. 2000;162:1589–1593.
20. Alberts MJ, Chaturvedi S, Graham G, Hughes RL, Jamieson DG, Krakowski F, et al. Acute stroke teams: results of a national survey. National Acute Stroke Team Group. *Stroke*. 1998;29:2318–2320.
21. Nazir FS, Petre I, Dewey HM. Introduction of an acute stroke team: an effective approach to hasten assessment and management of stroke in the emergency department. *J Clin Neurosci*. 2009;16:21–25.
22. Hamidon BB, Dewey HM. Impact of acute stroke team emergency calls on in-hospital delays in acute stroke care. *J Clin Neurosci*. 2007;14:831–834.
23. de la Ossa NP, Sanchez-Ojanguren J, Palomerias E, Millan M, Arenillas JF, Dorado L, et al. Influence of the stroke code activation source on the outcome of acute ischemic stroke patients. *Neurology*. 2008;70:1238–1243.
24. de Lecinana-Cases MA, Gil-Nunez A, Diez-Tejedor E. Relevance of stroke code, stroke unit and stroke networks in organization of acute stroke care—the Madrid acute stroke care program. *Cerebrovasc Dis*. 2009;27(suppl 1):140–147.
25. Saposnik G, Hill MD, O'Donnell M, Fang J, Hachinski V, Kapral MK. Variables associated with 7-day, 30-day, and 1-year fatality after ischemic stroke. *Stroke*. 2008;39:2318–2324.
26. Lattimore SU, Chalela J, Davis L, DeGraba T, Ezzeddine M, Haymore J, et al. Impact of establishing a primary stroke center at a community hospital on the use of thrombolytic therapy: the NINDS Suburban Hospital Stroke Center experience. *Stroke*. 2003;34:e55–e57.
27. Douglas VC, Tong DC, Gillum LA, Zhao S, Brass LM, Dostal J, et al. Do the Brain Attack Coalition's criteria for stroke centers improve care for ischemic stroke? *Neurology*. 2005;64:422–427.
28. Pervez MA, Silva G, Masrur S, Betensky RA, Furie KL, Hidalgo R, et al. Remote supervision of IV-tPA for acute ischemic stroke by telemedicine or telephone before transfer to a regional stroke center is feasible and safe. *Stroke*. 2010;41:e18–e24.
29. Silverman IE, Beland DK, Chhabra J, McCullough LD. The 'drip-and-ship' approach: starting IV tPA for acute ischemic stroke at outside hospitals prior to transfer to a regional stroke center. *Conn Med*. 2005;69:613–620.
30. Rymer MM, Thurtchley D, Summers D. Expanded modes of tissue plasminogen activator delivery in a comprehensive stroke center increases regional acute stroke interventions. *Stroke*. 2003;34:e58–e60.
31. Wang S, Gross H, Lee SB, Pardue C, Waller J, Nichols FT III, et al. Remote evaluation of acute ischemic stroke in rural community hospitals in Georgia. *Stroke*. 2004;35:1763–1768.
32. Jeng JS, Tang SC, Deng IC, Tsai LK, Yeh SJ, Yip PK. Stroke center characteristics which influence the administration of thrombolytic therapy for acute ischemic stroke: a national survey of stroke centers in Taiwan. *J Neurol Sci*. 2009;281:24–27.
33. The implementation of intravenous tissue plasminogen activator in acute ischaemic stroke—a scientific position statement from the National Stroke Foundation and the Stroke Society of Australasia. *Intern Med J*. 2009;39:317–324.
34. Quain DA, Parsons MW, Loudfoot AR, Spratt NJ, Evans MK, Russell ML, et al. Improving access to acute stroke therapies: a controlled trial of organised pre-hospital and emergency care. *Med J Aust*. 2008;189:429–433.
35. Chan YF, Kwiatkowski TG, Rella JG, Rennie WP, Kwon RK, Silverman RA. Tissue plasminogen activator for acute ischemic stroke: a New York City emergency medicine perspective. *J Emerg Med*. 2005;29:405–408.
36. Wentworth DA, Atkinson RP. Implementation of an acute stroke program decreases hospitalization costs and length of stay. *Stroke*. 1996;27:1040–1043.
37. Gil Nunez AC, Vivancos Mora J. Organization of medical care in acute stroke: importance of a good network. *Cerebrovasc Dis*. 2004;17(suppl 1):113–123.
38. Hinkle JL, Guanci MM. Acute ischemic stroke review. *J Neurosci Nurs*. 2007;39:285–293, 310.
39. Newell SD Jr, Englert J, Box-Taylor A, Davis KM, Koch KE. Clinical efficiency tools improve stroke management in a rural southern health system. *Stroke*. 1998;29:1092–1098.
40. van der Meijden MJ, Tange HJ, Boiten J, Troost J, Hasman A. An experimental electronic patient record for stroke patients. Part 2: system description. *Int J Med Inform*. 2000;58–59:127–140.
41. Micieli G, Cavallini A. Stroke Active Guideline Evaluation (STAGE) project. *Neurol Sci*. 2006;27(suppl 3):S273–S276.
42. Millin MG, Gullett T, Daya MR. EMS management of acute stroke—out-of-hospital treatment and stroke system development (resource document to NAEMSP position statement). *Prehosp Emerg Care*. 2007;11:318–325.
43. Abdullah AR, Smith EE, Biddinger PD, Kalenderian D, Schwamm LH. Advance hospital notification by EMS in acute stroke is associated with shorter door-to-computed tomography time and increased likelihood of administration of tissue-plasminogen activator. *Prehosp Emerg Care*. 2008;12:426–431.
44. Maestroni A, Mandelli C, Manganaro D, Zecca B, Rossi P, Monzani V, et al. Factors influencing delay in presentation for acute stroke in an emergency department in Milan, Italy. *Emerg Med J*. 2008;25:340–345.
45. Inatomi Y, Yonehara T, Hashimoto Y, Hirano T, Uchino M. Pre-hospital delay in the use of intravenous rt-PA for acute ischemic stroke in Japan. *J Neurol Sci*. 2008;270:127–132.
46. Crocco TJ, Grotta JC, Jauch EC, Kasner SE, Kothari RU, Larmon BR, et al. EMS management of acute stroke—prehospital triage (resource document to NAEMSP position statement). *Prehosp Emerg Care*. 2007;11:313–317.
47. Evenson KR, Brice JH, Rosamond WD, Lellis JC, Christian JB, Morris DL. Statewide survey of 911 communication centers on acute stroke and myocardial infarction. *Prehosp Emerg Care*. 2007;11:186–191.
48. Linder A, Winkvist L, Nilsson L, Sernert N. Evaluation of the Swedish version of the Modified Elderly Mobility Scale (Swe M-EMS) in patients with acute stroke. *Clin Rehabil*. 2006;20:584–597.

49. Lindsberg PJ, Happola O, Kallela M, Valanne L, Kuusma M, Kaste M. Door to thrombolysis: ER reorganization and reduced delays to acute stroke treatment. *Neurology*. 2006;67:334–336.
50. Shaeffer Z, Gohdes D, Legler J, Taillac P, Larsen B. Monitoring pre-hospital stroke care in Utah to assess the feasibility of using EMS data for surveillance. *Prev Chronic Dis*. 2009;6:A137.
51. Lellis JC, Brice JH, Evenson KR, Rosamond WD, Kingdon D, Morris DL. Launching online education for 911 telecommunicators and EMS personnel: experiences from the North Carolina Rapid Response to Stroke Project. *Prehosp Emerg Care*. 2007;11:298–306.
52. Wojner-Alexandrov AW, Alexandrov AV, Rodriguez D, Persse D, Grotta JC. Houston paramedic and emergency stroke treatment and outcomes study (HoPSTO). *Stroke*. 2005;36:1512–1518.
53. Harper GD, Haigh RA, Potter JF, Castleden CM. Factors delaying hospital admission after stroke in Leicestershire. *Stroke*. 1992;23:835–838.
54. Wenneker WW, Murray DH Jr, Ledwich T. Improved trauma care in a rural hospital after establishing a level II trauma center. *Am J Surg*. 1990;160:655–657; discussion 657–658.
55. Martin GD, Cogbill TH, Landercasper J, Strutt PJ. Prospective analysis of rural interhospital transfer of injured patients to a referral trauma center. *J Trauma*. 1990;30:1014–1019; discussion 1019–1020.
56. Whyte BS, Ansley R. Pay for performance improves rural EMS quality: investment in prehospital care. *Prehosp Emerg Care*. 2008;12:495–497.
57. Peleg K, Pliskin JS. A geographic information system simulation model of EMS: reducing ambulance response time. *Am J Emerg Med*. 2004;22:164–170.
58. Bray JE, Martin J, Cooper G, Barger B, Bernard S, Bladin C. An interventional study to improve paramedic diagnosis of stroke. *Prehosp Emerg Care*. 2005;9:297–302.
59. Price CI, Clement F, Gray J, Donaldson C, Ford GA. Systematic review of stroke thrombolysis service configuration. *Expert Rev Neurother*. 2009;9:211–233.
60. Audebert HJ, Kukla C, Vatankhah B, Gotzler B, Schenkel J, Hofer S, et al. Comparison of tissue plasminogen activator administration management between Telestroke Network hospitals and academic stroke centers: the Telemedical Pilot Project for Integrative Stroke Care in Bavaria/Germany. *Stroke*. 2006;37:1822–1827.
61. Fisher M. Developing and implementing future stroke therapies: the potential of telemedicine. *Ann Neurol*. 2005;58:666–671.
62. Thomas SH, Kociszewski C, Schwamm LH, Wedel SK. The evolving role of helicopter emergency medical services in the transfer of stroke patients to specialized centers. *Prehosp Emerg Care*. 2002;6:210–214.
63. Conroy MB, Rodriguez SU, Kimmel SE, Kasner SE. Helicopter transfer offers a potential benefit to patients with acute stroke. *Stroke*. 1999;30:2580–2584.
64. Chalela JA, Kasner SE, Jauch EC, Pancioli AM. Safety of air medical transportation after tissue plasminogen activator administration in acute ischemic stroke. *Stroke*. 1999;30:2366–2368.
65. Pedragosa A, Alvarez-Sabin J, Molina CA, Sanclemente C, Martin MC, Alonso F, et al. Impact of a telemedicine system on acute stroke care in a community hospital. *J Telemed Telecare*. 2009;15:260–263.
66. Henninger N, Chowdhury N, Fisher M, Moonis M. Use of telemedicine to increase thrombolysis and advance care in acute ischemic stroke. *Cerebrovasc Dis*. 2009;27(suppl 4):9–14.
67. Wu O, Langhorne P. The challenge of acute-stroke management: does telemedicine offer a solution? *Int J Stroke*. 2006;1:201–207.
68. Switzer JA, Hall C, Gross H, Waller J, Nichols FT, Wang S, et al. A web-based telestroke system facilitates rapid treatment of acute ischemic stroke patients in rural emergency departments. *J Emerg Med*. 2009;36:12–18.
69. Schwab S, Vatankhah B, Kukla C, Hauchwitz M, Bogdahn U, Furst A, et al. Long-term outcome after thrombolysis in telemedical stroke care. *Neurology*. 2007;69:898–903.
70. Hess DC, Wang S, Hamilton W, Lee S, Pardue C, Waller JL, et al. REACH: clinical feasibility of a rural telestroke network. *Stroke*. 2005;36:2018–2020.
71. Misra UK, Kalita J, Mishra SK, Yadav RK. Telemedicine in neurology: underutilized potential. *Neurol India*. 2005;53:27–31.
72. Audebert HJ, Kukla C, Clarmann von Claranau S, Kuhn J, Vatankhah B, Schenkel J, et al. Telemedicine for safe and extended use of thrombolysis in stroke: the Telemedical Pilot Project for Integrative Stroke Care (TEMPIS) in Bavaria. *Stroke*. 2005;36:287–291.
73. Schwamm LH, Rosenthal ES, Hirshberg A, Schaefer PW, Little EA, Kvedar JC, et al. Virtual TeleStroke support for the emergency department evaluation of acute stroke. *Acad Emerg Med*. 2004;11:1193–1197.
74. Schwamm LH, Holloway RG, Amarencu P, Audebert HJ, Bakas T, Chumbler NR, et al. A review of the evidence for the use of telemedicine within stroke systems of care: a scientific statement from the American Heart Association/American Stroke Association. *Stroke*. 2009;40:2616–2634.
75. Gries A, Zink W, Bernhard M, Messelken M, Schlechtriemen T. Realistic assessment of the physician-staffed emergency services in Germany. *Anaesthesist*. 2006;55:1080–1086.
76. Leira EC, Ahmed A, Lamb DL, Olalde HM, Callison RC, Torner JC, et al. Extending acute trials to remote populations: a pilot study during interhospital helicopter transfer. *Stroke*. 2009;40:895–901.
77. Leira EC, Lamb DL, Nugent AS, Ahmed A, Grimsman KJ, Clarke WR, et al. Feasibility of acute clinical trials during aerial interhospital transfer. *Stroke*. 2006;37:2504–2507.
78. Nakagawa Y, Morita S, Akieda K, Nagayama M, Yamamoto I, Inokuchi S, et al. Critical role of the ‘Doctor-Heli’ system on cerebral infarction in the superacute stage—report of a outstanding pilot case. *Tokai J Exp Clin Med*. 2005;30:123–126.
79. Gorelick AR, Gorelick PB, Sloan EP. Emergency department evaluation and management of stroke: acute assessment, stroke teams and care pathways. *Neurol Clin*. 2008;26:923–942, viii.
80. Bratina P, Greenberg L, Pasteur W, Grotta JC. Current emergency department management of stroke in Houston, Texas. *Stroke*. 1995;26:409–414.
81. Semplicini A, Benetton V, Macchini L, Realdi A, Manara R, Carollo C, et al. Intravenous thrombolysis in the emergency department for the treatment of acute ischaemic stroke. *Emerg Med J*. 2008;25:403–406.
82. Broderick J, Connolly S, Feldmann E, Hanley D, Kase C, Krieger D, et al. Guidelines for the management of spontaneous intracerebral hemorrhage in adults: 2007 update: a guideline from the American Heart Association/American Stroke Association Stroke Council, High Blood Pressure Research Council, and the Quality of Care and Outcomes in Research Interdisciplinary Working Group. *Stroke*. 2007;38:2001–2023.
83. Barroso B, Morisset C, Larrieu JM, Bertandeanu E, Dakar A, Mangon H, et al. Stroke thrombolysis in the emergency department as an alternative service for community hospitals lacking a stroke unit. *Eur J Emerg Med*. 2008;15:71–74.
84. Langhorne P, Williams BO, Gilchrist W, Howie K. Do stroke units save lives? *Lancet*. 1993;342:395–398.
85. Collaborative systematic review of the randomised trials of organised inpatient (stroke unit) care after stroke. Stroke Unit Trialists’ Collaboration. *BMJ*. 1997;314:1151–1159.
86. Candelise L, Gattinoni M, Bersano A, Micieli G, Sterzi R, Morabito A. Stroke-unit care for acute stroke patients: an observational follow-up study. *Lancet*. 2007;369:299–305.
87. Cavallini A, Micieli G, Marcheselli S, Quaglini S. Role of monitoring in management of acute ischemic stroke patients. *Stroke*. 2003;34:2599–2603.
88. Douen AG, Pageau N, Medic S. Serial electrocardiographic assessments significantly improve detection of atrial fibrillation 2.6-fold in patients with acute stroke. *Stroke*. 2008;39:480–482.
89. Steiner T. Stroke unit design: intensive monitoring should be a routine procedure. *Stroke*. 2004;35:1018–1019.
90. Sulter G, Elting JW, Langedijk M, Maurits NM, De Keyser J. Admitting acute ischemic stroke patients to a stroke care monitoring unit versus a conventional stroke unit: a randomized pilot study. *Stroke*. 2003;34:101–104.
91. Richardson J, Murray D, House CK, Lowenkopf T. Successful implementation of the National Institutes of Health Stroke Scale on a stroke/neurovascular unit. *J Neurosci Nurs*. 2006;38:309–315.
92. Rocco A, Pasquini M, Ceconi E, Sirimarco G, Ricciardi MC, Vicenzini E, et al. Monitoring after the acute stage of stroke: a prospective study. *Stroke*. 2007;38:1225–1228.
93. Varelas PN, Schultz L, Conti M, Spanaki M, Genarrelli T, Hacein-Bey L. The impact of a neuro-intensivist on patients with stroke admitted to a neurosciences intensive care unit. *Neurocrit Care*. 2008;9:293–299.
94. Committee on Trauma. Chicago, IL: American College of Surgeons. *Resources of the Optimal Care of the Injured Patient 2006*. 2007.
95. Vahedi K, Hofmeijer J, Juettler E, Vicaut E, George B, Algra A, et al. Early decompressive surgery in malignant infarction of the middle cerebral artery: a pooled analysis of three randomised controlled trials. *Lancet Neurol*. 2007;6:215–222.

96. Vahedi K. Decompressive hemicraniectomy for malignant hemispheric infarction. *Curr Treat Options Neurol*. 2009;11:113–119.
97. Grotta J. Acute hospital care: resource utilization. In: Marler J, Jones P, Emr M, eds. Proceedings of a National Symposium on Rapid Identification and Treatment of Acute Stroke. Arlington, VA: National Institute of Neurological Disorders and Stroke; 1997:87–89.
98. Thrall JH. Teleradiology. Part I. History and clinical applications. *Radiology*. 2007;243:613–617.
99. de Bustos EM, Moulin T, Audebert HJ. Barriers, legal issues, limitations and ongoing questions in telemedicine applied to stroke. *Cerebrovasc Dis*. 2009;27(suppl 4):36–39.
100. de Bustos EM, Vuillier F, Chavot D, Moulin T. Telemedicine in stroke: organizing a network—rationale and baseline principles. *Cerebrovasc Dis*. 2009;27(suppl 4):1–8.
101. Chalela JA, Kidwell CS, Nentwich LM, Luby M, Butman JA, Demchuk AM, et al. Magnetic resonance imaging and computed tomography in emergency assessment of patients with suspected acute stroke: a prospective comparison. *Lancet*. 2007;369:293–298.
102. Schellinger PD, Bryan RN, Caplan LR, Detre JA, Edelman RR, Jaigobin C, et al. Evidence-based guideline: the role of diffusion and perfusion MRI for the diagnosis of acute ischemic stroke: report of the Therapeutics and Technology Assessment Subcommittee of the American Academy of Neurology. *Neurology*. 2010;75:177–185.
103. Leclerc X, Gauvrit JY, Nicol L, Pruvo JP. Contrast-enhanced MR angiography of the craniocervical vessels: a review. *Neuroradiology*. 1999;41:867–874.
104. Torres-Mozqueda F, He J, Yeh IB, Schwamm LH, Lev MH, Schaefer PW, et al. An acute ischemic stroke classification instrument that includes CT or MR angiography: the Boston Acute Stroke Imaging Scale. *AJNR Am J Neuroradiol*. 2008;29:1111–1117.
105. Wintermark M, Meuli R, Browaeys P, Reichhart M, Bogousslavsky J, Schnyder P, et al. Comparison of CT perfusion and angiography and MRI in selecting stroke patients for acute treatment. *Neurology*. 2007;68:694–697.
106. Rem JA, Hachinski VC, Boughner DR, Barnett HJ. Value of cardiac monitoring and echocardiography in TIA and stroke patients. *Stroke*. 1985;16:950–956.
107. Cheitlin MD, Alpert JS, Armstrong WF, Aurigemma GP, Beller GA, Bierman FZ, et al. ACC/AHA guidelines for the clinical application of echocardiography. A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Clinical Application of Echocardiography). Developed in collaboration with the American Society of Echocardiography. *Circulation*. 1997;95:1686–1744.
108. Rustemli A, Bhatti TK, Wolff SD. Evaluating cardiac sources of embolic stroke with MRI. *Echocardiography*. 2007;24:301–308; discussion 308.
109. Freeman WD, Aguilar MI. Stroke prevention in atrial fibrillation and other major cardiac sources of embolism. *Neurol Clin*. 2008;26:1129–1160, x–xi.
110. de Bruijn SF, Agema WR, Lammers GJ, van der Wall EE, Wolterbeek R, Holman ER, et al. Transesophageal echocardiography is superior to transthoracic echocardiography in management of patients of any age with transient ischemic attack or stroke. *Stroke*. 2006;37:2531–2534.
111. Kannel WB, Wolf PA, Verter J. Manifestations of coronary disease predisposing to stroke. The Framingham study. *JAMA*. 1983;250:2942–2946.
112. Huiart L, Ernst P, Suissa S. Cardiovascular morbidity and mortality in COPD. *Chest*. 2005;128:2640–2646.
113. Branson BM, Handsfield HH, Lampe MA, Janssen RS, Taylor AW, Lyss SB, et al. Revised recommendations for HIV testing of adults, adolescents, and pregnant women in health-care settings. *MMWR Recomm Rep*. 2006;55:1–17; quiz CE11–14.
114. Corral I, Quereda C, Moreno A, Perez-Elias MJ, Dronda F, Casado JL, et al. Cerebrovascular ischemic events in HIV-1-infected patients receiving highly active antiretroviral therapy: incidence and risk factors. *Cerebrovasc Dis*. 2009;27:559–563.
115. Dobbs MR, Berger JR. Stroke in HIV infection and AIDS. *Expert Rev Cardiovasc Ther*. 2009;7:1263–1271.
116. Qureshi AI, Safdar K, Patel M, Janssen RS, Frankel MR. Stroke in young black patients. Risk factors, subtypes, and prognosis. *Stroke*. 1995;26:1995–1998.
117. Levine SR, Welch KM. Cocaine and stroke. *Stroke*. 1988;19:779–783.
118. Rodin M, Saliba D, Brummel-Smith K. Guidelines abstracted from the Department of Veterans Affairs/Department of Defense clinical practice guideline for the management of stroke rehabilitation. *J Am Geriatr Soc*. 2006;54:158–162.
119. Deutsch A, Granger CV, Heinemann AW, Fiedler RC, DeJong G, Kane RL, et al. Poststroke rehabilitation: outcomes and reimbursement of inpatient rehabilitation facilities and subacute rehabilitation programs. *Stroke*. 2006;37:1477–1482.
120. Dromerick AW, Lang CE, Birkenmeier RL, Wagner JM, Miller JP, Videen TO, et al. Very Early Constraint-Induced Movement during Stroke Rehabilitation (VECTORS): a single-center RCT. *Neurology*. 2009;73:195–201.
121. Miller EL, Murray L, Richards L, Zorowitz RD, Bakas T, Clark P, et al. Comprehensive overview of nursing and interdisciplinary rehabilitation care of the stroke patient: a scientific statement from the American Heart Association. *Stroke*. 2010;41:2402–2448.
122. Mitchell JB, Ballard DJ, Whisnant JP, Ammering CJ, Samsa GP, Matchar DB. What role do neurologists play in determining the costs and outcomes of stroke patients? *Stroke*. 1996;27:1937–1943.
123. Gillum LA, Johnston SC. Characteristics of academic medical centers and ischemic stroke outcomes. *Stroke*. 2001;32:2137–2142.
124. Goldstein LB, Matchar DB, Hoff-Lindquist J, Samsa GP, Horner RD. VA Stroke Study: neurologist care is associated with increased testing but improved outcomes. *Neurology*. 2003;61:792–796.
125. Gillum LA, Johnston SC. Influence of physician specialty on outcomes after acute ischemic stroke. *J Hosp Med*. 2008;3:184–192.
126. Nguyen-Huynh MN, Johnston SC. Is hospitalization after TIA cost-effective on the basis of treatment with tPA? *Neurology*. 2005;65:1799–1801.
127. Gropen TI, Gagliano PJ, Blake CA, Sacco RL, Kwiatkowski T, Richmond NJ, et al. Quality improvement in acute stroke: the New York State Stroke Center Designation Project. *Neurology*. 2006;67:88–93.
128. Lichtman JH, Allen NB, Wang Y, Watanabe E, Jones SB, Goldstein LB. Stroke patient outcomes in US hospitals before the start of the Joint Commission Primary Stroke Center certification program. *Stroke*. 2009;40:3574–3579.
129. Meretoja A, Roine RO, Kaste M, Linna M, Roine S, Juntunen M, et al. Effectiveness of primary and comprehensive stroke centers: PERFECT stroke: a nationwide observational study from Finland. *Stroke*. 2010;41:1102–1107.
130. Smith EE, Dreyer P, Prvu-Bettger J, Abdullah AR, Palmeri G, Goyette L, et al. Stroke center designation can be achieved by small hospitals: the Massachusetts experience. *Crit Pathw Cardiol*. 2008;7:173–177.
131. Stradling D, Yu W, Langdorf ML, Tsai F, Kostanian V, Hasso AN, et al. Stroke care delivery before vs after JCAHO stroke center certification. *Neurology*. 2007;68:469–470.
132. Amin A, Likosky D. The role of hospitalists in the acute care of stroke patients. *Curr Treat Options Cardiovasc Med*. 2010;12:240–249.
133. Wattigney WA, Croft JB, Mensah GA, Alberts MJ, Shepard TJ, Gorelick PB, et al. Establishing data elements for the Paul Coverdell National Acute Stroke Registry: Part 1: proceedings of an expert panel. *Stroke*. 2003;34:151–156.
134. Reeves MJ, Fonarow GC, Zhao X, Smith EE, Schwamm LH. Quality of care in women with ischemic stroke in the GWTC program. *Stroke*. 2009;40:1127–1133.
135. Schwamm LH, Fonarow GC, Reeves MJ, Pan W, Frankel MR, Smith EE, et al. Get With the Guidelines—Stroke is associated with sustained improvement in care for patients hospitalized with acute stroke or transient ischemic attack. *Circulation*. 2009;119:107–115.
136. Cumbler E, Murphy P, Jones WJ, Wald HL, Kutner JS, Smith DB. Quality of care for in-hospital stroke: analysis of a statewide registry. *Stroke*. 2011;42:207–210.
137. George MG, Tong X, McGruder H, Yoon P, Rosamond W, Winquist A, et al. Paul Coverdell National Acute Stroke Registry Surveillance—four states, 2005–2007. *MMWR Surveill Summ*. 2009;58:1–23.
138. Heuschmann PU, Biegler MK, Busse O, Elsner S, Grau A, Hasenbein U, et al. Development and implementation of evidence-based indicators for measuring quality of acute stroke care: the Quality Indicator Board of the German Stroke Registers Study Group (ADSR). *Stroke*. 2006;37:2573–2578.
139. Lyden P, Lu M, Jackson C, Marler J, Kothari R, Brott T, et al. Underlying structure of the National Institutes of Health Stroke Scale: results of a factor analysis. NINDS tPA Stroke Trial Investigators. *Stroke*. 1999;30:2347–2354.
140. Lyden P, Raman R, Liu L, Grotta J, Broderick J, Olson S, et al. NIHSS training and certification using a new digital video disk is reliable. *Stroke*. 2005;36:2446–2449.

141. Bushnell CD, Johnston DC, Goldstein LB. Retrospective assessment of initial stroke severity: comparison of the NIH Stroke Scale and the Canadian Neurological Scale. *Stroke*. 2001;32:656–660.
142. Willey JZ, Williams O, Boden-Albala B. Stroke literacy in Central Harlem: a high-risk stroke population. *Neurology*. 2009;73:1950–1956.
143. Kleindorfer D, Khoury J, Broderick JP, Rademacher E, Woo D, Flaherty ML, et al. Temporal trends in public awareness of stroke: warning signs, risk factors, and treatment. *Stroke*. 2009;40:2502–2506.
144. Hodgson C, Lindsay P, Rubini F. Using paid mass media to teach the warning signs of stroke: the long and the short of it. *Health Promot J Austr*. 2009;20:58–64.
145. Gropen T, Magdon-Ismail Z, Day D, Melluzzo S, Schwamm LH. Regional implementation of the stroke systems of care model: recommendations of the northeast cerebrovascular consortium. *Stroke*. 2009;40:1793–1802.
146. Marx JJ, Gube C, Faldum A, Kuntze H, Nedelmann M, Haertle B, et al. An educational multimedia campaign improves stroke knowledge and risk perception in different stroke risk groups. *Eur J Neurol*. 2009;16:612–618.
147. Williams O, Noble JM. ‘Hip-hop’ stroke: a stroke educational program for elementary school children living in a high-risk community. *Stroke*. 2008;39:2809–2816.
148. Kleindorfer D, Miller R, Sailor-Smith S, Moomaw CJ, Khoury J, Frankel M. The challenges of community-based research: the beauty shop stroke education project. *Stroke*. 2008;39:2331–2335.
149. Kidwell CS, Shephard T, Tonn S, Lawyer B, Murdock M, Koroshetz W, et al. Establishment of primary stroke centers: a survey of physician attitudes and hospital resources. *Neurology*. 2003;60:1452–1456.
150. Xian Y, Holloway RG, Chan PS, Noyes K, Shah MN, Ting HH, et al. Association between stroke center hospitalization for acute ischemic stroke and mortality. *JAMA*. 2011;305:373–380.
151. Leys D, Cordonnier C, Debette S, Hacke W, Ringelstein EB, Giroud M, et al. Facilities available in French hospitals treating acute stroke patients: comparison with 24 other European countries. *J Neurol*. 2009;256:867–873.
152. Cooper D, Jauch E, Flaherty ML. Critical pathways for the management of stroke and intracerebral hemorrhage: a survey of US hospitals. *Crit Pathw Cardiol*. 2007;6:18–23.
153. Batmanian JJ, Lam M, Matthews C, Finckh A, Duffy M, Wright R, et al. A protocol-driven model for the rapid initiation of stroke thrombolysis in the emergency department. *Med J Aust*. 2007;187:567–570.
154. Stickrath CR, Cumbler EU, Glasheen JJ. Improving stroke outcomes through collaboration and hospitalist-focused training. *J Hosp Med*. 2009;4:327.
155. Censullo JL, Mokracek M, Newmark M. Quality improvement: stroke plan-do-study-act for primary stroke center certification. *J Nurs Care Qual*. 2007;22:279–285.
156. Saposnik G, Baibergenova A, O’Donnell M, Hill MD, Kapral MK, Hachinski V. Hospital volume and stroke outcome: does it matter? *Neurology*. 2007;69:1142–1151.
157. Heuschmann PU, Berger K, Misselwitz B, Hermanek P, Leffmann C, Adelman M, et al. Frequency of thrombolytic therapy in patients with acute ischemic stroke and the risk of in-hospital mortality: the German Stroke Registers Study Group. *Stroke*. 2003;34:1106–1113.
158. Richie AN, Trejo J, Bowers CG, McNeil RB, Gamble DM, Luke SH, et al. Joint Commission primary stroke center certification does not affect proband enrollment: the siblings with ischemic stroke study. *J Stroke Cerebrovasc Dis*. 2009;18:363–366.