deficits <1% but acknowledged that it is difficult to set universal thresholds, and the Task Force advised institutions to alter the thresholds as needed to higher or lower values to meet their own quality improvement program needs. To define a metric in a way that minimizes the need for subjective interpretation and simplifies data collection, we propose the inclusion of only those strokes or deaths that occur within 24 hours of the diagnostic angiogram. Because of the consensus that diagnostic angiography should be a low-risk procedure, and because the end point should be straightforward to collect, this is a core metric.

Additional Data Elements

Centers should consider monitoring the nature of individual complications to assist in quality improvement efforts. Centers should also consider tracking the major nonneurological angiographic complications, specifically renal failure, retroperitoneal or thigh hematoma requiring transfusion or surgical evacuation, arterial occlusions requiring thrombectomy or thrombolysis, arteriovenous fistula, and pseudoaneurysm, as detailed by the Joint Standards of Practice Task Force.[95] We have not included these complications as part of this or other metrics because of concerns about the number of patients who would require follow-up and because of difficulty in the identification of complications, because they may occur after discharge and patients may not necessarily return for treatment to the center where the procedure was performed. Centers should also consider tracking the use of measures to prevent acute renal injury, such as treatment with N-acetylcysteine and prehydration.

Metric 24

Percentage of patients who have a diagnosis of ischemic or hemorrhagic stroke who undergo EVD and then develop ventriculitis.

For this metric, ventriculitis is defined as the presence of positive cerebrospinal fluid cultures in a patient with EVD if there is no documentation in the medical record stating that the culture results are thought to be the result of a contaminant or of some other process (eg, preexisting infection or infection resulting from another surgical procedure).

Numerator: All patients with ventriculitis after EVD, as defined above, and a diagnosis of ischemic or hemorrhagic stroke.

Denominator: All patients who undergo ventriculostomy because of problems related to ischemic or hemorrhagic stroke.

Justification

Ventriculitis is a dangerous and potentially avoidable nosocomial infection that can lead to serious morbidity or mortality and significantly prolong hospitalization. For these reasons, it is important for hospitals to identify all cases of ventriculitis for purposes of quality improvement. Although there are no guideline statements that specifically address ventriculitis, because the consequences are so significant and because it is a nosocomial problem, we recommend that this be a core metric.[168,169]

Additional Data Element

For patients with ventriculitis, CSCs should consider tracking the unit (or units) to which a patient who developed ventriculitis was admitted while the EVD was in place. CSCs should also consider tracking the number of days that an EVD was in place before the development of ventriculitis; the total number of days that an EVD was in place, whether or not an infection developed; the frequency with which the EVD was changed; and other measures taken to prevent ventriculitis. CSCs should also consider tracking whether ventriculitis developed in the setting of systemic sepsis, whether patients were treated with prophylactic antibiotics, and where the EVD was placed (eg, operating room, ICU, or emergency department).

Poststroke Rehabilitation

Metric 25

Median number of days from admission to completion of evaluations for physical therapy, occupational therapy, speech-language pathology, and rehabilitation medicine, unless there is documentation on admission that some or all of these evaluations are not needed or that the patient cannot tolerate them because of medical instability.

The center should track its record for each discipline separately, but the overall metric for completion of all of the rehabilitation-related consultations that are deemed appropriate for an individual patient should be the primary statistic to be monitored. In other words, the primary time recorded for each patient would be the time when the last of the consultations that were deemed necessary on admission was completed.

Justification

There is limited evidence that early initiation of stroke rehabilitation is associated with improved functional outcomes, on the basis of nonrandomized trials and 1 meta-analysis[170] ***(Class I; Level of Evidence B)***. In their review of 38 randomized controlled trials dating back to 1965, Cifu and Stewart[171] concluded that early stroke rehabilitation "appears to have a strong relationship" with improved functional outcome at hospital discharge and follow-up. However, as with many reviews of the topic, the studies did not delineate a specific amount of time at which rehabilitation began. They did not describe the association of the provision and timing of specific therapies with functional gain. None of the studies compared early therapy with either delayed therapy or standard care.

There is evidence from 2 randomized controlled trials that early mobilization is associated with improved outcome ***(Class I; Level of Evidence B)***. There are, however, no randomized trials that directly examined the intensity, duration, frequency, and risks and benefits of early rehabilitation therapy[172] ***(Class IIa; Level of Evidence B)***. Early mobilization in acute stroke care is recommended in a range of European, US, and United Kingdom policy guidelines as a strategy to minimize or prevent complications.[173,174]

Despite the advent of tPA and other therapies for the hyperacute treatment of stroke, rehabilitation remains the primary treatment modality for patients recovering from stroke. Fifty percent to 70% of stroke survivors regain functional independence, but 15% to 30% are permanently disabled, and 20% require institutional care at 3 months after onset.[175] Published studies have demonstrated that organized multidisciplinary stroke rehabilitation reduces death, death or disability, and death or institutionalization[176–184] *(Class I; Level of Evidence B)*. Rehabilitation may increase the stroke patient's quality of life and reduce the financial and physical burden on society.[185–187] In addition to inpatient rehabilitation, outpatient rehabilitation programs can improve outcomes and prevent functional deterioration.[188]

Stroke rehabilitation begins during the acute hospitalization, as soon as the diagnosis of stroke is established and the stroke survivor is deemed medically stable. During the acute phase, the primary goals of rehabilitation are to ensure proper management of general health functions, mobilize the patient, encourage resumption of self-care activities, and provide emotional support to the patient and family. The evidence for acute stroke rehabilitation care suggests that organized care for poststroke patients achieves substantial and optimal outcomes, such as decreased mortality and dependency and a return to community living.[186]

The Joint Commission PSC performance standard for rehabilitation states, "A rehabilitation plan must be considered."[7] The standard reminds PSCs that they should assess stroke survivors for postacute rehabilitation services but only requires documentation of the necessity of a postacute rehabilitation program. On the other hand, the PSC is not accountable for the infrastructure of the rehabilitation team, the timing of mobilizing the patient, or the process of synthesizing a rehabilitation plan.

To differentiate itself from a PSC, a CSC should explicitly involve appropriate members of the rehabilitation team: Physical therapy, occupational therapy, speech-language pathology, and a physician specializing in physical medicine and rehabilitation or having specific expertise in stroke rehabilitation. On the basis of evidence in the literature, the CSC must mobilize the stroke survivor and begin rehabilitation as soon as possible.

Additional Data Elements

CSCs should consider tracking whether there is documented communication between rehabilitation disciplines involved in the care of stroke patients on all normal business days. Brief documentation that simply states that rehabilitation therapy is being performed by the necessary disciplines as discussed at multidisciplinary rounds would be adequate. Because of the relatively short period of time that a stroke survivor may spend in an acute-care hospital, the clinical record should document formal or informal communication among the rehabilitation disciplines on normal business days (ie, Monday through Friday, except for holidays) to (1) assess the stroke survivor's progress or problems impeding progress, (2) consider possible resolutions to such problems, and (3) assess or reassess the rehabilitation plan (including discharge plans) established by the team.[7] Results of formal conferences or rounds should be documented in the clinical record.

Research

Metric 26

Percentage of patients admitted with diagnoses of ischemic stroke, SAH, AVM, intracranial hemorrhage, extracranial cervical stenosis, intracranial stenosis, or TIA who are enrolled in a clinical research study.

Numerator: Patients who are admitted with diagnoses of ischemic stroke, SAH, AVM, intracranial hemorrhage, extracranial cervical stenosis, intracranial stenosis, or TIA and are enrolled in a clinical research trial studying acute ischemic or hemorrhagic stroke or TIA, prevention of ischemic or hemorrhagic stroke, rehabilitation after stroke, or other aspects of cerebrovascular disease.

Denominator: All patients admitted with diagnoses of ischemic stroke, SAH, AVM, intracranial hemorrhage, extracranial cervical stenosis, intracranial stenosis, or TIA.

Any protocol approved by the institutional review board of the CSC is considered a clinical research study for the purposes of this metric.

If a patient meets all criteria for enrollment in a clinical study that is active at the center and is not enrolled in that study, the reasons for this should be documented and tracked.

Justification

The BAC CSC report states that research is an important but optional component of CSCs. We strongly suggest that CSCs be active participants in ongoing acute stroke research, because there is a need for coordinated multisite initiatives to improve our ability to address critical questions about stroke treatments.[189] We propose this metric to assess actual enrollment of patients in clinical trials. As noted previously, enrollment of patients in trials studying acute ischemic stroke is especially important. Other trials, including those studying aneurysm and AVM treatment, interventions for ICH, stenting of carotid and intracranial stenosis, medical management for secondary prevention of ischemic stroke, and rehabilitation, are also critical to improving stroke care, and CSCs should participate in such trials and actively enroll patients in them.

Additional Data Element

CSCs should also consider tracking the percentage of patients who are eligible for a clinical trial that is active at the center and are actually enrolled in a clinical trial.

Decompressive Surgery

Although the AHA/ASA "Guidelines for the Early Management of Adults With Ischemic Stroke" and the AHA/ASA "Guidelines for the Management of Spontaneous Intracerebral Hemorrhage" both state that decompressive surgery is recommended under certain circumstances,[18,114,190] we have not recommended metrics related to this type of surgery because of its relatively uncommon nature and because of difficulties in defining the patients to whom such metrics would apply. We do recommend that CSCs consider collecting the data elements noted below about patients who undergo decompressive surgery.

Additional Data Elements

The AHA/ASA "Guidelines for the Management of Spontaneous Intracerebral Hemorrhage" advise cerebellar decompression for patients with a cerebellar hemorrhage >3 cm in size who are deteriorating neurologically or have brain stem compression or hydrocephalus ***(Class I; Level of Evidence B)***.[18,114,190] The AHA/ASA "Guidelines for the Early Management of Adults With Ischemic Stroke" support decompression for patients with "space-occupying cerebellar infarction" ***(Class I; Level of Evidence B)***.[18,114,190] The AHA/ASA "Guidelines for the Early Management of Adults With Ischemic Stroke" also suggest that hemicraniectomy may be appropriate for some patients with large infarcts in the cerebral hemispheres, but this is a weaker recommendation ***(Class IIa; Level of Evidence B)***, and again, there is not a definition that would be easy to apply to identify patients in whom the procedure should be performed.[18,114,190] In view of these issues, we recommend only that CSCs should consider tracking patients who undergo decompressive procedures, with attention given to their clinical examination before surgery, the time from stroke onset to surgery, and details of the procedure, and use these additional data elements for quality improvement efforts in combination with data about initial stroke severity and follow-up data, including the mRS at 3 months.

Other Complications

We have not recommended routine tracking of complications not related to procedures because such complications are often difficult to define and because we want to avoid creating an excessively time-consuming burden on CSCs. However, we recognize that centers may choose to monitor neurological and medical complications that we have not mentioned explicitly in our discussion. This could be done through participation in registries or through quality improvement projects that focus on different complications for limited periods of time.

Neurological complications in this category may include extension of ischemic stroke, new strokes, or hemorrhagic conversion of stroke, as well as others. Medical complications may include myocardial infarction, pneumonia, urinary tract infections, deep venous thrombosis, pulmonary embolism, and falls, among others.

Risk Adjustment

Measurement of outcomes and use of outcome data to improve quality are fundamental to the efforts of CSCs to provide the best possible quality of care to stroke patients; however, we recognize that outcome measures without adjustment for severity of illness or patient characteristics and clinical situation can be misleading. Basic clinical characteristics that should be collected include age, sex, race, ethnicity, and initial disease severity (eg, NIHSS score for ischemic stroke patients). These factors can provide the rudimentary risk adjustment that will be necessary so that patient outcomes can be compared fairly across centers. Indeed, the initial NIHSS score by itself is a strong predictor of outcome.[191,192] Many additional factors (eg, medical comorbidities, degree of stenosis, location and size of occlusive lesion) may also need to be tracked for proper risk adjustment. These factors vary to some extent depending on the specific type of stroke that a patient has had and on the specific procedures and therapies that are used to treat it. More detailed risk adjustment schemes in the future should be collected in registries that centers are encouraged to participate in, as discussed in the next section.

Registries

To facilitate data collection in a standardized way and to avoid the redundant efforts that would occur if CSCs designed their own databases, we expect that CSCs will make use of national databases or registries to collect data required for metrics and to collect additional detailed data that will assist in quality improvement, some of which we have noted in the additional data elements discussed above. Such data may include information about the baseline characteristics of patients, the location and size of their strokes and vascular abnormalities, diagnostic tests and their results, treatments that are initiated, complications that develop, discharge plans, and clinical outcomes and ongoing treatments at follow-up after discharge. Although registries do exist for some of the diseases, conditions, and procedures that CSCs will need to monitor, some may require modification to capture all of the data elements that will be needed, and other databases will need to be developed. Participation in standardized registries will permit risk adjustment and eventually allow for comparisons between different CSCs. To optimize the efficiency of data collection and analysis, unified databases with different modules covering all of the types of patients seen at CSCs may be desirable.

Discussion

We have proposed a set of metrics and related data elements to facilitate monitoring the quality of care delivered at CSCs. Collection of such data will be an essential part of the dedication to quality improvement that is expected of CSCs.[2,3] In this regard, the data that CSCs collect will be more useful if they are collected in a standardized way so that they can be pooled for analysis. The willingness of CSCs to share data for this purpose will therefore be important. We recommend that one of the initial goals of analysis of data collected by CSCs should be refinement of these proposed metrics. We expect that such analysis will lead to improved protocols for clinical care and to hypotheses that can be tested in clinical trials.

Experience with the establishment of PSCs has demonstrated that designation of hospitals as stroke centers with formalized protocols for care and with mechanisms for monitoring their performance has been associated with improved performance.[12–15] The metrics that we have proposed for CSCs should help provide a framework for establishing CSCs and a foundation for improving care once they are established.

Acknowledgments

We acknowledge thoughtful comments on the manuscript from Drs Mark Alberts, Colin Derdeyn, Larry Goldstein, Scott Kasner, Jeffrey Saver, Lee Schwamm, and from Anne Leonard, RN, MPH. We are very grateful to Connie Land and Donna Stephens for assistance in preparation of the manuscript.

Disclosures

Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honoraria	Expert Witness	Ownership Interest	Consultant/ Advisory Board	Other
Dana Leifer	New York Presbyterian Hospital–Cornell Campus	NIH (Site PI) 1P50NS044378 (MR and Recanalization of Stroke Clots Using Embolectomy)†; NIH (Site PI) U01 NS58728 (Stenting & Aggressive Medical Management for Preventing Recurrent Stroke in Intracranial Stenosis)†	None	None	None	None	None	None
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S. Claiborne Johnston	University of California, San Francisco	Boston Scientific†; NINDS–PI for POINT: trial of clopidogrel aspirin vs aspirin after TIA†; Sanofi-Aventis† (providing drug and placebo to NINDS for the POINT trial)	None	None	None	None	None	Deputy Director, *Annals of Neurology**
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Christopher Ogilvy	Massachusetts General Hospital, Boston	NIH (PI; COSS–Carotid Occlusion Surgery Study)†; NIH (Univ. of Cincinnati subcontract–FIA II–Familial Intracranial Aneurysms)†; NIH (MISTIE–Minimally Invasive Treatment of Intracerebral Hemorrhage)†	Conscious II (Sponsor–Actelion Pharmaceuticals)†	None	None	None	Mizuho America*	None
Adnan I. Qureshi	University of Minnesota Medical Center	NIH R0-1-NS44976-01A2 (medication provided by ESP Pharma)†; AHA Established Investigator Award 0840053N†; Minnesota Medical Foundation*	None	None	None	None	None	None
Debbie Summers	Saint Luke's Brain and Stroke Institute	None	None	Genentech†; Concentric*	None	None	National Stroke Association (Prevention Advisory Board–no financial support)*	None

(*Continued*)

Writing Group Disclosures, *Continued*

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This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.

*Modest.

†Significant.

Reviewer Disclosures

Reviewer	Employment	Research Grant	Other Research Support	Speakers' Bureau/ Honoraria	Expert Witness	Ownership Interest	Consultant/Advisory Board	Other
E. Sander Connolly	Columbia University	None	None	None	None	None	None	None
Brett Cucchiara	University of Pennsylvania	None	None	None	None	None	None	None
Steven R. Levine	Mount Sinai School of Medicine	None	None	None	None	None	None	None
Stephan Mayer	Columbia University	None	None	None	None	None	None	None
Barney Stern	University of Maryland	None	None	None	None	None	None	None

This table represents the relationships of reviewers that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all reviewers are required to complete and submit. A relationship is considered to be "significant" if (a) the person receives $10 000 or more during any 12-month period, or 5% or more of the person's gross income; or (b) the person owns 5% or more of the voting stock or share of the entity, or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "modest" if it is less than "significant" under the preceding definition.

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Recommendations for Comprehensive Stroke Centers

A Consensus Statement From the Brain Attack Coalition

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Background and Purpose—To develop recommendations for the establishment of comprehensive stroke centers capable of delivering the full spectrum of care to seriously ill patients with stroke and cerebrovascular disease. Recommendations were developed by members of the Brain Attack Coalition (BAC), which is a multidisciplinary group of members from major professional organizations involved with the care of patients with stroke and cerebrovascular disease.

Summary of Review—A comprehensive literature search was conducted from 1966 through December 2004 using Medline and Pub Med. Articles with information about clinical trials, meta-analyses, care guidelines, scientific guidelines, and other relevant clinical and research reports were examined and graded using established evidence-based medicine approaches for therapeutic and diagnostic modalities. Evidence was also obtained from a questionnaire survey sent to leaders in cerebrovascular disease. Members of BAC reviewed literature related to their field and graded the scientific evidence on the various diagnostic and treatment modalities for stroke. Input was obtained from the organizations represented by BAC. BAC met on several occasions to review each specific recommendation and reach a consensus about its importance in light of other medical, logistical, and financial factors.

Conclusions—There are a number of key areas supported by evidence-based medicine that are important for a comprehensive stroke center and its ability to deliver the wide variety of specialized care needed by patients with serious cerebrovascular disease. These areas include: (1) health care personnel with specific expertise in a number of disciplines, including neurosurgery and vascular neurology; (2) advanced neuroimaging capabilities such as MRI and various types of cerebral angiography; (3) surgical and endovascular techniques, including clipping and coiling of intracranial aneurysms, carotid endarterectomy, and intra-arterial thrombolytic therapy; and (4) other specific infrastructure and programmatic elements such as an intensive care unit and a stroke registry. Integration of these elements into a coordinated hospital-based program or system is likely to improve outcomes of patients with strokes and complex cerebrovascular disease who require the services of a comprehensive stroke center. (***Stroke*. 2005;36:1597-1618.**)

Key Words: cerebrovascular disorders ■ cerebral hemorrhage ■ healthcare systems ■ patient care ■ university medical centers

Stroke is a common and serious disorder. Each year, ≈750 000 individuals have a new or recurrent stroke in the United States.[1] Hospitalizations attributable to stroke appear to be increasing, with 822 000 per year in 1997 compared with 593 000 per year in 1988.[2] These figures suggest that the care of patients hospitalized because of a stroke will continue to be a significant health care issue into the foreseeable future.

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Received January 5, 2005; accepted February 8, 2005.

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***Stroke* is available at http://www.strokeaha.org** **DOI: 10.1161/01.STR.0000170622.07210.b4**

In 2000, the Brain Attack Coalition (BAC) discussed the concept of stroke centers and proposed 2 types of centers: primary and comprehensive.[3] A primary stroke center (PSC) has the necessary staffing, infrastructure, and programs to stabilize and treat most acute stroke patients. Details about specific elements of a PSC have been published previously.[3] Efforts are now under way to credential facilities as PSCs.[4] Several dozen hospitals have either been certified as PSCs or are going through a certification process. Although PSCs provide stroke patients with high-quality care, some patients with complex stroke types, severe deficits, or multiorgan disease may require and benefit from specialized care and technological resources not available in a typical PSC. Such patients often require advanced diagnostic and treatment procedures directed by specially trained physicians and other health care professionals.

A comprehensive stroke center (CSC) is defined as a facility or system with the necessary personnel, infrastructure, expertise, and programs to diagnose and treat stroke patients who require a high intensity of medical and surgical care, specialized tests, or interventional therapies. The types of patients who might use and benefit from a CSC include (but are not limited to) patients with large ischemic strokes or hemorrhagic strokes, those with strokes from unusual etiologies or requiring specialized testing or therapies, or those requiring multispecialty management. Additional functions of a CSC would be to act as a resource center for other facilities in their region, such as PSCs. This might include providing expertise about managing particular cases, offering guidance for triage of patients, making diagnostic tests or treatments available to patients treated initially at a PSC, and being an educational resource for other hospitals and health care professionals in a city or region.

In an effort to provide guidance to health care professionals, hospitals, and administrators, BAC has established recommendations for the development of a CSC or system. The purposes of this article are to present the key components of a CSC or system and outline how each element of a CSC can be met and documented. These recommendations should be viewed with some flexibility so that individual facilities and health care systems may develop their own CSC criteria on the basis of these recommendations, yet modified to address and meet local practices and preferences. The designation of a PSC versus a CSC does not imply a difference in the quality of care, which is expected to be high at both types of centers. As this document is circulated and discussed, BAC anticipates further refinements and improvements that will meet the needs of patients, health care providers, hospitals, and health care systems.

Methods

Five processes were used for the development of the CSC recommendations: (1) a comprehensive literature review, (2) a questionnaire survey of stroke thought leaders, (3) input from the professional organizations represented by BAC, (4) grading of published medical evidence for treatments and diagnostic tests, and (5) group consensus of the BAC executive committee. The literature review was conducted using the Medline database and Pub Med from 1966 to December 2004. English language articles that focused on various tests, techniques, expertise, or programs related to the care of stroke patients were reviewed and evaluated. Meta-analyses, consensus statements, practice guidelines, and position articles were also reviewed. Some components such as personnel and staffing are not easily graded using evidence-based medicine protocols. In such cases, the other methods listed above were used to formulate recommendations.

Members of the executive committee of BAC were asked to query their parent organizations for guidance about the essential elements for a CSC. Their specific recommendations were considered for inclusion into this document. The questionnaire survey consisted of 40 questions dealing with various potential elements of a CSC. It was mailed to 160 stroke program directors and other physicians with interest and expertise in stroke care (ie, vascular neurosurgeons, neurologists, emergency department [ED] physicians). Respondents were asked to rank each element on a scale of 1 to 5 (least important to most important) in terms of importance for the care of stroke patients in a CSC and to indicate whether their hospital had each element.

Where appropriate, standard evidence-based medicine assessment criteria were used to grade recommendations for various therapies used at a CSC (Table 1).[5] For diagnostic testing, we evaluated the evidence using criteria developed recently for assessing the utility of cerebral perfusion techniques (with some modifications).[6] Responses from the questionnaire cited above were used when appropriate. Finally, BAC executive committee members met on several occasions in person and via teleconference to review and refine the list of elements for a CSC and to develop suggestions for how each component could be documented.

Results

The key components of a CSC or system can be defined in 4 major areas: (1) personnel with specific areas of expertise, (2) specialized diagnostic and treatment techniques, (3) facility infrastructure, and (4) other programmatic areas (Table 2). These elements are best illustrated by the types of patients cared for in a CSC and the medical needs of those patients (Table 3). Results of the national survey are included in the appendix.

Personnel and Clinical Expertise

A CSC should have the following personnel: (1) a center director, (2) neurologists and neurosurgeons, (3) surgeons with expertise performing carotid endarterectomy (CEA), (4) diagnostic radiologists, (5) physicians with expertise in interventional endovascular neuroradiology procedures and techniques (6) ED personnel and links to emergency medical services (EMS), (7) radiology technologists, (8) nursing staff who are trained in the care of stroke patients, (9) advanced practice nurses (APNs), (10) physicians with expertise in critical care or neurointensive care, echocardiography, carotid ultrasound (U/S), and transcranial Doppler (TCD), (11) physicians and therapists with training in rehabilitation, and (11) case managers and social workers.

Strong leadership is an important element for the successful formation and operation of a CSC. The need for the CSC director to have a significant amount of training and expertise in vascular neurology or neurosurgery is supported by the questionnaire survey and BAC. The CSC director might be a neurologist or neurosurgeon, although other medical professionals could fulfill this role. Examples of qualifications for a CSC director include ≥2 of the following: (1) a board-certified neurologist or neurosurgeon who has completed a stroke fellowship or vascular neurosurgery fellowship or has equivalent experience, (2) board certified in vascular neurology, (3) a fellow of the Stroke Council of the American Heart

TABLE 1. Approach to Grading Recommendations*

Level of Evidence	Therapy/Treatment	Diagnostic Test
I	Data from RCT with sufficient statistical power to make false positive/negative findings unlikely; treatment may be FDA-approved	Evidence from prospective study(s) in a broad spectrum of patients; gold standard comparisons when appropriate; high accuracy rate
II	Data from RCT, but may have false positives or negatives; may not be FDA-approved, but Rx is widely or commonly used in many medical centers	Evidence from prospective study of a narrow patient population or well-designed retrospective studies of a broad population; comparison with gold standard or other reasonable validated alternative test
III	Data from nonrandomized cohort studies; Rx is used in some settings but not widely adopted	Evidence from retrospective studies in a narrow patient population
IV	Data from nonrandomized studies using historical controls	Most evidence from case series or expert opinion panels
V	Data from anecdotal case series or several case reports	...
Strength of Recommendation		
Grade A	Supported by level I evidence	Established as useful/predictive for condition in specific population
Grade B	Supported by level II evidence	Probably useful/predictive for condition in specific population
Grade C	Supported by level III, IV, or V evidence	Possible useful/predictive for condition in specific population
Grade D	...	Data inadequate or conflicting; value of test unclear or controversial

*In cases in which this type of grading is not directly applicable to a specific recommendation, the authors considered the body of available evidence and practice standards to determine the appropriate grading.

RCT indicates randomized controlled trial; Rx, therapy.

Association (AHA) (4) a clinician who diagnoses and treats ≥50 patients with cerebrovascular disease annually; (5) a clinician with ≥10 peer-reviewed publications dealing with cerebrovascular disease, (6) a clinician with ≥12 continuing medical education (CME) credits each year in areas directly related to cerebrovascular disease, and (7) other criteria as determined by the local health care system.

The center director or his/her designee should be available 24 hours per day, 7 days per week (24/7) to provide leadership and deal with difficult medical, logistical, and administrative issues. It is expected that in most cases, the center director would be involved in the assessment of patients and provide consultative advice to other treating physicians. It is recommended that ≥1 other physicians with expertise in cerebrovascular disease also be on staff so that continuous 24/7 coverage can be assured. A CSC should have ≥1 neurologists (preferably with fellowship training in vascular neurology). Published observational studies have shown that stroke patients cared for by neurologists have improved outcomes compared with care by other physicians (level IIIC).[7,8] Such physicians should be available within 20 minutes to answer emergency calls by phone and be available in-house within 45 minutes if needed. The need for a neurosurgeon is discussed below.

Many patients cared for in a CSC will have hemorrhagic strokes and require care in an intensive care unit (ICU). Physicians with training in critical care medicine or neurocritical care should be part of the CSC to manage these patients in the ICU or neuroscience ICU.[9,10] Such personnel would typically be a board-eligible or board-certified neurologist, neurosurgeon, anesthesiologist, or internist who has completed either a critical care fellowship or neurocritical care fellowship. It is recommended that these clinicians care for ≥20 patients with acute strokes per year and attend ≥4 hours per year of CME activities (or similar educational programs) related to or focused on cerebrovascular disease.

Although it is difficult to quantify the quality of nursing care, the consensus of BAC and other practitioners is that high-quality nursing care is a key factor in determining patient outcomes after a stroke. The majority of nurses caring for stroke patients in an ICU, stroke unit, and ward should be registered nurses. All nurses in a CSC should be familiar with standard neurologic assessments and scales, stroke protocols, care maps, ongoing research projects, and new patient care techniques related to stroke. Nurses caring primarily for stroke patients should attend training sessions sponsored by the CSC (ie, in services, seminars, specialized lectures) ≥3 times per year. Such nurses should participate in ≥10 hours of continuing education units (CEUs) activities (or other educational programs) annually that are related to or focused on cerebrovascular disease. Each nurse should have a file that documents his/her participation in the above activities. It is suggested that each CSC nurse (stroke unit or ICU) attend ≥1 national or regional meeting every other year that focuses on some aspect of cerebrovascular disease.

An APN is a vital team member involved in several important aspects of a CSC such as patient care, care maps, research activities, stroke registries, educational programs, and quality assurance.[11] The designation of APN could include a nurse practitioner, master's-prepared clinical nurse specialist, or American Board of Neuroscience Nurses–certified nurse. It is recommended that a CSC have ≥1 APN (or similar personnel) to implement and coordinate the programs outlined below. This recommendation is supported by BAC as well as the survey results.

It is vital that the CSC staff be fully integrated with EMS personnel and ED staff. EMS and ED personnel should be very familiar with the diagnosis and treatment of patients with cerebrovascular disease. Several studies have docu-

TABLE 2. Components of a CSC

Recommendation (grade)	Optional
Personnel with expertise in the following areas	
Vascular neurology	Neuroscience intensive care
Vascular neurosurgery	Nursing director for stroke program
APN	
Vascular surgery	
Diagnostic radiology/neuroradiology	
Interventional/endovascular physician(s)	
Critical care medicine	
Physical medicine and rehabilitation	
Rehabilitation therapy (physical, occupational, speech therapy)	
Staff stroke nurse(s)	
RT	
Swallowing assessment	
Diagnostic techniques	
MRI with diffusion (IA)	MR perfusion (IIB)
MRA/MRV (IA)	CT perfusion (IIIC)
CTA (IA)	Xenon CT (IIIC)
Digital cerebral angiography (IA)	SPECT (IIIC)
TCD (IA)	PET (IIB)
Carotid duplex U/S (IA)	
Transesophageal echo (IA)	
Surgical and interventional therapies	
CEA (IA)	
Clipping of intracranial aneurysm (IA)	Stenting/angioplasty of extracranial vessels (IIB)*
Placement of ventriculostomy (IA)	Stenting/angioplasty of intracranial vessels (IIIC)*
Hematoma removal/draining (IIB–VC)	
Placement of intracranial pressure transducer (VC)	
Endovascular ablation of IAs/AVMs (IA)	
IA reperfusion therapy (IIB)	
Endovascular Rx of vasospasm (IIIC)	
Infrastructure	
Stroke unit† (IA)	
ICU	Stroke clinic
Operating room staffed 24/7	Air ambulance
Interventional services coverage 24/7	Neuroscience ICU
Stroke registry (IIIC)	
Educational/research programs	
Community education (IA)	Clinical research
Community prevention (IA)	Laboratory research
Professional education	Fellowship program
Patient education	Presentations at national meetings

*Although these therapies are currently not supported by grade IA evidence, they may be useful for selected patients in some clinical settings. Therefore, a CSC that does not offer these therapies should have an established referral mechanism and protocol to send appropriate patients to another facility that does offer these therapies; †stroke unit may be part of an ICU.

Rx indicates therapy.

mented the importance of the EMS system and ED personnel for the rapid identification and transportation of stroke and patients and the initiation of therapy.[12–16] EMS and ED personnel should attend initial and ongoing educational programs (ie, in services, CME programs, grand rounds) that focus on cerebrovascular disease. Ideally, the ED physicians should be board certified. They should meet with the CSC director at least semiannually and review care issues. Other aspects of the integration of the ED/EMS personnel with a stroke center are reviewed in the PSC recommendations.[3]

TABLE 3. Use of CSC Components in Various Patient Populations

	Ischemic Stroke	ICH	SAH
Personnel			
Vascular neurologist	X	X	X
Neurosurgeon	X	X	X
Intensivist	As needed	X	X
Vascular surgeon	X		
Endovascular specialist	X	X	X
Care setting			
Stroke unit	X	X	X
ICU	X	X	X
Neuroimaging			
MRI/MRA, DWI	X	X	X
MRV	X	X	X
Digital angiography	X	X	X
Carotid ultrasound	X		
TCD	X		X
TEE	X		
Endovascular therapy			
Aneurysm ablation			X
AVM embolization		X	X
Angioplasty for vasospasm			X
Stent/angioplasty for atherothrombosis	X		
Reperfusion techniques	X		
Surgery			
Ventriculostomy	X	X	X
Intracranial pressure transducer	X	X	X
Hemicraniectomy	X	X	
Hematoma removal		X	X
Aneurysm clipping			X
CEA	X		
Brain biopsy	X	X	

Rehabilitation assessments and treatments (physical therapy, occupational therapy, and speech therapy) are an important component of acute care and long-term recovery and should begin soon after the patient is admitted and stabilized.[17,18] Below is a more complete discussion of the personnel recommendations for rehabilitation. Expertise in assessing swallowing function is an important element of a CSC because of high rates of dysphagia in stroke patients (up to 50%) and a risk of aspiration pneumonia.[19,20] These assessments are often performed by a specially trained speech therapist or otolaryngologist, although nurses and others can perform some swallowing evaluations.[21] Case managers and social workers who have experience dealing with stroke patients and their families/caregivers are an invaluable resource. It is recommended that a CSC have ≥1 case manager or social worker on staff to provide coverage for patients in need of his/her services.

Much of what distinguishes a CSC from other facilities is expertise and infrastructure in 3 key areas: diagnostic radiology, endovascular therapy, and surgery. These areas are vital in the management of patients with large ischemic strokes and hemorrhagic strokes, and they are discussed below in detail. There is a separate section that reviews recommendations for rehabilitation.

Diagnostic Imaging: Techniques and Personnel

Patients in a CSC need accurate imaging of the brain and related vasculature and physiological evaluation regarding the effects of cerebral ischemia and hemorrhage. Appropriate computed tomographic resources are a prerequisite for being a PSC, the recommendations for which are not repeated.[3] This section details the recommendations for other imaging and related techniques.

MRI and Related Techniques

The contrast resolution of MRI is significantly higher than computed tomography (CT), making it far more sensitive than CT for detecting the often subtle abnormalities seen in early cerebral ischemia and other conditions.[22,23,24] Numerous studies have clearly demonstrated the superiority of MRI for detecting acute ischemia (especially in the posterior fossa) as well as other processes that can present with stroke-like symptoms (grade IA).[5,25–28] Basic MRI at a CSC must be available on a 24/7 basis, even if personnel are called in from home. An MRI should be completed within 2 hours of the test being ordered at a CSC.

Diffusion-weighted MRI (DWI) is very sensitive for detecting cerebral ischemia within minutes after its onset, far exceeding any other imaging method available today.[29,30] Calculation of the apparent diffusion coefficient is important to confirm that a diffusion abnormality is attributable to ischemia.[31] DWI detects >90% of acute ischemic lesions in the brain.[27,32–34] Patterns of stroke seen with DWI may also provide important information about stroke mechanism.[35] Although results of DWI may not affect outcome, it is a valuable diagnostic tool and should be part of the evaluation of patients with an acute ischemic stroke (grade IA).[36,37,38] It should be performed as part of a standard MRI, with the same time requirements.

Magnetic resonance (MR) perfusion provides valuable information about blood flow in specific brain regions and vascular territories. It can be useful in determining the size of a perfusion deficit and identifying brain tissue that may be ischemic but not infarcted.[39] MR perfusion defects may correlate with clinical outcomes.[40] However, the clinical utility of MR perfusion for guiding therapy or affecting outcome has not been documented by large prospective trials; therefore, it is considered an optional element of a CSC (grade IIB).[6,37,38]

MR angiography (MRA) is an effective and noninvasive technique for visualizing abnormalities of the extracranial and the intracranial cerebral circulation. The overall sensitivity and specificity of MRA for extracranial carotid disease is 82% to 86% and 98%, respectively.[24,41] MRA is more sensitive than U/S alone for diagnosing high-grade extracranial carotid stenosis.[42] Its accuracy for detecting significant high-grade extracranial vascular disease in some cases (particularly elliptic centric contrast MRA) approaches that of catheter-based digital angiography (CA), considered to be the "gold standard," with a sensitivity of 97% and a specificity of 95% (grade IA).[43] The use of intravenously injected contrast material has further increased the accuracy, spatial resolution, and reproducibility of MRA.[43–47] The accuracy and reproducibility of MRA for detecting intracranial stenoses is less.[48] The time frame for doing MRA is similar to that for a brain MRI.

MRA can also be useful for detecting intracranial aneurysms. The accuracy of this technique depends on the size of the aneurysm, the field strength of the magnet, and the type of MRA sequence used.[24] For intracranial aneurysms >5 mm, nonenhanced 3D time-of-flight MRA performed on a 1.5-T system has an accuracy of >85% relative to CA, although accuracy approaches 100% with increasing aneurysm size (grade IIB).[49–51]

MR venography (MRV) is a safe, rapid, and noninvasive technique to diagnose cerebral venous thrombosis (CVT).[52] A positive MRV can eliminate the need for invasive cerebral angiography in many cases of CVT, although false positives can occur.[53–55] Software for performing MRV is available on all current scanner systems. Because of the ability of MRV to noninvasively diagnose CVT and the wide availability of MRV, it is a recommended technique for a CSC (grade IIB).

Catheter Angiography (Grade IA)

Digital subtraction angiography (DSA) represents the gold standard for the detection and characterization of cerebral aneurysms, arteriovenous malformations (AVMs), and arteriovenous fistulae (AVFs), and for measuring the exact degree of stenosis in extracranial and intracranial arteries (grade IA).[56–59] It is the procedure of choice for evaluating the third- and fourth-order intracranial branches to make a diagnosis of a central nervous system (CNS) vasculitis.[24] Single-plane systems suffice for diagnostic uses, although biplane systems provide a shorter examination time and fewer injections. Because of the emergent nature of some of the stroke types discussed above, cerebral angiography must be available at a CSC on a 24/7 basis, with support personnel available to come in from home for a procedure within 60 minutes of being called. A CSC must demonstrate a periprocedure stroke and death rate of <1% and an overall serious complication rate of ≤2% for CA.[60]

CT Angiography (Grade IA)

CT angiography (CTA) is a noninvasive technique that is very useful for rapidly imaging the large vessels in the neck and many first- and second-order arteries in the brain. CTA can detect vascular stenoses, acute emboli, and cerebral aneurysms with a high degree of sensitivity and specificity.[61–63] The spatial resolution of CTA is superior to MRA, and a "string sign" may be detected more accurately than even DSA because of its cross-sectional image acquisition and ability to detect minute amounts of contrast material.[64] In general, CTA has sensitivities and specificities of 80% to 100% for detecting high-grade extracranial lesions.[64–66] CTA has a sensitivity of 53% to 100% and a specificity of 87% to 100% for detecting intracranial aneurysms. For aneurysms ≥7 mm, CTA has a sensitivity of 95% and a specificity of 98.9%.[67] Most recent studies have reported sensitivities and specificities for CTA of >90% to 95% when compared with digital angiography for the detection of aneurysms.[68–71] In some cases, a CTA can detect an aneurysm missed by CA.[62] CTA cannot provide the same detailed cerebral hemodynamic data provided by CA, nor can it accurately image small cerebral vessels. However, because of the significant flexibility and accuracy of CTA, particularly for patients who cannot undergo an MRA or a conventional cerebral angiogram, and its noninvasive nature, it is a recommended element for a CSC (grade IA). It is possible that in the near future, CTA might replace CA for many indications.[72]

Extracranial Ultrasonography (Grade IA)

Carotid U/S is relatively inexpensive, very safe, and can be used to noninvasively screen for disease and follow known disease in the extracranial carotid and vertebral arteries. It can be used in patients unable to receive contrast dyes or in whom an MRA is contraindicated (pacemaker, metal implants, etc). The sensitivity and specificity of carotid U/S can be as high as 85% to 90% for hemodynamically significant lesions at the carotid bifurcation, although it is less sensitive for disease in the vertebral arteries.[24,41,73] Because of its ease of use and accuracy, it is recommended that a CSC have extracranial U/S and demonstrate acceptable proficiency using guidelines established by the Intersocietal Committee for the Accreditation of Vascular Laboratories (ICAVL) or a similar credentialing organization.

Transcranial Doppler (Grade IA)

TCD is a safe, noninvasive, and low-cost technique for imaging the large intracranial vessels at the skull base. It is used in patients with acute cerebral ischemia for the detection of intracranial stenosis and occlusions and for the detection of vasospasm in patients with neurological deterioration after subarachnoid hemorrhage (SAH).[74–77] For the detection of vasospasm, TCD has a sensitivity of 80% and a specificity of 95% compared with CA.[78,79] Other studies have shown TCD to be useful for monitoring recanalization after thrombolytic therapy.[80] Based on its accuracy and importance in monitoring patients with SAH, TCD is a recommended element of a CSC.[81] As with carotid U/S, the TCD laboratory should track their results and seek certification from ICAVL or a similar organization.

Transthoracic and Transesophageal Echocardiography (Grade IA)

Because a significant percentage of strokes are of cardioembolic origin, cardiac imaging is an important test in most stroke patients.[5] Practice guidelines support cardiac imaging in cases of transient ischemic attack and stroke.[82] Transthoracic echocardiography (TTE) is a routine test used to image the heart for the presence of clots, valvular abnormalities, and the determination of left ventricular function and wall motion abnormalities.[83] Transesophageal echocardiography (TEE) is a highly sensitive test for detecting several cardiac and aortic lesions that may cause ischemic strokes, including thrombi in the left atrium, masses on the mitral and aortic valves, a patent foramen ovale, intra-atrial septal aneurysm, and atherothromobotic lesions in the aortic arch.[84–89] Numerous studies have proven the increased sensitivity of TEE compared with TTE in patients with ischemic strokes.[90,91] TTE and TEE must be performed and interpreted by technicians and cardiologists with training in these techniques.[92]

Tests of Cerebral Blood Flow and Metabolism

There are a variety of methodologies currently available that assess cerebral blood flow, including MR perfusion, CT perfusion, single-photon emission CT, positron emission tomography (PET), and xenon CT.[6] PET provides data about cerebral blood flow, brain metabolism, and degree of ischemia. It may be useful in some cases for guiding acute therapy (grade IIIC).[93,94] However, sophisticated hardware is required to detect and measure these isotopes, and their production requires expensive infrastructure. All of these tests are noninvasive. There is no compelling data that these tests alter management or outcomes in most patients. Some cannot be done on an emergent basis. They may be most useful at the present time as part of research protocols.

Diagnostic Radiology Personnel

A CSC must have physicians available to evaluate imaging studies 24/7. Although it is preferable that the attending physician be a fellowship-trained neuroradiologist, very few institutions have an in-house fellowship-trained neuroradiologist on a 24/7 basis, although many have a general diagnostic radiologist available in-house 24/7. For urgent neuroimaging studies, physicians experienced in interpreting head CT and brain MRI studies must be available to read these scans within 20 minutes of their completion. The proliferation of telecommunications systems for the rapid assessment of diagnostic images makes quite feasible the requirement that an emergency CT scan or MRI is evaluated by a neuroradiologist, general diagnostic radiologist, or other suitably trained physician in a variety of care settings within 20 minutes of scan acquisition.[95,96]

Because of the need for the performance of a CT scan within 25 minutes, there must be an in-house technologist capable of performing a CT scan and any CT-based studies. The American Society of Radiological Technologists, American Registry of Radiological Technologists, and the Joint Review Committee on Education in Radiologic Technology all have requirements for the training, testing, and certification of technologists performing all types of imaging studies. A CSC must have ≥1 certified radiology technologist trained in CT techniques in-house on a 24/7 basis.

The requirement that a CSC will perform MRI studies on a 24/7 basis means that a qualified MR technologist must be available (but not necessarily in-house) on a 24/7 basis. The technologist may take calls from home as long as he/she can be at the hospital within 1 hour of being paged. A similar requirement applies to technologists and technicians needed to perform a cerebral angiogram. U/S and various cerebral perfusion studies are commonly elective, and the availability of technologists to perform them will vary among institutions.

Endovascular Therapy: Procedures and Personnel

Endovascular techniques and devices are being used with increasing frequency for the treatment of a variety of cerebrovascular diseases. These include ablation of cerebral aneurysms, angioplasty and stenting of occlusive lesions, intracranial angioplasty for vasospasm, intra-arterial (IA) thrombolysis for acute stroke, and embolization of AVMs and AVFs.

The endovascular ablation of aneurysms is a safe and effective alternative to surgical clipping in selected patients (grade IA). Published multicenter trial results and guidelines support the use of endovascular therapy in such patients.[97,98] A multinational trial of endovascular treatment using the Guglielmi detachable coil (GDC) versus surgical clipping of ruptured intracranial aneurysms found a 7% absolute risk reduction of death or dependency in patients treated with the GDC compared with surgery.[99] These results may not be extrapolated to all patients with all types of aneurysms. Complete aneurysm ablation may be less common with endovascular coiling than with clipping, and there may be a higher rate of early rebleeding.[100] The long-term durability of endovascular ablation versus surgical clipping remains unclear.[100] Some aneurysms appear to be better treated with an endovascular approach and others with surgical therapy. Therefore, a CSC is required to have the capability to perform microsurgical neurovascular clipping and neuroendovascular coiling.

Vasospasm is a frequent and deadly complication of an SAH.[101] Medical management such as hemodynamic therapy often fails to reverse the clinical effects of the vasospasm.[102,103] Catheter-directed intracerebral IA infusion of vasodilators is an important therapeutic option used routinely in some cases of vasospasm with mixed results (grade IIIC).[104–108] Intracranial angioplasty for vasospasm has a success rate of >90% in correcting the angiographically visible vasospasm, with clinical improvement in 60% to 80% of patients (grade IIIC)[106,109,110] and a complication rate of 2% to 4%.[111] Although angioplasty for vasospasm has not been subjected to rigorous clinical study, it is considered very effective and is a standard therapy for severe vasospasm.[110–112] Because the other therapeutic options for symptomatic vasospasm are limited and often ineffective, the ability to perform intracranial angioplasty or IA infusions of vasodilators is recommended for a CSC. If a CSC is temporarily unable to offer this therapy, it is recommended that protocols be developed for the rapid transfer of patients needing these treatments to a nearby facility that does offer this therapy.

IA thrombolysis involves the use of advanced angiographic techniques for the placement of a microcatheter into a cerebral vessel for the infusion of a thrombolytic drug. IA thrombolytics have increased efficacy compared with intravenous lytics for dissolving thrombi within the large arteries at the skull base, although it carries a 10% to 18% risk of symptomatic intracerebral hemorrhage (ICH) in some cases.[113–116] The use of IA lytic agents might extend the time window for therapy beyond the 3-hour requirement for intravenous thrombolysis.[114] One prospective, randomized trial of IA pro-urokinase showed a 15% absolute increase in good neurologic outcomes and a 10% rate of symptomatic ICH.[115] Other smaller case series have also found significant benefits for IA thrombolysis in stroke patients with large artery occlusions.[117–119]

There is currently no fibrinolytic agent with a Food and Drug Administration (FDA) label indication for IA administration for the treatment of acute ischemic stroke. However, there has been extensive experience with this technique, it is commonly used at many medical centers, and it is recommended in the current AHA *Advanced Cardiac Life Support* handbook.[120–122] Based on all of these factors and the consensus of BAC, IA lytics are considered a recommended component of a CSC (grade IIB). Complication rates should be monitored closely. Mechanical thrombectomy techniques for the cerebral circulation are also being developed that use a variety of devices such as microcatheters, snares, clot retrievers, and balloons[123–126](grade VC). A clot retrieval device recently received FDA approval, although clinical experience is limited.[127] Intrasinus lytic agents may also be efficacious in treating selected cases of CVT, although this therapy has not been studied in a rigorous manner[128–132] (grade VC).

Carotid angioplasty and stenting (CAS) may be an option for the treatment of selected patients with symptomatic or asymptomatic carotid artery stenosis. Over the past 10 years, the technical success rate for CAS has risen to >97%, and the complication rates have fallen.[133,134] However, there is a paucity of data from prospective, randomized studies comparing the efficacy and safety of CAS to CEA or to best current medical therapy One randomized study of 220 patients with symptomatic carotid artery stenosis found the 1-year stroke and vascular death rate to be higher in the stent group versus CEA group (10.4% versus 4.6%), although these differences were not statistically significant.[135] The Carotid and Vertebral Artery Transluminal Angioplasty Study (CAVATAS) compared endarterectomy with angioplasty (25% of patients also received a stent) in patients with carotid or vertebral artery stenosis.[136] Overall, there were no significant differences in major outcomes such as stroke and death. Data from a large unrandomized registry found the 1-year stroke and death rate to be 11% in the stent group, about half of whom had asymptomatic lesions.[137] A study of high surgical–risk patients found the 30-day complication rate of carotid stenting to be half that of CEA when using a distal protection device (6% versus 12%).[138]

There is general agreement that CAS may be an acceptable treatment option in patients thought to be at high risk for a CEA (ie, restenosis after CEA, radiation fibrosis, fibromuscular dysplasia, surgically inaccessible stenosis, contralateral carotid disease, and significant cardiac or pulmonary disease).[139,140] Stenting may also be considered in patients with arterial dissection that is unresponsive to medical therapy or in whom treatment with anticoagulation is contraindicated.[141,142] Based on all of this information, stenting of extracranial carotid arteries for atherothrombotic disease is grade IIB and is considered an optional element of a CSC (see below). The National Institutes of Health (NIH)–sponsored multicenter CREST (Carotid Revascularization: Endarterectomy versus Stenting) trial that is now under way will hopefully determine the relative safety and efficacy of CAS compared with CEA in patients with average surgical risk and symptomatic extracranial carotid stenosis.[143]

BAC recommends that for patients with average surgical risk, such as those who would have qualified for enrollment in the North American Symptomatic Carotid Endarterectomy Trial (NASCET) and the Asymptomatic Carotid Atherosclerosis Study (ACAS), CAS should be performed as part of a randomized clinical trial such as CREST or under a local institutional review board–approved investigational program. CAS placement should only be performed by an individual or team with training and expertise in cerebral angiography, cerebrovascular pathophysiology, hemodynamics, and neurovascular interventions.[144,145]

Angioplasty and stenting of stenotic lesions in the intracranial circulation (including vertebral–basilar territory) is another area of great interest because of the poor outcome in patients who fail medical therapy.[146] However, there is a paucity of data from randomized controlled trials to properly evaluate this treatment approach.[147] Some studies have found 30-day complications rates of 5% to 30% and 12-month stroke and death rates of 28% to 40% for intracranial angioplasty/stenting.[148–151] In comparison, the Warfarin–Aspirin Symptomatic Intracranial Disease (WASID) study found an annual stroke rate of 15% for patients with intracranial symptomatic lesions with >50% stenosis.[152]

The Stenting of Symptomatic Lesions of the Vertebral and Intracranial Arteries (SSYLVIA) trial reported a stroke and death rate of 6.6% in 30 days and a 12-month stroke and death rate of 13.2%.[153] The SSYLVIA trial resulted in FDA approval for a specific angioplasty balloon and stent for intracranial atherosclerotic stenosis. The 2 largest reported series of long-term stroke prevention for intracranial angioplasty or stenting demonstrated very low long-term stroke/death rates of <3.5%, with >300 patient years of follow-up in 1 series and 70 patient years in the other.[151,154] Because of the lack of data from large, prospective randomized trials, extracranial and intracranial angioplasty/stenting for cerebrovascular disease is considered an optional component for a CSC, although there are selected cases in which such techniques may be of value (grade IVC). If a center does offer this procedure, it is recommended that cases be entered into a registry to track outcomes. It is recommended that if a CSC does not offer extracranial and intracranial angioplasty/stenting, it has available a referral arrangement to send selected patients to another facility that does offer these interventions.

Some AVMs cannot be easily treated with conventional surgery alone. Preoperative embolization may decrease the flow sufficiently so that surgical resection is possible.[155,156] In other cases, embolization may reduce the size of the AVM sufficiently to allow focused irradiation.[157,158] Rarely, embolization alone may be curative.[159] Some AVFs are treated solely with endovascular ablation techniques, whereas others might be treated with surgery alone. Occasionally, a combination of methods must be used.[160,161] These techniques have not been studied in rigorous, randomized clinical trials (grade IIIC).[162,163]

A neuroendovascular specialist (eg, endovascular surgical neuroradiologist) is recommended as a necessary component of a CSC. An individual with such expertise is capable of performing extracranial and intracranial angioplasty and stenting for atherosclerosis or vasospasm as well as performing emergency catheter-directed IA stroke therapy. The endovascular treatment of patients with cerebral aneurysms, AVMs, and AVFs requires these specialized skills.[98] These neuroendovascular procedures are technically and cognitively demanding and should only be performed by physicians with formal and specific training (or equivalent experience) in neurointerventional therapy, working in coordination with a multidisciplinary team.[144,145] Specific pathways and guidelines for the training and credentialing of a neuroendovascular specialist and for carotid stenting have been published.[164–167] In all cases, BAC recommends that the neuroendovascular specialists receive specific formal training and accrue significant experience in a procedure because past studies have shown that more experience and an increasing number of procedures reduce complication rates.[168]

It is recommended that a multidisciplinary team evaluate patients before and after some of the endovascular procedures outlined above to discuss treatment options and assess for complications during and after the intervention.[169] This is important because of the emerging and changing role of endovascular approaches to disease treatment but should also be applied to some vascular surgical procedures. Other vital team members include nurses and technologists with training in endovascular procedures. A registry should be established to track treatments, outcomes, and complications. Yearly comparisons should be made between the CSC complication rate and rates reported from national surveys and guidelines.

For all of the endovascular and surgical procedures performed at a CSC, the number, indications, and outcomes should be recorded and available for review. A quality assurance process should confirm that procedures and therapies are performed for appropriate indications, with rates of success and complications that meet acceptable standards. The committee should define a list of appropriate indicators that would trigger automatic chart review. When case reviews find significant deviations in the standards of care, the committee should recommend corrective action through appropriate methods.

Neurosurgery and Vascular Surgery

Some patients with an ICH, SAH, large ischemic stroke, or significant carotid disease will require surgical interventions (Table 3). Operative procedures may include evacuation of intracerebral hematoma, clipping of an intracranial aneurysm, excision of an AVM, placement of a ventriculostomy for drainage of cerebrospinal fluid, a CEA, decompressive craniotomy, and other procedures.[97,156,170–172] The medical evidence in support of these recommendations varies between levels IIB and VC depending on the specific clinical scenario, especially in the case of ICH.[170,173,174] Nonetheless, there are several surgical procedures important for the management of stroke patients that only a neurosurgeon can perform such as insertion of a ventriculostomy, clipping of an intracranial aneurysm, excision of an AVM, or removal of an intracerebral hematoma. Therefore, neurosurgical expertise must be available in a CSC on a 24/7 basis. The attending neurosurgeons at a CSC should have expertise and experience in cerebrovascular surgery. At all times, there must be personnel in-house (or able to be at the hospital within 30 minutes) who are capable of performing emergent neurosurgical procedures and treating life-threatening intracranial conditions such as increased intracranial pressure, mass effect from a hemorrhage, etc. Such personnel may include residents or fellows in an approved neurosurgery residency training program. Such trainees must have attending-level back-up, available on a 24/7 basis, by a board-eligible or board-certified neurosurgeon. Written neurosurgical call schedules must be available in the ED and hospital wards of a CSC.

A CSC must have individuals with expertise and experience in microsurgery for aneurysm clipping and surgical excision of AVMs. A study of in-hospital deaths after craniotomies performed for unruptured aneurysms between 1987 and 1993 in New York state hospitals revealed a 53% decrease in mortality rate in the 21 hospitals in which >10 craniotomies per year were performed, compared with the 89 hospitals in which ≤10 craniotomies per year were performed (5.3% versus 11.2% mortality rate, respectively.)[175] The range for mortality and morbidity rates for surgical clipping of unruptured intracranial aneurysms is quite broad, varying from 0% to 7% for death, and 4% to 15.3% for complications.[176] A meta-analysis of 2460 patients reported a mortality rate of 2.6% and a morbidity rate of 10.9%.[177] An international study of clipping of unruptured aneurysms reports a 1-year mortality of 3.2%, a 5.8% rate of moderate or severe disability, and a 6% rate of isolated cognitive impairment.[178]

For patients with SAH attributable to ruptured intracranial aneurysms, hospital volume is also strongly associated with outcomes. A study in New York state found a 43% reduction in mortality in hospitals that operated on >30 SAH/IA patients per year.[175] Another study found that hospitals that cared for ≥21 patients per year with aneurysmal SAH had a significantly lower mortality rate (32% versus 49%) and reduced rate of adverse outcomes (56% versus 76%) compared with hospitals with lower volumes.[179] A recent study of 16 399 hospitalizations for SAH in 18 states found that hospitals caring for ≥19 patients per year with SAH had reduced mortality compared with lower volume centers.[180] Another recent study based on data from 1995 to 1999 found that hospitals with very low patient volumes for cerebral aneurysm clipping had higher mortality rates than very high-volume hospitals for emergency and elective surgeries.[181]

Based on these data, it is recommended that for an institution to be considered a CSC, the institution should care for ≥20 SAH patients per year and should accomplish >10 craniotomies per year for aneurysm clipping (grade IA). This does not preclude lower-volume centers from having excellent outcomes, nor does it guarantee that high-volume centers will achieve excellent results.[182,183] Each center should monitor its perioperative complication rates and overall outcomes for comparison with national benchmarks after correcting for various comorbidities. Each neurosurgeon should participate in ≥10 such cases per year. The perioperative mortality rate for aneurysm clipping at a CSC should be documented, reviewed, and compared with published outcomes. For the treatment of AVMs, individual expertise is of paramount importance in treating these complex lesions. The CSC should have the capability and expertise to provide the full spectrum of treatment options required for the treatment of

TABLE 4. Complication Rates for CEA

	Asymptomatic	Symptomatic
Perioperative mortality*	<0.2%	<0.7%
Perioperative stroke and death*	<3%	<6%

*Perioperative refers to within 30 days of surgery (see text for references).

AVMs, including microsurgical excision, endovascular embolization, and stereotactic radiosurgery.[156]

CEA can reduce the risk of stroke in patients with symptomatic and asymptomatic carotid artery stenosis (grade IA).[184–186] A CEA is typically performed by a vascular surgeon or a neurosurgeon. Documentation of expertise in this operation is critical to ensuring its efficacy. Published recommendations for perioperative complication rates for CEA should be used as benchmarks (Table 4).[171,187] Results of CSC neurosurgeons and vascular surgeons should be audited on a yearly basis, and the results of a rolling average >3 years should be compared with published outcome and complication rates.

Revascularization procedures and microvascular techniques are important options for the treatment of some ischemic disorders, and in the management of complex intracranial aneurysms. A large, prospective, randomized study of EC/IC by-pass found that this surgery was not of benefit for the management of carotid occlusion/stenosis, or middle cerebral artery occlusion/stenosis (grade I A).[188] Other neurosurgical procedures may have benefit in the management of select patients. For example, microsurgical bypass procedures are an important treatment option for a select but diverse group of other disorders, including moyamoya disease, aneurysms requiring sacrifice of the parent vessel, and tumors needing vessel occlusion (grade IV C).[189–194,199,200–202] There has been renewed interest in these procedures for patients with symptomatic carotid occlusion.[191] Recent studies have indicated that a select group of patients with carotid occlusion in whom there is a documented alteration of cerebrovascular reserve, such as shown by an increase in the oxygen extraction fraction, have an increased risk of subsequent stroke.[196–198] An NIH-sponsored multicenter study is currently underway to determine if superficial temporal to middle cerebral artery bypass is effective in reducing the risk of stroke in this select group of patients (http://www.clinicaltrials.gov/ct/show/NCT00029146).[195] Based on all of these considerations, and the limited treatment options for some of these patients, it is recommended that a CSC have the ability and equipment to perform revascularization procedures and microvascular surgery (grade III C–IV C). Perioperative complications and graft patency rates should be tracked prospectively.

Neurosurgeons are needed for procedures to diagnose and treat increased intracranial pressure, including placement of an intracranial pressure transducer, placement of a ventriculostomy, and performance of a decompressive craniectomy (grade IIB).[170,202–207] At a CSC, an attending neurosurgeon (or senior-level resident) must be available within 30 minutes for such procedures on a 24/7 basis. Periprocedure complication rates should be tracked and reviewed, and any significant deviations should be addressed at regular quality improvement/quality assessment (QI/QA) meetings.

Infrastructure

EMS, ED, Referral, and Triage

Integration of acute stroke care begins with the EMS system and extends to the ED. Many of these components were reviewed in the PSC publication.[3] Written care protocols for acute stroke patients should be available to EMS and ED personnel. Such protocols should be reviewed and revised at least annually. EMS areas that should be included in such protocols include (1) rapid, efficient patient assessment and triage; (2) prehospital EMS communication with hospital staff; and (3) medical stabilization en route. Systems should be in place to allow for rapid communication between EMS and ED personnel during the transportation of acute stroke patients.[208,209] The ED should have well-defined and -documented procedures for calling the acute stroke team, including a call schedule. The ED should have a door-to-needle time of ≤60 minutes for the administration of intravenous tissue plasminogen activator (tPA) to stroke patients.[3,210] The EMS and ED staff should meet and review patient care issues with the CSC staff at least twice per year. At least 2 specific assessment criteria and benchmarks related to acute stroke care should be defined, measured, and reviewed annually. It is recommended that the EMS and ED physicians, nurses, and paramedics attend ≥2 in-service programs (or equivalent educational program) annually that focus on acute stroke care.

The CSC should be viewed as a community and regional resource in the management of stroke patients. EMS and ED personnel, along with members of the stroke team, should play an active role in the triage of acute stroke patients. This might include advice about diagnostic procedures, acute therapies, and referral to an appropriate facility if transfer is required or requested. For example, personnel at a CSC should be available to health care personnel at other hospitals and provide them with guidance and recommendations about the diagnosis and treatment of specific patients. In an emergency setting, such guidance might also include the review of radiologic studies via teleradiology techniques as well as advice about the use of acute therapies such as tPA. A CSC might also coordinate acute care within a geographic region to ensure that patients are transferred appropriately in a timely manner to the facility best suited to care for them. Several examples exist of successful regional acute triage systems for stroke patients.[211–214] Whenever such communications occur, CSC personnel should not be legally liable, assuming that they provide prudent advice that is consistent with community medical standards.

Stroke Unit and ICU

The PSC recommendations include a discussion about the importance of a stroke unit if patients are going to be admitted to the hospital (grade IA).[3] More recent studies have generated additional data supporting the efficacy and cost-effectiveness of stroke units.[215,216] A recent study found that stroke patients cared for in a stroke unit with continuous cardiac telemetry monitoring were more likely to have significant cardiac arrhythmias detected compared with stroke unit patients who did not have such monitoring.[217] This observation is shared by many vascular neurologists. There-