Telemedicine Quality and Outcomes in Stroke

A Scientific Statement for Healthcare Professionals From the American Heart Association/American Stroke Association

The American Academy of Neurology affirms the value of this statement as an educational tool for neurologists.

Endorsed by the American Telemedicine Association

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Purpose**—**Telestroke is one of the most frequently used and rapidly expanding applications of telemedicine, delivering much-needed stroke expertise to hospitals and patients. This document reviews the current status of telestroke and suggests measures for ongoing quality and outcome monitoring to improve performance and to enhance delivery of care.

Methods**—**A literature search was undertaken to examine the current status of telestroke and relevant quality indicators. The members of the writing committee contributed to the review of specific quality and outcome measures with specific suggestions for metrics in telestroke networks. The drafts were circulated and revised by all committee members, and suggestions were discussed for consensus.

Results**—**Models of telestroke and the role of telestroke in stroke systems of care are reviewed. A brief description of the science of quality monitoring and prior experience in quality measures for stroke is provided. Process measures, outcomes, tissue-type plasminogen activator use, patient and provider satisfaction, and telestroke technology are reviewed, and suggestions are provided for quality metrics. Additional topics include licensing, credentialing, training, and documentation. **(*Stroke*. 2017;48:e3-e25. DOI: 10.1161/STR.0000000000000114.)**

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Telestroke is one of the most successful applications of telemedicine, bringing the experience of stroke experts to hospitals lacking appropriate stroke expertise. The number and extent of telestroke networks continue to grow in the United States and throughout the world. As telestroke matures, monitoring practice quality and outcomes becomes essential to

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maintaining a high level of performance and ensuring that patients receive the full potential benefit of this advance. The purpose of this document is to review the current status of quality and outcomes in telestroke networks and to provide recommendations for telestroke providers and clients of these services to measure and improve performance and health outcomes.

History of Telestroke

Levine and Gorman[1] introduced the term telestroke in their editorial published in *Stroke* in 1999. In early experiences with the use of intravenous tissue-type plasminogen activator (tPA) in acute ischemic stroke patients, complication rates were significantly increased when intravenous tPA was administered by inexperienced or untrained physicians.[2,3] Subsequently, telemedicine was used to provide neurological consultation in hospitals lacking this specialized expertise.[4] Several studies demonstrated that adherence to intravenous thrombolysis protocols could be improved by implementing telestroke networks. This applies to decision making for patient suitability for intravenous tPA,[5] including the identification of stroke mimics,[6] interpretation of brain scans,[7] and improved process times.[8] In contrast, intravenous tPA protocol adherence was reported as inferior compared with stroke center treatment when intravenous thrombolysis was started after telephone consultation alone.[9] Thrombolysis rates were significantly greater after telemedicine implementation without an increase in the rate of incorrect treatment decisions.[10]

The objective of applying telemedicine to stroke is to provide patients experiencing symptoms and signs of stroke with an immediate stroke expert–directed clinical assessment, a review of tests, a diagnosis, and an emergency management plan. These should be performed in collaboration with local healthcare providers, regardless of geographic location, time, and distance from the nearest stroke center.[11] Despite the demonstrated benefit of acute stroke therapies in improving outcomes from stroke, use remains limited. In a recent analysis, only 3% to 5% of acute stroke patients were treated with intravenous tPA.[12] One of the reasons for low use is the lack of available stroke expertise at small community and rural hospitals. In a prior study, 64% of all hospitals did not treat a single patient with intravenous tPA over the 2-year study period.[12] An urban-to-rural disparity exists, with intravenous tPA use lowest in small hospitals, hospitals with <100 beds, and those located in sparsely populated communities.[12] With telestroke, rural hospitals can effectively treat ischemic stroke patients with intravenous tPA on site rather than transferring them to the closest available stroke center for delayed evaluation and treatment, often arriving beyond thrombolytic time windows.

The availability of effective treatment for stroke, the lack of stroke expert access in many emergency departments (EDs), the pressures to improve quality of care for stroke patients, the time sensitivity of thrombolytic treatment, the high cost of air and ground ambulance transfer, and the technological improvements in data network bandwidth have all culminated in ideal conditions for telemedicine care for acute stroke patients.[13] A telestroke system of care provides stroke expertise to remote sites with limited or no vascular neurology coverage, allowing rapid evaluation and treatment decisions by skilled and experienced stroke physicians.

Telestroke Network Models

Telestroke networks consist of originating sites where the patients are located and distant sites where the telestroke provider is situated. Telestroke systems most commonly exist as either a distributed or a hub-and-spoke model. In the distributed model, telestroke services are delivered to hospitals from providers at distant sites on a contractual basis. The providers may have no other connection with the telestroke hospital besides the remote stroke care discrete episode. If a patient requires a higher level of stroke care such as endovascular therapy for ischemic stroke or surgical intervention for intracranial hemorrhage, protocols are usually established to facilitate transfer to a nearby comprehensive stroke center (CSC). Coverage for stroke consults may be supplied by an organized group of providers or an independent for-profit company. In this arrangement, the responsibility for quality assurance and outcome monitoring may rest with the originating site, although some private telestroke companies also provide this service. The entity providing professional services must obtain appropriate state licenses and credential the providers at all originating sites. The distributed model relieves hospitals of the burden of finding adequate stroke coverage from local providers and limits the need for transfer of acute stroke patients because of a lack of in-house expertise.

In the hub-and-spoke model, a stroke center such as an academic medical center or CSC provides telestroke services at the site distant to hospitals within its catchment area (originating sites). Immediate assessment with telemedicine facilitates rapid evaluation for intravenous tPA eligibility. The stroke physicians are typically credentialed at the originating hospitals, the sites at which the patient resides, allowing the consulting physician to order intravenous tPA. In the United States, credentialing can be facilitated by proxy in most states, with the spoke sites relying on the hub stroke center documentation, avoiding the need for primary source verification. When transfers are necessary, the hub stroke center receives the patient from the spoke hospital, having already observed and evaluated the patient by telemedicine. In most cases, the hub hospital is the closest CSC to the spoke hospital, but if transfer to a closer CSC would result in shorter times to treatment, arrangements should be worked out in advance and the closest CSC notified about patients before transfer. Both absolute distance and most rapid time to initiation of endovascular therapy should be considered in the transfer decision. Quality measures, operational protocols, order sets, policies, and procedures are established by agreement between the hub and spoke sites. Thus, the spoke sites usually benefit from the experience and expertise of the hub stroke center.

In a 2009 survey of telestroke programs throughout the United States, Silva and colleagues[14] surveyed 56 active telestroke programs in 27 states. The majority of responding programs were traditional hub-and-spoke networks, although 2 had no hub hospital and a few hospitals were served by a private telestroke provider. Almost all systems incorporated some form of quality review, although the specifics varied considerably. The most frequent method of quality review was case reviews, followed by recording of process measures and patient satisfaction. Since publication of the results of this environmental scan, there has been continued growth in telestroke networks, both the hub-and-spoke model and services provided by for-profit companies. Whether these results continue to be representative of the evolving telestroke landscape is uncertain.

A telestroke model used in the eastern section of England includes a "hubless" horizontal network of community hospitals organized to provide telestroke coverage for 7 hospitals during times when regular neurology coverage is not available.[15] Consults are performed by the local neurologists in rotation. The network demonstrated outcomes, including time to treatment, hemorrhage rates, and in-hospital mortality, that were comparable to other reports from hub-and-spoke networks. An additional arrangement used mainly in the United Kingdom and Ireland involves the local senior stroke physicians (stroke consultants) serving their own hospital by remote guidance during on-call services.[15] This model is used in a health system in which typically large district hospitals almost always run their own stroke unit and implies that stroke aftercare is the responsibility of the same specialists (or their colleagues from neighboring hospitals).

Telestroke as a Component of Stroke Systems of Care

In 2005, the American Stroke Association published recommendations for the establishment of stroke systems of care, a new model for conceptualizing the multiple domains of care required for effective stroke prevention, treatment, and recovery.[16] Telestroke was identified as serving in multiple capacities to support the stroke system of care, with an emphasis on facilitating linkages between providers throughout a stroke system, especially for those in rural or neurologically underserved areas. Telestroke also promoted the aims of use of an organized, standardized approach to acute stroke care across facilities and provided the tools necessary to promote effective treatment. Because telestroke bridges the geographical and temporal barriers that can introduce disparities in access to services, it helps achieve the goal of appropriate patients receiving care from the appropriate providers in the appropriate amount of time and can help to ensure that the best interests of stroke patients are considered first and foremost above those of geopolitical boundaries or corporate affiliations. Because telestroke levels the playing field for smaller and more rural hospitals, the availability of telestroke has played an important role in supporting implementation of state-based stroke legislation or regulations mandating stroke center designation and in increasing the use of thrombolysis.[17,18] Many hospitals have been able to achieve stroke center designation by states or accrediting bodies through the use of telestroke that provides the required 24×7×365 access to acute stroke expertise. The incorporation of small and rural hospitals into stroke systems of care is increasingly important, given new findings that support the use of mechanical thrombectomy in selected patients with large-vessel occlusions after intravenous thrombolysis.[11,19]

Telestroke Policy and Implementation

In 2009, the American Heart Association/American Stroke Association published companion articles that specifically reviewed the evidence for telemedicine within the stroke systems of care and made recommendations for implementation.[20,21] The best and, in some cases, only evidence available to support telestroke is derived from networks in which an academic medical center serves as a coordinating site supporting multiple smaller facilities in its geographical referral region in a hub-and-spoke relationship. In the United States, many patients are transferred to a stroke center after thrombolysis. In some US and European centers, ongoing care and consultation are provided for patients who remain at originating site hospitals through telestroke. For-profit companies have proliferated in recent years, offering telestroke services in many cases by neurologists located in other states who will have no further involvement in the patient's care after the consultation. Little is known about the outcomes of patients treated under this paradigm. The 2009 policy statement included guidelines[20] that contained 14 recommendations, 9 of which were based on Class I evidence. They emphasized the value of telestroke to support the immediate assessment of stroke severity via the National Institutes of Health Stroke Scale (NIHSS) and other instruments and its equivalence to that of a bedside assessment, the review of brain computed tomography (CT) scans by stroke specialists to decide about thrombolysis eligibility, urgent decisions about thrombolysis, and the implementation of inpatient stroke units, including assessments of occupational, physical, or speech disability in stroke patients by allied health professionals. Current acute stroke guidelines[22] continue to endorse the use of telestroke for these indications.

The 2009 policy article[20] outlined a set of general recommendations that defined how telestroke should be implemented and laid the foundation for identifying measures of quality appropriate to telestroke providers and recipients of those services. These included full integration into the stroke system of care whenever possible, with the use of standardized evidence-based stroke management, continuous quality improvement, collection of standardized and accepted state or national stroke quality measures, and contractual agreements between organizations requesting or providing telestroke services. Implementation requires compliance with all applicable laws and statutes and continuous quality improvement that should include an assessment of the adoption and use of the technology, rates of technical and human failures related to the system, and needs for training and maintaining competency. The use of widely accepted industry technology standards is encouraged, and the care provided during telestroke consultation should be similar to that given during on-site consultation. Although 90-day functional outcome is the gold standard for research trials establishing the efficacy of stroke interventions, it unfortunately is not routinely collected in standard clinical practice because of the high cost and complexity. This scientific statement expands and extends those recommendations on the basis of current knowledge and published literature.

Telestroke and the NIHSS

Most telestroke networks use the NIHSS for remote stroke assessment. Reliability of the NIHSS performed remotely is similar to onsite examination for both subacute and acute stroke patients.[23–26] The NIHSS-based stroke examination has also been shown to be reliable even when remote examiners are not trained in the use of telemedicine.[27] Remote video examination has been evaluated with smartphones, showing an excellent level of agreement for most of the NIHSS items.[28,29] A simplified NIHSS for real-time assessment of stroke in a prehospital setting was tested in standardized patients and appears to be reliable but has yet to be tested in a real ambulance setting.[30] In a real ambulance-based setting in Berlin, Germany, technical stability of video streaming based on a 3G connection was shown not to be sufficient for reliable NIHSS assessment.[31] The new 4G technology with higher bandwidth and optional prioritization in public mobile networks appears to be more appropriate for the use of ambulance-based telestroke applications.[13,32] A streamlined unassisted telestroke scale[33] was evaluated with healthy volunteers mimicking stroke syndromes during ambulance transportation[34] and demonstrated sufficient stability in a moving ambulance using 4G connectivity. Further testing in actual acute stroke transport situations is needed to assess this promising approach.

Telestroke and Acute Stroke Triage

In many cases, originating hospitals are capable of administering intravenous tPA with the support of a stroke specialist by telemedicine but cannot provide subsequent stroke care, particularly for those patients who require more advanced procedures. The identification of patients likely to benefit from a higher level of care at more specialized centers and initiation of immediate transfer of those patients are critical functions of a telestroke network. In hospitals without intensive care unit capabilities, stroke physicians, or qualified nursing staff, tPA treatment is usually initiated on site, and patients are then transported to a primary stroke center or CSC.[35] Compared with patients directly admitted to the stroke center, outcomes of patients with remote supervision of intravenous tPA initiation and subsequent transport to a regional stroke center are similar.[36] Consultation to identify candidates for transfer to stroke centers with a higher level of care can also be successfully initiated via telemedicine for patients with malignant infarcts who are likely to need decompressive surgery.[37] Five recent randomized trials demonstrating significant benefit with large treatment effects established the efficacy of endovascular treatment of stroke. Endovascular treatment requires extensive infrastructure resources and experience, which is currently provided primarily in CSCs.

Telemedicine has also been applied to the triage of those patients with proximal occlusion of brain-supplying arteries. The first experience using telemedicine to triage for endovascular therapy in patients with basilar artery occlusions was disappointing. The TEMPiS network (Telemedic Pilot Project for Integrative Stroke Care) identified patients with basilar artery occlusions by telemedicine. Compared with patients directly admitted to CSCs, interventional treatment and intravenous thrombolysis were delayed, and clinical outcomes were significantly worse.[38] Treatment protocols were later changed to start intravenous tPA before transport, resulting in better outcomes.[39] In the Barcelona stroke network, patients who were transferred from telemedicine-linked hospitals had a shorter time from onset to groin puncture and better outcome compared with patients transferred from hospitals without telemedicine connection.[40] The Stroke Eastern Saxony Network reported a high rate of endovascular treatment in patients evaluated by telemedicine before transfer.[41] In some situations, stroke expertise delivered through telemedicine may reduce long-distance transports.[8,42–44] In some networks, telemedicine is used to establish specialized stroke unit care on site in a telestroke unit, often with supplementary resources such as speech or physical therapy provided on site, allowing patients to remain in their local hospital with a higher quality of stroke care.[4] These data reinforce the central principle of telestroke, which is that earlier access to stroke expertise is associated with faster tPA initiation, which is strongly associated with improved outcomes.

Interpreting CT images in the acute stroke setting is essential to the appropriate evaluation and decision making for patients at an originating site. Emergency image transfer of CT scans is a standard component of the telestroke workflow, and interpretation of images is necessary for decisions on acute stroke therapy. When imaging data are transmitted in the digital imaging and communications in medicine standard, imaging quality at a remote site can be equivalent to that on site. When neurologists are trained in the structured assessment of brain scans, their quality of imaging interpretation is similar to that of readings by radiologists.[7,45] Although screens of current smartphone devices are much smaller than conventional radiology workstations, the accuracy of CT interpretation with a specific smartphone client-server teleradiology system was almost as good as the accuracy of a medical diagnostic workstation.[46] CT angiography is added to the imaging workflow in some sites when the studies can be completed rapidly without increasing door-to-needle time or delaying transfers for endovascular therapy. CT angiography in addition to CT has also been accomplished as part of CT imaging in specialized stroke ambulances in recent prehospital stroke projects.[47–49]

Cost-Effectiveness of Telestroke

Despite limited reimbursement from insurers, telestroke networks are cost-effective from both a societal[50,51] and a hospital[52] perspective. In addition to improving triage of endovascular patients,[41] telestroke enhances the ability of networks to identify patients who might qualify for trials of new or improved therapies and either initiate those studies at originating sites or start treatment more rapidly after transfer to stroke centers.[53]

Science of Quality Measures and Reporting

Since the first large-scale cardiovascular epidemiological studies were initiated in the United States >70 years ago, results from clinical trials and observational studies in cardiovascular disease care have done as much to standardize clinical practice as they have to define it. These studies have informed the development of best-practice recommendations, clinical guidelines, and specific quality-of-care performance measures and have been applied in other disease states. For the findings of research studies to have real-world impact and to be translated into broad changes in community practice, consensus must be established on performance measures, and their value must be broadly and effectively communicated and implemented.

The push to develop measurable quality improvement indicators in the United States first started in response to the critical issues raised in the Institute of Medicine's 2001 challenge to the American healthcare system, *Crossing the Quality Chasm: A New Health System for the 21st Century*.[54] In this landmark call to action to improve the American healthcare delivery system, the Institute of Medicine recognized that all Americans should be able to expect to receive care that meets their needs and that is based on the best scientific knowledge available. In its report, the Institute of Medicine laid the groundwork for the development of meaningful, measurable quality indicators and established 6 key quality domains—safety, effectiveness, patient-centeredness, timeliness, efficiency, and equity—that continue to guide the way we think about quality today.

Types of Quality Measures

Although there has been interest in defining and measuring the quality of health care for well over 100 years,[55] Donabedian[56] first described the 3 interconnected constructs of structure, process, and outcomes and is credited with defining a usable organizational framework for measuring healthcare quality and outcomes in modern-day health systems. According to Donabedian, structural measures denote the attributes of the settings in which care occurs. Structural measures describe the characteristics of the healthcare system itself, including system capacity (eg, number of hospitals, bed size), human and physical resources (eg, availability of specialists, staffing ratios, number of wards/units), and organization structure (eg, hospital referral networks, stroke units, stroke teams). Process measures denote what is actually done in giving and receiving care.[56] They describe the complicated processes and actions required to deliver care and are most often linked to specific recommendations from clinical guidelines.[22,57] Outcome measures denote the effects of care on the health status of patients and populations.[56] Ideally, outcome measures should reflect those outcomes that are important to patients such as death, disability, functional status, and quality of life[58] and should be measured in a time window that is relevant to the actual delivery of care. For example, stroke mortality and readmission outcome measures used by Centers for Medicare & Medicaid Services for its value-based purchasing programs[59] are measured 30 days from the stroke event.

Recently, progress has been made in standardizing the definitions and development steps required for the generation of valid quality measures. The American College of Cardiology/American Heart Association Task Force on Performance Measures provides a comprehensive framework for developing quality measures for cardiovascular diseases.[58,60,61] The task force defines quality metrics as "any objective measure that has been developed to support self-assessment and quality improvement at the provider, hospital, and/or health care system level."[62] The term performance measure is applied to a subset of quality metrics that have sufficient attributes (including strength of evidence, clinical relevance/interpretability, validity, reliability, feasibility, impact, and cost-effectiveness)[60] that can be used for public reporting, provider profiling, and other quality improvement programs such as value-based purchasing and pay for performance.[61] Increasingly, the National Quality Forum, a national public-private partnership that has developed consensus standards for the endorsement of quality measures, is serving as the final clearinghouse for the approval of quality measures developed by many organizations.[62] The National Quality Forum provides a rigorous set of evaluation criteria that address the importance, reliability and validity, feasibility, and usability of the measures, as well as comparability with other measures,[62] that are used as guides in the endorsement process.

Prior Experience With the Use of Quality Measures in Stroke

Since 2001, more than a dozen performance measure guidelines have been published and sponsored or cosponsored by the American Heart Association/American Stroke Association. These include guidelines for the treatment of chronic heart failure,[63] myocardial infarction,[64] coronary artery disease and hypertension,[65] and acute ischemic stroke.[66] In acute stroke, implementation of quality improvement initiatives based on performance measure data has been associated with improved timeliness of intravenous tPA administration after acute ischemic stroke, reduced rates of in-hospital mortality and intracranial hemorrhage, and an increase in the percentage of patients discharged home.[67] Other studies demonstrated similar results for improvements in defect-free care for stroke,[68,69] lipid management,[70] smoking cessation counseling,[17] and discharge rehabilitation plans.[71]

A systematic approach to measuring the quality of stroke care in the United States began in the early 2000s with the funding of the pilot Coverdell stroke registries[72] and the establishment[73] and rapid expansion of the Get With The Guidelines–Stroke program,[74] which now represents one of the largest ongoing clinical quality registries in the world.[75,76] The effort to establish a comprehensive system to monitor and to improve stroke care was accompanied by the establishment of common stroke performance measures. The Stroke Performance Measure Consensus Group was created to harmonize different measure definitions and to develop guidelines for data collection. Subsequent review by the National Quality Forum resulted in the 2008 endorsement of the following 8 measures: the use of thrombolytic therapy, antithrombotic therapy by the end of hospital day 2, venous thromboembolism prophylaxis by the end of hospital day 2, cholesterol therapy at discharge, antithrombotic therapy at discharge, anticoagulation if atrial fibrillation is present, assessment for rehabilitation, and stroke education.[77] The Centers for Medicare & Medicaid Services now includes these 8 National Quality Forum stroke measures as part of its public reporting system Hospital Compare, which also includes data on hospital-specific, risk-adjusted, 30-day stroke mortality and readmission rates.[78] In addition, the American Heart Association/American Stroke Association recently set up a new body, the Stroke Performance Measures Oversight Committee, which will oversee its development of stroke-specific clinical performance measures and quality metrics. The Stroke Performance Measures Oversight Committee recently published its first report on quality measures for inpatient management of acute ischemic stroke.[79] The expert panel acknowledged that because performance measurement is, by definition, dynamic, it must continuously evolve with the accumulating scientific evidence on best practice.

In recent years, an increasing number of reports have demonstrated the value of systematically collecting and analyzing data on stroke quality measures. Studies show that this activity often leads to a steady improvement in the quality of stroke care.[76,80–82] Demonstrating a link between improved quality and better patient outcomes with stroke registry data has remained difficult,[83] although examples exist, especially those specific to the delivery of thrombolytic therapy.[67,84,85] Although the stroke quality movement has achieved a substantial amount of progress in the past 15 years, significant challenges to the current system remain. Most of the current stroke performance measures are process measures that are limited to the inpatient setting; many have also reached a universally high level of compliance. New inpatient-based measures such as those addressing telestroke are clearly required. The scope of the existing measures should be expanded to include both prehospital and postdischarge settings. Additional challenges include the collection and reporting of patient-reported outcome measures, particularly those relevant to functional recovery and quality of life. Researchers also need to continue to develop higher-quality evidence linking better quality of care to improved patient outcomes.

Telestroke Process Measures

The expansion of telemedicine in the past decade and, more recently, the application of telemedicine in the diagnosis and treatment of acute stroke have led to an interest in developing specific performance measures in this area. Further refinement and expansion of telestroke can be facilitated by continuous quality improvement activities, with results on quality, performance, and outcome metrics shared across networks.[86] Indeed, recommendations suggest that every telestroke network hospital should participate in the collection of stroke quality measures.[20]

Time to Treatment

Given the critical importance of treating acute ischemic stroke patients quickly with intravenous tPA, several components of time to treatment should be key quality metrics in an acute stroke network. The goal should be to initiate intravenous tPA to eligible patients within 1 hour of patient arrival,[22] just as it is for in-person treatment. Similar to a primary stroke center monitoring critical time points in a patient's care path, telestroke process metrics should include all aspects of the chain of care: patient arrival at the originating site (door), time of CT, and time of the start of treatment with intravenous tPA. In addition to these standard measures, telestroke sites should record the time of telestroke request to the distant site, time of response by the stroke consultant, modality of first response (via phone or video), time of video connection if different from the first response, and duration of the consult. From these parameters, important calculations include time from door to consult and time from consult to start of treatment. Several published results of telestroke network experiences have shown that it is feasible to collect such time data within a randomized trial of telestroke[5] and within established networks.[10,35,87,88]

Response times have been variably defined as time of patient arrival to time of consult request, time to initial phone contact, or time to telestroke activation. It is recommended that time from consult request to initiation of phone or video connection be used as a standard to enable uniform reporting of connection times. The modality should be noted in addition to the time parameter. The optimal timing of the consult request varies, depending on the sophistication of the originating site. In some cases, a CT is completed first, but in other cases, it might be best to request the consult even before the CT scan to minimize time to treatment, realizing that sometimes patients will not be candidates for intravenous tPA on the basis of the CT results. No data currently exist favoring either approach. Response times may vary by hour of day, with longer response times at night, likely depending on both the awareness and activity of the originating site and the stroke provider.[87]

Consult time has been variably defined as either the time spent on camera or the entire duration of a consult, including initial consult time and time spent offline viewing neurovascular imaging and other diagnostic test results and documentation requirements. Reported consult duration varies from a mean of 14 minutes[87] to 32 minutes.[5] The large variability likely reflects both definitions of consult duration (as described above) and unique network practices: In some networks, telestroke is activated before the completion of head CT, whereas in others, the consultant may be called after the majority of the work has been done and is asked only to confirm a strongly suspected clinical diagnosis. Earlier activation likely increases the number of video encounters for nonischemic stroke patients (eg, if the telestroke consult is requested before the head CT completion, more patients with intracranial hemorrhage and brain tumors will be included), but this will also allow parallel processing in those eligible for intravenous tPA, resulting in reduced door-to-needle times.[89] The issue of overactivation and consultant physician and stroke team member burnout must be balanced within networks with the goal of best care for acute stroke patients.

Similar to measures at primary stroke centers and CSCs, telestroke quality focuses on door-to-needle and consult-to-needle times to provide targets for improvement. These metrics require close collaboration between originating and distant sites because the door time can be measured only by the originating site and the final needle time also can be known only by the site if the consultant is not on camera when the drug is delivered. Telestroke networks in and of themselves do not necessarily shorten door-to-needle times.[10] The randomized STRokE DOC trial (Stroke Team Remote Evaluation Using a Digital Observation Camera) showed that within a trial structure, video-enabled consults were longer (32 minutes) than phone-only consults (23 minutes), likely because stroke consultants repeated a neurological history and examination.[5] Early networks focused on proof of concept reported short consult-to-needle times (≈35 minutes[35,90]) but long door-to-needle times (106[35]–121[5] minutes). A US-based network showed that reducing door-to-consult times reduced door-to-needle times,[89] and a German-based network showed that with high volumes and longitudinal experience, door-to-needle times can dramatically improve, with the percentage of intravenous tPA treatments delivered by telemedicine in <60 minutes improving from 26% in 2003 to 80% in 2012.[8]

Most telestroke networks have the option of conducting consultations via phone, real-time audio/video, or both, with the method of consult depending on patient factors (eg, intravenous tPA eligibility) or technology availability (network or camera failures). In one study, phone consultation for acute stroke was found to be feasible when provided by a hotline to stroke experts at an academic medical center.[91] A randomized trial of phone-only versus video-enabled consults showed that the 2 approaches differed in quality of decision making.[5] The method of consultation is ideally recorded for analysis by method. Not all networks currently record the presence or details of phone-only consultations, given that there is no face-to-face encounter and they do not generally consist of billable services by third-party payers.

Transfers

Recording whether patients transfer between facilities after the telestroke consult and the destination hospital is important to follow patients' outcomes and to understand the practice patterns of their networks. A recent analysis using US-wide quality improvement registry data found that intravenous tPA is given via a drip-and-ship method for nearly one quarter of patients nationwide.[92] Because transfer rates and methods often drive the care costs and may affect patient outcomes, it is important for networks to develop methods to quantify what proportion of transfers are necessary and how to reduce those that are unnecessary.[52] Recording the method of transfer (private vehicle, ground or air ambulance), distance traveled, and duration of transfer is useful for determining patient and system costs.

Suggestions for Measuring Telestroke Processes

1. Times should be measured in a standardized fashion and include off-camera work flow, specifically recording the time of consult notification, phone response, video-consult initiation, consult completion, and each critical patient treatment point such as patient arrival, CT scan, diagnosis, decision making, and initiation of intravenous tPA bolus or the decision not to treat. Some telestroke software interfaces provide time stamping of the face-to-face video time, which can automate the data collection of consult duration.[87]
2. Data on both phone and audio/video encounters for acute stroke evaluations should be included in quality metrics at telestroke sites.
3. Tracking transfers between facilities is important for understanding the flow of patients, cost structure, and eventual outcomes. Time of transfer, destination facility, and time of arrival should be recorded for all such cases.

Telestroke Outcome Measures

The impact of telestroke on stroke care is ultimately measured by improved system-related and patient-related outcomes. Process measures such as door-to-treatment times are related to outcomes, but direct monitoring of patient outcomes should also be included in the quality assessment of a telestroke network.

Patient Outcomes

Measuring patient outcomes with standardized metrics is critical for understanding the success of a telestroke network. In stroke patients, important outcomes include severity of persisting neurological deficits, length of hospital stay, complications, discharge disposition, and disability. Whether the outcome is recorded at the originating site or the distant site depends on where the patient is hospitalized after presenting with stroke and the capabilities of both sites. It is recommended that an agreement to provide telestroke services includes a statement on the responsibility for collecting information on outcomes. The distant site will most likely record whether patients were admitted to the originating site, distant site, or a third hospital (in or out of network) on the basis of the information gathered during the telestroke consultation. If the patient remains at the origination site, that site would likely record hospital-related data such as length of stay, complications, and discharge status. Responsibility for monitoring outcomes after discharge should be agreed on but more commonly falls to the distant site or provider group with greater experience in measuring stroke disability if this metric is included. Ninety-day functional status is the preferred longer-term outcome in stroke studies and reports of stroke treatment. It is important that telestroke networks adhere to this standard if they are part of the continuum of stroke care. The most commonly used stroke outcome is the modified Rankin Scale, which ideally is measured at 90 days after stroke.[93] It is recommended that telestroke networks make every effort to obtain 90-day follow-up for all patients treated with intravenous tPA because this has become the standard for comparison with results of randomized trials, registries, and other networks. Follow-up modified Rankin assessments may be obtained in person or by phone either through a standardized assessment form or by a skilled and certified examiner,[94,95] although there is controversy concerning the reliability of phone Rankin scoring.[96] However, obtaining any long-term follow-up is often difficult and requires resources that may be beyond the capabilities of some telestroke systems. When postdischarge follow-up is not possible, recording in-hospital mortality, NIHSS at 24 hours, modified Rankin Scale score, or NIHSS at discharge and the discharge location is helpful because these are short-term proxies for functional outcome.[97]

Because outcomes depend strongly on initial stroke severity, the admission NIHSS should always be recorded. Although other validated stroke severity scores exist and are equally capable of measuring stroke severity accurately, the NIHSS has emerged as the de facto standard and allows meaningful intersite and interstudy comparisons. It is the scale for which the best data exist on telestroke consultation. In a telestroke network using a drip-and-ship method, the NIHSS scores at hospital admittance at the originating (before tPA) and later at the receiving (after transfer) hospital are relevant. All examiners should obtain certification in the NIHSS.

Few research studies report long-term outcomes after thrombolysis via telestroke. Meyer et al[98] examined long-term functional outcome and mortality in a subgroup of patients entered into the STRokE DOC trial comparing telephone and telemedicine evaluation of acute stroke patients. There was no significant difference in mortality or functional status determined by a modified Rankin Scale score of 0 to 1 at 6 months. Similar results were found in the TEMPiS network comparing long-term outcomes after thrombolysis in hub-and-spoke hospitals.[99]

Stroke Diagnosis and Mimics

A critical measure of telestroke consultation quality is diagnostic accuracy. Diagnosis is an element often not recorded in telestroke networks.[87] A comparison of initial and final diagnosis will allow greater understanding of diagnostic accuracy via telemedicine, which was shown to be high in a single-network study[100] but has not yet been benchmarked or studied nationally. This information would allow understanding of the use of networks and analysis of whether certain disorders are more difficult to diagnose with a video interface. This is particularly important, given that telestroke networks are often used for nonstroke cases, including stroke mimics and nonstroke neurology requests by telemedicine sites.[101]

Rates of stroke mimics among those presenting acutely for the sudden onset neurological deficits are as high as 30%[102–104] with similar rates in telestroke settings (11%[37]–22%[105]). Given the time pressures of decision making in ischemic stroke and the similarity of presentation for ischemic stroke and many stroke mimics, treatment rates of stroke mimics are 6% to 16%.[103,106,107] Reports vary as to whether this fraction is higher or the same in drip-and-ship paradigms[103] for in-person treatments compared with patients treated by telestroke.[107] Collecting outcome data on treated stroke mimics by the stroke center can be done more easily when patients are transferred and follow-up imaging can confirm or exclude infarction, but this needs to be a collaborative effort by both the originating and distant sites. Although current evidence suggests that stroke mimics are not exposed to excessive risk by the use of intravenous tPA,[108] it is an expensive therapy (including drug cost, 24 hours of monitoring in an intensive care unit, follow-up head imaging, and potential ground or air transport to a stroke center).[109] The goal should be to minimize stroke mimic intravenous tPA treatment without missing or delaying an opportunity to treat ischemic stroke.[108]

tPA Use

An important outcome related to acute ischemic stroke treatment reported by telestroke programs has been the increased the use of thrombolytic therapy. Meyer and Demaerschalk[86] reviewed 14 telestroke networks that reported rates of intravenous thrombolysis via telestroke consultation of 18% to 36% compared with nationally reported rates of 5% to 8%. The higher rate of treatment may be related to the implementation and training to establish telestroke services at these facilities and the preselection of patients referred for telestroke on the basis of local treatment protocols.

Amorim et al[10] reported their thrombolytic experience implementing telestroke within a 12-hospital spoke telemedicine network at the University of Pittsburgh Medical Center. They retrospectively reviewed all patients discharged with a diagnosis of acute ischemic stroke before and after the institution of telestroke at each of their spoke hospitals with rate of intravenous thrombolysis as a primary study outcome. Before the implementation of telestroke, 2.8% of acute stroke patients were treated with intravenous tPA. The treatment rate increased to 6.8% after telestroke services were started ($P<0.001$). In addition, there was a significant increase in the percentage of stroke patients in the posttelemedicine phase who arrived within 3 hours of symptom onset (6% before telestroke and 9.5% after telestroke).

Yang and colleagues[87] benchmarked telestroke consultations as they related to time performance and reviewed the clinical data from 8 stroke centers that provided 235 telestroke consults over a 7-month period. Of the 203 consults that met their study criteria, 60 of 203 or ≈ 30% carried a diagnosis of stroke or transient ischemic attack, and 13 of 60 stroke cases (21.7%) were recommended for intravenous tPA. Although the mean response time (time from arrival to physician log-on) was 76 minutes, the percent of patients eligible and considered for thrombolysis was more than triple the current nationally reported intravenous tPA administration rate. In a smaller study, Nystrom and colleagues[110] also demonstrated that with a single hub-and-spoke network, there was a 160% increase (10 cases in 2007 and 26 cases in 2009) in the use of intravenous tPA within 2 years after telestroke services were implemented ($P<0.05$). Patients with mild strokes were found more likely to be treated in the posttelestroke implementation phase than in the pretelestroke phase, in large part because functional status and specific deficits affecting quality of life were also considered in the treatment decision process.

Safety Measures

Treatment with intravenous tPA includes risks, particularly intracerebral hemorrhage, sometimes causing neurological deterioration or death. Monitoring complications is an essential element of quality and outcomes in telestroke networks. Major safety outcomes include in-hospital and up to 90-day mortality and intracerebral hemorrhage. Other less common complications of intravenous tPA that should be recorded are angioedema and systemic hemorrhage.

Intracranial Hemorrhage

Most publications report symptomatic hemorrhagic intracranial complications but do not use a consistent definition. The National Institute of Neurological Disorders and Stroke,[111] ECASS (European Cooperative Acute Stroke Study),[112] Get With The Guidelines–Stroke registry, and SITS-MOST (Safe Implementation of Thrombolysis in Stroke–Monitoring Study)[113] define symptomatic hemorrhage differently, requiring in some cases that the symptomatic intracranial hemorrhage be described as the cause of the worsening, in other cases simply any hemorrhage with a 4-point worsening on the NIHSS or requiring a type 2 parenchymal hematoma. Some telemedicine studies do not provide a specific definition. Rates of symptomatic intracranial hemorrhages were reported in uncontrolled telestroke studies,[15,35,42,114–118] pretelestroke/posttelestroke implementation evaluations,[10,119] and comparisons between remote- and on-site–initiated thrombolysis[36,88,93,120–126] and telephone and telemedicine (video assessment based) thrombolysis.[36] Two randomized controlled trials report intracerebral hemorrhage rates without specific definition.[5,90] Symptomatic intracranial hemorrhage rates were also reported from 2 prehospital stroke ambulance projects in Germany.[127–129] Systemic hemorrhage rates were reported in only 1 publication.[36] The rate of asymptomatic hemorrhage should also be monitored, although it does not have the same consequences on outcomes because some reports have found asymptomatic intracranial hemorrhage to be associated with improved outcomes.[130]

Mortality

In-hospital or short-term (up to 10 days) mortality is one of the most frequently used safety parameters in telestroke reports. It has previously been reported in uncontrolled reports of patients treated with intravenous tPA,[6,42,91,115] pretelestroke/posttelestroke implementation evaluations,[131] comparisons between telemedicine-guided thrombolysis and in-person–initiated thrombolysis,[36,120–122,132] and comparisons of telephone- and telemedicine-based thrombolysis.[36,133] Mortality after thrombolysis was reported as an outcome in a randomized trial of telephone and telemedicine acute stroke consultations, with no difference found between the modalities.[90] In-hospital mortality has been described for unselected stroke patients with or without thrombolysis in a report comparing hospitals within a telestroke unit network with matched conventional hospitals.[134,135] Mortality rates at 7 days were also reported from 2 prehospital stroke ambulance projects in Germany.[127–129] Although telemedicine including video examination equipment is mentioned, it remains unclear how many patients treated with tPA were remotely assessed in the latter studies. Mortality at 90 days has been reported in a limited number of cohorts of uncontrolled studies and reports,[93,116] comparisons between telemedicine-guided thrombolysis and in-person–initiated thrombolysis,[99,119,124] an observational study of telephone versus telemedicine thrombolysis,[91] and 2 randomized controlled trials.[5,136] Longer-term mortality after thrombolysis by telestroke has been described for unselected stroke patients in an uncontrolled study,[117] pretelestroke/posttelestroke implementation evaluations,[131,137] and a comparison of hospitals within a telestroke unit network and matched conventional hospitals,[134,135] as well as 1 randomized controlled trial.[98,136]

Suggestions for Measuring Telestroke Outcomes

1. Patient characteristics predictive of stroke outcome, including age, sex, time to treatment, and NIHSS score at first presentation and arrival after transfer, should be collected. Disposition after the telestroke consultation should be recorded such as ED discharge, admission to hospital, or transfer to another facility, with notation of which facility was selected for transfer.
2. Telestroke networks should collect initial patient outcomes, including NIHSS score at first presentation, time of arrival and departure at the originating site for interhospital transfer, and arrival time at the receiving hospital. Preliminary diagnosis by the telestroke consultant at the initial evaluation and final discharge diagnosis should also be recorded. For patients treated by telestroke but not transferred to the hub hospital, the final diagnosis should be obtained by the originating site. Hospitals engaged in providing or using telestroke services should have written agreements that explicitly require the exchange of these data.
3. Patient outcomes should also include hospital length of stay and in-hospital complications, including symptomatic and asymptomatic intracerebral hemorrhage and mortality.
4. At hospital discharge, a measure of residual deficit such as the modified Rankin scale or NIHSS and discharge location should be recorded. Other measures such as ambulatory status may be desirable if they conform to a standardized definition or database, for example, Get With The Guidelines–Stroke.
5. Telestroke networks are encouraged to obtain longer-term outcomes at least for all patients treated with thrombolysis, ideally by assessment with the modified Rankin Scale at 90 days by telephone, by video, or in person.
6. When telestroke consultations are provided outside of a hub-and-spoke network, collection of discharge and longer-term outcomes is encouraged, and contractual relationships should make provisions for collecting such information.
7. Telemedicine systems should record intravenous tPA treatment rates relative to total telestroke consults and intravenous tPA protocol adherence at all hospitals within the telestroke system.
8. The tPA treatment rate reports should include the percent of all patients seen in the ED with the initial diagnosis of stroke and, when available, the percent of all patients discharged with a stroke diagnosis, percent of stroke patients arriving in the ED within the 3- and 4.5-hour time windows since last known well, and percent of all stroke patients within these windows in whom documentation does not include a reason for not treating with intravenous tPA (eg, eligible for tPA).
9. Safety measures such as symptomatic intracranial hemorrhage and mortality are important outcomes after intravenous thrombolysis and should be monitored and reported in telestroke systems with the use of a standard definition.
10. For assessment of treatment safety, short-term mortality should ideally be assessed at 7 days, but survival at discharge from acute care is a pragmatic compromise.
11. When follow-up at 90 days is obtained for patients receiving thrombolysis, mortality should be added to disability assessments as reported outcomes.
12. Monitoring of hemorrhagic complications should include symptomatic hemorrhage rates according to one of the established definitions and asymptomatic hemorrhage rates.

Patient and Provider Satisfaction

Patient Satisfaction

Although telestroke services have been available for some time, only in the past 10 years has patient and family experience with telestroke as a medium for delivering acute stroke care been reported. This may be due in large part to the recent initiatives that hospitals have taken to gain stroke center certification status. As a mandated outcome measure for stroke recovery care and as a correlate to quality effectiveness and patient safety, patient satisfaction has been a focus of more recently published qualitative studies.

In the early 2000s, patient satisfaction with acute telestroke services was often reported as a secondary measure, with general statements referring to the overall positive feedback from patients about such elements as the speed of receiving care, perceiving the added benefit of teleconferencing versus a telephone consultation, and expressing satisfaction about having an examination performed by a stroke specialist involved in their care.[35,138,139] In a 2008 follow-up study publishing outcomes from their stroke telemedicine network, LaMonte and colleagues[138] reported patient and family satisfaction data using a standardized questionnaire in which respondents reported that their care was "enhanced" with immediate access to a stroke specialist via teleconferencing. Another study from Germany assessed the overall patient satisfaction with stroke care in hospitals running a telestroke unit compared with those without telemedicine service. Satisfaction with quality of care was significantly higher in patients treated in the telestroke unit, but teleconsultation itself was not an independent factor for improved ratings.[140] These early studies reflected a functional dimension of the patient experience in which patients provided feedback about the effectiveness, timeliness, and coordination of treatment and the smoothness of the transition of care.[141]

Several more recent studies were designed principally to examine the patient's perspective of telestroke, identifying aspects of care related to emotional/cognitive support and mutual decision making. Gibson and colleagues[142] explored both the patients' and caregivers' perspectives of the use of an acute stroke telemedicine system using the normalization process theory, which expanded on the dimensions for measuring satisfaction. These included interactions with staff, cognitive participation, emotional reactions, and coherence (understanding) of care. The results suggested that telemedicine added complexity to the stroke evaluation that benefited from clear explanations and cooperative efforts among the staff, patients, and caregivers.

The domains outlined above in this study offer detailed insight into the breadth of experiences that can influence patients' perception of their acute care. Although generally an acceptable modality for delivering care via remote consultation, excellent communication from a defined practitioner with adequate information about the use of technology in assisting with the evaluation was an deemed important element to incorporate into the algorithm.[142]

Patient satisfaction is now a high priority for most healthcare systems. Organizations that certify disease-specific care programs have also mandated a process for collecting and analyzing patient satisfaction scores to identify potential solutions to improving overall quality and clinical care effectiveness. The need to standardize the metric for reporting patients' perception of their experience with telestroke services is timely, given that telemedicine for acute stroke and stroke recovery care is now a well-established modality. The added dimension of a remote expert clinician and the interface of videoconferencing technology to provide acute stroke consultations should be incorporated into any survey process that examines the perspective of the patient's experience and overall satisfaction of that experience.

Provider Satisfaction

Measuring physician satisfaction should not be overlooked because it is a critical factor in predicting network success.[143] The concept of provider satisfaction is imprecise. It is traditionally defined as meeting the expectations of treatment and care but includes more complex concepts such as acceptance, use, effectiveness, and efficiency among others.[144] It has been shown that although patients and providers are generally satisfied with telemedicine services, providers are somewhat less enthusiastic than patients. This may be attributable to inadequate training or less obvious personal benefit for physicians.[144] However, the explosion of telestroke networks in the United States and worldwide suggests that stroke experts may be earlier-adopters or find more benefit in their practice than other physician groups. Little is known about how to measure satisfaction. It has been studied in many fields but is generally understudied in the field of stroke. Although there has been some success in designing validated measures in cardiovascular medicine,[145] this has not yet been adapted to stroke specifically. What has been studied generally falls in the category of showing that physicians feel that the consult has improved care for the patient but does not always address the true realms of physician satisfaction.[35]

An element of professional burnout could be reasonably expected in the field of telestroke if the duties are just added incrementally to an already full clinical schedule, particularly given the often-inconsistent reimbursement in which traditional, time-based reimbursement does not reflect the burden of off-hours, after-hours, and weekend urgent consults.[87] Although there are physicians whose entire practice is telemedicine based, it is not known if their satisfaction is increased, perhaps because of the flexibility of schedule, or diminished, as a result of the loss of longitudinal patient relationships and potential isolation from peers and colleagues. Ideal measures of consultant satisfaction include call burden, adequacy of call reimbursement, overall quality of life, and perceived quality of the care they are providing.[146] Additional metrics could include assessment of cultural barriers.[147]

Suggestions for Measuring Patient and Provider Satisfaction

1. Patient satisfaction should be an integral component of a telestroke quality monitoring program. Surveys should assess satisfaction with the provider, staff, technology, interactions, and audio and video components, as well as the overall experience. Teamwork and concise communication are important to counteract any negative influence of the remote aspect of the consultation.
2. Provider feedback on the adequacy of the network operation and patient care helps identify problems and facilitate system-wide improvements to improve patient care and should be a component of quality reporting. The ideal vehicle for tracking this parameter requires further study.

Telestroke Technology Quality

The success of telestroke depends not only on the quality of professional services and remote interaction with patients but also on the working technology that enables videoconferencing. If the technology does not perform as expected, clinical care may be compromised. Several aspects of this technology should be subject to quality monitoring to ensure that adequate telestroke consultations can be performed on an emergent basis when needed. Telestroke sites should continuously monitor technical quality and performance to ensure that patients receive the benefit of real-time audio and video communication.

High-quality 2-way videoconferencing is important in acute stroke, in which, for example, the ability to discriminate between a mild aphasia and an acute confusional state is critical and affects clinical decision making. Video quality is determined by image refresh cycles as measured by frame rate and by resolution as measured in pixels. Video input and output devices (eg, cameras and displays) also are factors in the quality of the video image transmitted and received. Although no studies have defined the minimum video quality needed in acute stroke decision making, an American Stroke Association expert panel suggested a standard refresh rate of at least 20 frames per second with synchronous 2-way audio/video and a resolution of at least 352×258 pixels.[20] Many telemedicine systems leverage the H.323 videoconferencing protocol standards, which manage call signaling, communication, and bandwidth control over a wide variety of networks. These standards incorporate video compression and decompression called H.261, H.262, and H.264 and generally consume 64×10^3 to 1.2×10^6 bits per second of network bandwidth for standard-definition video (640×480 pixels in North America).[13] The Scalable Video Coding extension of the H.264/MPEG-4 Advanced Video Coding standard (H.264/AVC) is the latest development for this successful specification, enabling high-resolution performance at the relatively low-bandwidth environments often available at more rural hospital sites.[148] New communication (Web Real-Time Communication) and compression and decompression standards (VP8) are also emerging that promote the use of a Web browser as the primary audio/video platform while maintaining equal or better quality at half the bandwidth cost. Accordingly, technological advances on the horizon coupled with increasing access to high-speed bandwidth continue to accelerate the implementation of telemedicine services.

Depending on the technology used, bandwidth requirements can range from as little as 64×10^3 bits per second to in excess of 1.2×10^6 bits per second. However, bandwidth $>512\times10^3$ bits per second or closer to 1.2×10^6 bits per second will usually be needed for seamless operation.[13] The quality of the connection is affected by many factors, including bandwidth (connection capacity and speed), distance (which introduces latency), network throttling (introduced by network configuration), and congestion (hospital systems will be "saturated" at peak times, limiting the available bandwidth).[13] The cell structure of mobile telecommunications may lead to low bandwidths during peak times of mobile Internet use. This becomes an issue in hospital and busy EDs where competing for limited bandwidth leads to degradation of quality. Other variables affecting the conferencing experience include the number of participants in a videoconference, video resolution, and video size. Recently developed technologies such as Scalable Video Coding[148] provide better performance in low-bandwidth environments by making adjustments to frame rate, the area of the image to be refreshed, and video quality based on network environment fluctuations during the conference.

Telestroke in the prehospital setting connects the consultant to the ambulance rather than to the hospital or ED. The first prehospital telestroke attempt was the TeleBat system, which used 4 simultaneous cellular phone connections, each with a bandwidth of 9.6 KB per second that provided a 320×240-pixel image every 2 seconds. This limited bandwidth and technical performance precluded real-time videoconferencing.[149,150] Prehospital telemedicine with 4G cellular systems is now commonplace in major cities and allows improved connectivity. In studies in Brussel using simulations in a moving ambulance[34] and then later live patients,[151] connectivity was much improved but not always reliable even with a 4G system, particularly during peak network use times. Prioritized access to bandwidth for medical services, which requires architecture that supports dedicated and guaranteed quality of service levels, is one potential solution for further improvements. However, this requires that all communications occur end to end over networks that support these standards, which have previously been available only in private networks. Telestroke examinations are also a component of stroke emergency mobiles in which an ambulance incorporating a CT scanner is dispatched and enables intravenous tPA treatment in the field.[152] The connectivity problems associated with a moving ambulance have not yet been overcome and are avoided by evaluation in a fixed location with a specially equipped ambulance.[153]

Hospital information technology (IT) services carefully control access to their network because telemedicine must adhere to Heath Insurance Portability and Accountability Act standards governing protected health information.[13] In many cases, this involves configuring firewall rules and providing secure access to the local area network or wireless local area network. Heath Insurance Portability and Accountability Act regulations require that protected health information be encrypted in transit and when data reside "at rest." Finally, rules have to be implemented for mobile telemedicine with laptops or handhelds used outside the hospital, sometimes in public places; therefore, it is critical that safeguards be put in place to ensure compliance with local and federal privacy and security regulations.

Interpretation of CT images by the telestroke provider is a component of the telestroke consult, and image quality is essential to proper interpretation. CT images can be viewed by direct access to the originating site picture archiving and communication system, by pushing images to the remote picture archiving and communication system, or by cloud-based imaging services. The American College of Radiology recently published a white paper on teleradiology practice and technical standards for teleradiology.[154] The US Food and Drug Administration regulates medical imaging management systems as devices and requires approval before they are marketed.

Smartphones are now used in some cases to perform the NIHSS on stroke patients.[28,29] In one study using the FaceTime videoconferencing application, vascular neurologists subjectively rated image quality, sound quality, ease of use, and ability to assess the subject with the NIHSS as good or very good in ≥94% of the assessments and rated reception in hospital as good or very good in 83% of the assessments.[29] More data are needed before widespread use of small-form-factor smartphones for telestroke evaluation can be recommended.

Quality monitoring of videoconferencing should always include the type of equipment used and the modality for communication so that ongoing evaluation of these video interactions can be further performed. It is important to recognize that poor-quality audio and video may impair the ability of the remote examiner to obtain accurate information and to make correct decisions about treatment.

Suggestions for Monitoring Telestroke Technology Quality

1. In a telestroke system, technical failures and limitations during consults should be continuously monitored, with the specific problems encountered, the frequency of communication problems, and the number of times technical issues resulted in limitations, delays, or inability to perform a telestroke consult noted. A backup system should be available in case of connection failures or significant delays. Any potential harm caused by failed or inadequate connections should be recorded and reported.
2. Both the originating site and the provider site should record failed consults resulting from technical issues, whether equipment problems, user error, or broadband lapses. In addition, technical issues causing delays or impairing assessment capabilities, whether audio, video, or both, should be noted and detailed. The number of failed and compromised calls should be expressed as a percent of all telemedicine interactions.
3. In systems using telestroke in a prehospital setting, technical quality measures should be recorded in addition to any specific limitations related to mobile communication in an air or a ground ambulance setting. Systems must provide bandwidth sufficient for meaningful decision making relative to the channel being used (eg, phone, video, or imaging), and there should be backup alternatives to address the connection failures or delays.
4. Any telestroke interactions in which a violation of security or protected health information policies is suspected as a result of technical problems should be recorded, investigated, and corrected.
5. Quality monitoring of CT image quality, technical failures, operational failures, or workflow issues should be recorded and regularly reviewed along with other technology quality measures.

Process of Quality Reporting

Ideally, every health system participating in a telestroke network should contribute to the collection of applicable regional, state, or national stroke quality measures, including those dedicated to the telestroke interaction.[18,20] The Joint Commission, for example, has published telemedicine requirements for hospital and critical-access hospital accreditation programs to ensure that care, treatment, and services provided through contractual agreements are provided safely and effectively.[155] Established national stroke registries such as Get With The Guidelines–Stroke, the Paul Coverdell National Acute Stroke Registry, or their equivalent may be useful to collect essential data and to facilitate consistent collection across disparate networks. Furthermore, this would allow comparison of performance between networks. These registries already contain many of the desired data elements but may require modification to include some of telestroke-specific metrics previously suggested.

Within hub-and-spoke networks, the coordinating stroke center should be responsible for collecting and entering patient-related data. However, data sharing must be bidirectional between the stroke center and originating sites to facilitate patient care and as a key element of a performance improvement plan. In distributed network telestroke configurations, telestroke coverage is not provided by consultants from a hub hospital but by a for-profit telemedicine physician supply company or by private practice neurologists.[14] In this circumstance, telemedicine-specific data collection should be coordinated with the contracting telemedicine entity. All telestroke providers should be responsible for quality monitoring.

Certification of stroke centers has become an established system to verify the capabilities and quality of stroke performance at a spectrum of hospitals. Telemedicine is an indispensable tool linking stroke centers to neurologically underserved hospitals and requires the same level of oversight. As with hospitals, it is crucial for prehospital providers and the public to be able to identify that a hospital is linked by telemedicine and able to perform 24/7 emergency stroke care. Self-certification is not always reliable, however, because physicians routinely overestimate the degree to which their facilities meet certification criteria.[156]

The majority of telestroke centers, and in fact many originating sites, are likely already involved in certification programs at the comprehensive, primary, or acute stroke-ready hospital level through The Joint Commission, state-based certification, or other national bodies. As a result, there would be unnecessary redundancy if a separate mechanism were created for the certification of telestroke systems. Nevertheless, the unique aspects of telemedicine previously detailed argue for some special designation. One solution might be to integrate telestroke certification into existing hospital certification for acute stroke-ready centers, primary stroke centers, and CSCs as an additional certificate. Telestroke is already a component of the German Stroke Unit certification process. This document should serve as a template for the quality component of a certification process across certifying bodies.

Because quality and outcomes research and reporting are integral components of any telestroke network, a program budget would generally include the cost associated with the necessary effort. For example, the Stroke Telemedicine for Arizona Rural Residents network plan budget contained quality and outcomes assessment and reporting costs, in addition to indirect quality research-associated costs.[157] The estimated annual quality and outcomes assessment and reporting budget for a 1-hub and 35-spoke network was approximately US $35 000.[157] Other estimates of the annual expenditure associated with telestroke network programmatic management, including quality assessment and outcomes reporting, are US $50 000 to $90 000.[50]

Suggestions for Quality Reporting

1. Within a telestroke system, measures of quality performance should be collected in a standardized fashion and shared across the network.
2. The responsibility for collecting quality data should be a component of the agreement between telestroke sites and either a coordinating stroke center or distributed partner.
3. Certification should be conducted by an independent, external organization with no financial or other ties to the network hospitals. The certification process should include a review of performance metrics, processes, and outcomes involving telemedicine and should be integrated into existing certifications mechanisms. Distributed networks that are not based inside a stroke system of care should be included in certification mechanisms to ensure uniform quality.
4. Standardization of telestroke quality data across networks is desirable and could be achieved by certifying organizations uniformly adopting the suggestions in this document.

Licensing, Credentialing, and Training Requirements

Medical licensure and hospital credentialing are identified barriers to the long-term success of telemedicine programs.[158] In a survey of 106 emergency medicine and critical care users of telemedicine in Europe and North America, 61% and 69.5% of respondents identified licensing and credentialing, respectively, as barriers to implementing telemedicine.[159] However, ensuring provider qualifications is essential to delivering quality care to patients within a telestroke network.

Licensing

The administrative burden of individual state licensure requirements for providers of telemedicine services has been recognized for 2 decades.[160] The growth of telemedicine meets resistance because of the timely, costly, and variable process of medical license portability. A survey of licensing application professionals revealed major disparities among states. The survey demonstrated delays introduced by the medical boards, lost documents, and lack of online access to application status as the major impediments. Survey respondents recommended a standardized process or a national license as potential solutions.[161] In April 2014, the US Federation of State Medical Boards introduced its "Model Policy for the Appropriate Use of Telemedicine Technologies in the Practice of Medicine."[162] The policy aims to provide guidance to state medical boards on the regulation of telemedicine. In terms of licensure, the US Federation of State Medical Boards policy states, "A physician must be licensed, or under the jurisdiction, of the medical board of the state where the patient is located. The practice of medicine occurs where the patient is located at the time telemedicine technologies are used." The US Federation of State Medical Boards recognizes the burden of individual state licensure requirements. The Interstate Medical Licensure Compact was initially proposed at the 2013 US Federation of State Medical Boards annual meeting. This initiative aims to establish an expedited licensure process for physicians who are licensed in a participating state and seeking licensure in other participating states.[163] The compact would not supersede individual state's licensing authority. Increased adoption of the compact may alleviate some of the current burden of state licensure for telemedicine providers.

Credentialing

In 2011, the Centers for Medicare & Medicaid Services began to allow credentialing and privileging by proxy at small and critical-access hospitals. This rule allowed smaller, poorly resourced hospitals that need telemedicine support to rely on the credentialing and privileging process performed at a stroke center hospital. Effective August 2011, The Joint Commission aligned its requirements with the Centers for Medicare & Medicaid Services rule; however, not all states have revised their state board of registration regulations and policies to allow credentialing by proxy.[164] No data are currently available on US national rates of use of credentialing by proxy within telestroke networks. More than 80% of telestroke originating hospitals in the United States are reported to be small rural hospitals, and the total number of participating hospitals in telestroke networks continues to increase.[14] Thus, future efforts should be directed toward mitigating the administrative burden created by credentialing requirements for telestroke services in both rural and urban clinical environments.

Training

To maintain quality in a telestroke system, there should be a training program at both the originating site and the distant site that educates providers and support personnel to keep clinical skills updated and ensures appropriate use of technology. No uniformly agreed-on training requirements have been established for clinical use of telestroke, but there are some generally agreed-on key players for successfully establishing a telestroke system.[165,166] The support and buy-in of hospital administrators, IT personnel, and legal and financial personnel, among others, are essential. A physician champion for telestroke at a stroke center may facilitate navigation of the administrative, IT, legal, and financial issues that arise as part of establishing a telestroke program. This person may be called the medical director for telestroke and benefit from the experience of others at the local and national levels to ensure the success of the individual program. This person would also cultivate enthusiasm for telestroke among other stroke center clinicians and cultivate relationships with telestroke sites to develop clinical care pathways that optimize care for all stroke patients. This role is best served by an identified vascular neurologist, neurosurgeon, or other stroke expert.

Training and background for the medical director should ensure sufficient knowledge of vascular disease, emergent therapy, and telemedicine to provide administrative and clinical leadership. Appropriate training might include at least 2 of the following: vascular neurology fellowship training; attendance at a minimum of 2 professional meetings or courses over 2 years concentrating on cerebrovascular disease or telemedicine; at least 4 continuing medical education (CME) credits (or equivalent) per year in cerebrovascular disease and at least 4 CME credits in telemedicine; and other criteria demonstrating competence in these areas as agreed on by local and national standards. The professional societies of vascular neurology, emergency medicine nursing, and telemedicine should partner to develop a curriculum and to make available a series of CME offerings that would meet the needs of telestroke medical directors and their teams. Telestroke programs should also assist in educational program development or implementation in their covered regions, in partnership with properly accredited CME organizations. These requirements closely follow the recommendations of the Brain Attack Coalition for medical directors of primary stroke centers.[167]

Training for other consultant vascular neurologists/stroke experts at the stroke center should be geared toward optimizing clinical care. Beyond the necessary clinical expertise, providers should be familiar with the use of the selected technology platform. They should be able to reliably troubleshoot technological difficulties with assistance from IT and have backup plans for providing clinical care if technical problems are insurmountable. Whenever new hardware or software is introduced, training should be provided to all users. Providers should also understand the general goals of clinical coverage for individual hospitals. For instance, a primary stroke center that receives telestroke coverage from a team of stroke experts may not need to transfer patients to a CSC, whereas a critical-access hospital receiving telestroke coverage may need to transfer all treated patients to a CSC. Physicians participating in telestroke consultations should also demonstrate an adequate knowledge base in acute stroke care and should maintain that knowledge through CME requirements.

In addition to the primary stroke center telestroke medical director, a dedicated program manager or administrator is helpful for a successful telestroke program. This person would interface with the medical staff, IT, and legal offices at both the stroke center and any supported hospitals. This person would ensure that contracts are in place and licensure and credentialing are current, schedule training and education of personnel at all hospitals within the network, ensure that quality measures are in place and followed, and provide overall oversight for the telestroke program.

Telestroke participation at telestroke originating sites may include emergency physicians, emergency nurses, advanced practice nurses, physician assistants, hospitalists, intensivists, administrators, or other personnel who are committed to training clinical providers and providing quality oversight to the clinical care of stroke patients at the originating hospital. Such quality oversight would include review of acute stroke cases for timeliness of ED evaluation, appropriateness of treatment delivered, and post-ED care at the site for patients not transferred to the stroke center. A telestroke champion at the originating site should be trained in and familiar with stroke clinical protocols shared by the stroke center and revised as needed for the telestroke site. This leader should also be familiar with use of the selected technology platform and able to reliably troubleshoot technological difficulties as discussed above. This person should have a comprehensive understanding of existing referral arrangements and which stroke patients may be best served locally versus transferred to a larger regional center. Some training in and knowledge of cerebrovascular disease, acute stroke care, and telemedicine are necessary for the telestroke leadership at originating sites, and ongoing education in the form of CME requirements or attendance at national or international meetings on these subjects is desirable.

At a minimum, emergency physicians at a telestroke facility should be familiar with the processes and procedures for initiating a telestroke consult in a timely and efficient manner. The physicians should be trained in the use of the selected technology platform for communicating with the consulting partner. Physicians should also be trained in the clinical protocol for stroke evaluation established by the telestroke champions. Emergency physicians at telestroke sites should have input into the development of the clinical protocol early in the process. With these measures, the protocol would have a genuine chance of being successfully implemented and used within the workflow of the ED. Ideally, the ED medical director is intimately involved with the development of the telestroke program and may serve as a highly effective champion.

Emergency nurses at the originating hospital may be the first medical personnel to interact with an acute stroke patient. Therefore, these nurses play a crucial role in the quick recognition, triage, evaluation, and treatment of the acute stroke patients. Emergency nurses should be trained in stroke recognition and the importance of rapid evaluation and treatment for stroke outcomes. Continuing education unit credits may be obtained for NIHSS or Emergency Neurologic Life Support training for nurses, thereby fulfilling ongoing certification educational requirements while enhancing stroke training.

Training for other hospital providers will depend on the scope of the practice of the provider. Emergency medical services personnel may require training to triage possible stroke patients to hospitals with telestroke capability over those without. Advanced practice providers such as nurse practitioners and physician assistants may require training similar to the emergency physician if practicing in the ED setting or may serve as telestroke champions as discussed above regardless of whether they practice primarily in the ED or in the hospital. Advanced practice providers may also play specific roles relating to quality monitoring and chart review. Non-emergency physicians such as hospitalists and intensivists may require training related to post-ED management aspects of the clinical protocol, in addition to training on the use of the technology, depending on the involvement of the stroke center in the post-ED care of the patient at the originating site.

Suggestions for Licensing, Credentialing, and Training Requirements

1. Efforts to mitigate the administrative burden of maintaining individual state licenses are warranted for telemedicine to reach its full potential for facilitating clinical care in the United States.
2. Smaller or poorly resourced hospitals may wish to rely on the credentialing and privileging process for primary source verification performed at stroke centers with which they are partnered for telestroke services,

that is, credentialing by proxy, where allowed by law or regulation.
3. Privileges for telestroke providers and ancillary staff should incorporate completion of training standards appropriate to their level of care.
4. Clinical personnel necessary for a provider of telestroke services include, at a minimum, a stroke center physician/medical director and a dedicated program manager or administrator. A successful telestroke system of clients should include a physician and nurse champion at each telestroke partner hospital.
5. Continuing education credits specific to stroke and telemedicine, training, and education on processes and protocols for all personnel involved in telestroke systems should be recorded at both the distant and originating sites.
6. Physicians providing telestroke services should be recredentialed at regular intervals. The recredentialing process should include review of continuing education credits specific to stroke and telemedicine, any adverse events, outcomes, and peer review of ≥1 telestroke interactions.
7. Ongoing technical and clinical training specific to clinical and other key personnel is essential.

Documentation

Documentation is an essential component of any medical encounter, including those performed by telemedicine. A complete telestroke consult includes a relevant history, examination, and assessment of the appropriateness of intravenous tPA. Most commonly, the neurological examination is quantified by the NIHSS score, and documentation should include at least the total score. In some cases, a more complete recording of the scores on the individual components of the examination and additional neurological findings might be included because this would facilitate comparison with subsequent neurological examinations. Final telestroke diagnosis should be noted. When consent for intravenous tPA is obtained by the telestroke physician, that process should be recorded, including the person or people providing consent. The decision process for giving or not giving thrombolytics should be outlined, and the time of administration of the intravenous tPA bolus should be noted if known. The documentation of the encounter should be entered into the patient's chart as soon as possible to ensure that other providers involved with the patient's care are informed of the acute stroke issues. The telestroke provider should also maintain a record of all consultations. In some systems with compatible electronic medical record (EMR) systems, the information may be entered directly into the EMR and will be available to both distant and originating hospitals immediately. In other cases, the EMR at an originating site may be accessed remotely for documentation. When an EMR solution is not possible, the provider may document the consult through an originating hospital dictation system or by faxing a completed note to that hospital. In all these cases, the goal is to provide a consultation accessible to the patient's care team in a timely manner and consistent with the standards of medical documentation for in-person encounters. Some telestroke systems use software solutions that record much or all of the essential information and include the capability of generating a report that can be printed, faxed, or directly imported into an EMR.

Suggestion for Appropriate Telestroke Documentation

1. All telestroke encounters, regardless of the means of connectivity (eg, video, phone, digital data transfer), should be documented in a manner consistent with an in-person consultation and provided to the originating site to support any verbal recommendations. These actions should be executed in a manner consistent with current privacy and security regulations.

Table 1. Telestroke Measures Overlapping With Other Stroke Quality Measure Recommendations

Telestroke Quality Measure	AHA/GWTG	BAC Articles	Hospital Accrediting Bodies*
Patient characteristics on arrival after transfer	Yes	Yes	Yes
CT scan completion time	Yes	Yes	Yes
tPA treatment (eligibility, door-to-needle time, protocol adherence)	Yes	Yes	Yes
The percent of tPA in patients seen in the ED with the initial diagnosis of stroke, arriving in the ED within the 3- and 4.5-h time windows, and eligible for tPA	Yes	No	Yes
Patient disposition after telestroke consultation	Yes	Yes	Yes
Short-term patient outcomes (length of stay, symptomatic and asymptomatic ICH, in-hospital or 7-d mortality)	Yes	Yes	Yes
Functional outcome at discharge	Yes	No	No
Longer-term outcomes (90-d mRS score) for patients treated with thrombolysis	Yes	No	Yes
Quality performance should be collected in a standardized fashion and shared across the network	Yes	Yes	Yes
Certification should be conducted by an independent, external organization	Yes	Yes	Yes

AHA indicates American Heart Association; BAC, Brain Attack Coalition; CT, computed tomography; ED, emergency department; GWTG, Get With The Guidelines; ICH, intracranial hemorrhage; mRS, modified Rankin Scale; and tPA, tissue-type plasminogen activator.

*The Joint Commission, DNV Healthcare, Healthcare Facilities Accreditation Program, and Center for Improvement in Healthcare Quality.

Table 2. New Telestroke Quality Measures Without Overlap in Existing Stroke Quality Recommendations

Telestroke Quality Measure	Comments
Telestroke workflow times (consult notification, phone response, video-consult initiation, consult completion)	BAC suggests telemedicine link be established within 20 min of consult request
Quality metrics on phone and audiovisual consults	
Tracking transfers between facilities (time of arrival and departure at originating site and arrival at receiving facility)	AHA/ASA policy and HFAP recommend only tracking the median facility-to-facility transfer times
Telestroke consultant preliminary diagnosis and final discharge diagnosis	GWTG only tracks patients with discharge diagnosis of stroke; this recommendation extends the collection of diagnosis to all patients seen as a telestroke consult, whether stroke or not
Patient satisfaction with the telestroke consult	
Provider feedback on network operation	
Monitoring of technical failures/ limitations during consults, including the frequency that technical issues affect patient care (for both ED-based and EMS-based systems)	Although this is new, as it applies solely to telestroke systems, it is in the spirit of general hospital quality monitoring
Investigation of any telestroke security breaches	Although this is new, as it applies solely to telestroke systems, it is in the spirit of general hospital quality monitoring
Quality monitoring of CT image quality, technical failures, operational failures, or workflow issues should be recorded and regularly reviewed, along with other technology quality measures	Although this is new, as it applies solely to telestroke systems, it is in the spirit of general hospital quality monitoring
The responsibility for collecting quality data should be a component of the agreement between telestroke sites and either a coordinating stroke center or distributed partner	Although this is new, as it applies solely to telestroke systems, it is in the spirit of general hospital quality monitoring

AHA indicates American Heart Association; ASA, American Stroke Association; BAC, Brain Attack Coalition; CT, computed tomography; ED, emergency department; EMS, emergency medical services; GWTG, Get With The Guidelines; and HFAP, Healthcare Facilities Accreditation Program.

Conclusion and Summary

Telestroke is a new approach to bringing expert stroke care to remote locations with limited or no neurological expertise. Although evidence supporting the equivalence of telestroke to in-person care is accumulating, the limits of medical care provided remotely by telemedicine remain to be defined. Ongoing monitoring of quality becomes increasingly important, given the relatively limited experience with stroke care in this environment. Data collected not only serve to ensure that patients receive optimal care but also provide a vehicle for continuous improvement in processes that lead to enhanced outcomes. Time is of the essence in treating acute stroke patients, and telestroke systems must ensure that technology does not introduce time delays that could reduce the probability of recovery after acute stroke therapy. Both the stroke center and the originating site must work together to institute appropriate protocols to ensure that eligible patients are identified, evaluated, and treated expeditiously. Adverse outcomes such as intracranial hemorrhage and mortality must be accurately monitored to assess safety. Screening of patients for endovascular therapy and transferring patients who might benefit from this therapy are now additional goals of telestroke networks, given the large treatment effects of endovascular therapy in recent randomized trials.[168] Ultimately, it is patient outcomes that are most important to the success of any medical treatment. Telestroke networks should monitor traditional stroke outcomes such as disability scales and patient-centered outcomes such as satisfaction and experience.

It is not our intention to add unnecessary burdens to telestroke networks and providers by suggesting quality and outcomes measurements. Quality reporting is currently a component of recommendations for stroke center certification and registries such as Get With The Guidelines. Tables 1 and 2 summarize the overlap between our suggestions for quality and outcomes measurements and those of other organizations. Modifications to existing reports and some additions may be necessary; however, the importance of delivering quality care by telemedicine outweighs these considerations.

Although the goal of telestroke at present is to achieve equivalence with in-person care, there is an opportunity to go further and perhaps improve stroke care through the application of this technology. Even in places with available stroke expertise, telestroke might provide additional speed or quality aids that increase protocol adherence and further improve outcomes. It is hoped that these suggestions serve as a foundation for ongoing improvement of telestroke networks and increasing quality across all providers.

Disclosures

Writing Group Disclosures

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*Modest.

†Significant.

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