Telestroke 10 Years Later – ‘Telestroke 2.0’

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Key Words

Acute stroke • Electronic medical record • Ischemic stroke • Recombinant tissue-plasminogen activator • Stroke training • Telestroke

Abstract

Background: The lack of physicians with specialty stroke training represents a significant challenge to the future of stroke. This deficit limits both quality stroke care and clinical research initiatives. **Methods:** The use of telemedicine for stroke (‘telestroke’) has been an attempt to overcome this shortage and extend stroke expertise to locations which lack coverage. However, the initial telestroke systems required a point-to-point connection for transmission and only provided videoconferencing which limited their generalizability and usefulness. ‘Telestroke 2.0’ is the authors’ vision of an integrative web-based telestroke system combining high-quality audiovideo transmission, the ability of consults and teleradiology to be carried out from any desktop or laptop computer with web-access, decision and technical support, creation of billable physician documentation and electronic medical record connectivity. **Results:** These features will facilitate the development of statewide and regional telestroke call networks with an opportunity for physician supply companies to fill in coverage gaps. In addition, telestroke 2.0 may improve acute stroke research by increasing trial efficiency via the addition of non-academic recruitment sites, enhancing trial validity by centralizing neurologic examinations via recorded encounters, and generalizing clinical trial results to community hospital settings. **Conclusions:** Greater diffu-

sion and long-term sustainability of telestroke systems will be dependent upon improvements in patient and hospital reimbursement for acute stroke and telestroke care.

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Introduction

Despite stroke being a leading cause of death and disability [1, 2], currently, the barriers to optimal stroke treatment are imposing. Since June 1996, intravenous (IV) recombinant tissue-plasminogen activator (rt-PA) remains the only FDA-approved pharmacologic therapy which reduces disability in acute ischemic stroke [3]. However, in spite of its established efficacy, utilization of IV rt-PA remains quite low in the United States, probably on the order of 2% of all ischemic stroke patients [4]. With limited exceptions, in rural and community hospital settings, the percentage of ischemic stroke patients treated with IV rt-PA is negligible. Obstacles to increased IV rt-PA use have been reviewed and no doubt include delays to presentation among stroke patients, *disproportionate* fear among some emergency department (ED) physicians and neurologists of hemorrhage and the potential litigation that a complication might ensue, misunderstanding and miseducation of the magnitude of the benefits and risks of the treatment, and minimal physician reimbursement for rt-PA administration [5]. Public education is still inadequate for many Americans to understand that stroke is an emergency and their need to call 911 is immediate. In addition, the recent negative results of phase

III clinical trials (SAINT II, DIAS II and FAST) in acute stroke mean that the immediate pipeline for complementary or additional pharmacologic treatments for acute stroke appears relatively dry [6–8].

Cerebrovascular Expertise: The Deficit in Stroke Specialists

Compounding these challenges is a tremendous shortage of physicians specializing in acute stroke management. Stroke care in the US has traditionally been the domain of neurologists, and stroke care by neurologists (contrasted with internists, family medicine physicians or other specialties) is associated with better outcomes [9, 10]. However, the number of neurologists currently involved in acute stroke management is likely insufficient to address both the present and growing burden of stroke in an aging population [11]. In fact, as few as 6% of all Medicare fee-for-service beneficiaries hospitalized for stroke in 2002 had a neurologist designated as their primary treating physician [12]. Many (if not most) of the hospitals in which neurologists were the primary physicians assigned to their care were likely at institutions with neurology residency training programs, with far fewer neurologists in the community setting involved with inpatient stroke care. Hospitalists, generally trained only in internal medicine, are increasingly taking over inpatient stroke care as many neurologists move to office-based practices and are withdrawing from ED call coverage. One in five hospitals in Oregon and California have expressed difficulty in maintaining neurologist backup for the ED, with the proportion of uncovered hospitals probably greatest in rural or community settings [13–15].

In 2005, the American Board of Psychiatry and Neurology began certification of a new neurology subspecialty, vascular neurology. However, as of December 31, 2007, only 379 vascular neurologists have been certified by the American Board of Psychiatry and Neurology [16]. With the ‘grandfathering period’ for applications ending in 2009, future vascular neurologists will be required to have completed a fellowship approved by the Accreditation Council for Graduate Medical Education. While over thirty current such programs exist, in the 2006–2007 academic year, only 32 positions were filled by fellows in accredited programs suggesting continued slow growth within this subspecialty [17]. For the sake of comparison, there were 2,300 fellows in cardiovascular disease fellowships during the same year and roughly 6,500 interventional cardiologists in practice as of 2000 [17, 18].

This dearth in stroke specialists has no doubt hampered clinical trial efficiency as well. In a meta-analysis performed by Elkins et al. [19] of 32 large acute ischemic stroke trials published since 1990, the average recruitment efficiency of individual centers in these trials was only 0.79 subjects enrolled per month, and only 0.57 in North American centers. Although some improvement in acute stroke trial efficiency may result from changes in trial design (e.g. inclusion/exclusion criteria, outcome measures and statistical analysis) [20, 21], the lack of qualified, trained clinical stroke investigators and sites for recruitment are also significant and not so easily fixed. Perhaps as a result of the lack of stroke specialists in community hospitals, the majority of acute stroke clinical trials have been conducted at a limited number of academic medical centers. However, this generally restricts clinical trial enrollment to those who present directly to these institutions, narrowing the potential pool of subjects. For patients who initially present to community hospitals, the time required for transportation to enrolling centers precludes most from participation in clinical trials. Consequently, patients in rural communities in particular are excluded from enrollment into acute clinical trials. EDs in these areas have more limited resources in terms of personnel, experience and equipment. As a result, some may question whether trials conducted in academic centers alone could be replicated in the community ED, limiting the ‘generalizability’ of their findings. This likely restricts implementation of acute stroke therapies in these settings, mimicking what has been seen with the utilization patterns of IV rt-PA [22].

With these issues in mind, perhaps the central challenges facing the field of acute stroke treatment are how to improve the quality of stroke care in the community and how to increase the efficiency of acute stroke clinical trials despite the lack of sufficiently trained (credentialed) experts. A mechanism is needed to extend our limited stroke expertise that typically resides in tertiary academic medical centers out into rural, suburban and even underserved urban areas.

‘Telestroke’

In 1999, Levine and Gorman [23] coined the term ‘telestroke’ to illustrate the application of video telecommunications to facilitate consultations by stroke specialists remote from stroke patients. Within a relatively short period of time, telestroke has become routine in numer-

Table 1. Commercial telestroke systems

Technology	Commercial website
BF Technologies	http://www.bf-technologies.com
InTouch Health	http://www.intouchhealth.com/products_rp7robot.html
Partners TeleStroke	http://telestroke.massgeneral.org/default.aspx
Polycom	http://www.polycom.com/usa/en/solutions/industry_solutions/healthcare/tele_medicine.html
REACH Call	http://www.reachcall.com
Specialists On Call	http://www.specialistsoncall.com
Tandberg	http://www.tandberg.com

ous settings, both rural and urban, throughout the US and Europe [24–29] (table 1). Concomitant with the extension of telestroke into clinical practice, evidence has accumulated regarding the reliability of the National Institutes of Health Stroke Scale (NIHSS) scoring using these systems [27, 30–32], as well as the safety, feasibility, and speed of telemedicine-guided thrombolysis [33–35]. Meyer et al. [36] have recently demonstrated that acute stroke decision-making for patients in a remote ED (including the decision whether or not to administer IV rt-PA) is superior using telemedicine when compared with telephone alone.

‘Telestroke 1.0’

The initial application of telemedicine for stroke, including many systems still used today, were point-to-point models requiring consultants to travel to a designated workstation to perform the consultation [24, 26, 28, 29]. While providing high-quality two-way audiovideo conferencing [plus or minus the additional transmission of Digital Imaging and Communications in Medicine for computerized tomography (CT) analysis] along dedicated ISDN lines, these systems have many limitations which restricted their broader implementation and appeal. First, a fixed workstation located within or near hospital confines means consultations must either be limited to working hours, force consultants to remain close to the workstation around the clock, or require the consultant to travel to the hospital to perform consults after hours. This is impractical in many environments. Most neurology groups, even those in academics, lack the manpower to have a trained physician in the hospital at all times. In addition, fixed workstations hinder group call networks in which specialists from different locations (within the same state, region, country or even internationally) pro-

Table 2. Core elements of TeleStroke 2.0

High-quality audiovideo
Neuroimaging integration
Mobility (site independence)
Decision support
Technical support
Consulting stroke physician note
EMR integration
Regional on-call networks

vide coverage for individual hospitals. Finally, traveling to the workstation will result in delays in treatment time that diminish the likelihood of a favorable outcome negating the intent of the system [37]. Many of these ‘1.0’ systems provide only videoconferencing and lack many other desirable elements as well, including decision support, delivery of billable documentation, integration with hospital medical records, and data collection and analysis for quality assurance and research purposes.

‘Telestroke 2.0’ – One Potential Solution to Alleviate the Shortage of Vascular Neurologists

The ideal telestroke system incorporates the high-quality, real-time, audiovideo of point-to-point teleconferencing systems with the mobility, decision and technical support features, electronic medical record (EMR) integration, billing documentation and other features that can best be implemented across the World Wide Web (WWW). We have called this unifying concept ‘Telestroke 2.0’ to reflect the assimilation of web-based technology with telestroke. The core elements of Telestroke 2.0 are detailed below (table 2).

High-Quality Audiovideo

The strength of point-to-point telestroke systems has been high-quality audiovideo using high-definition cameras and proprietary codec systems conducted across dedicated lines. More recently, these systems have allowed for viewing of remote sites through personal computers after a required download of a software application containing the necessary codec and transmission interfaces. The video conferencing capabilities of the Telestroke 2.0 would leverage a high-resolution IP camera that is accessible over the public Internet using a secure protocol such as secure HTTPS. This camera would enable the consulting physician to use controls embedded within a web page to pan, tilt, zoom and focus the camera so as to get a complete view of the patient as well as the surrounding bedside area in the spoke hospital. In order to support the video stream from this IP camera in the spoke hospital, a broadband Internet connection with at least 768 kbps upstream speed may be necessary. This bandwidth requirement allows the video to be smooth and uninterrupted. Higher speed connections of at least 1.3 Mbps may be required for high-definition video. Choppy or interrupted video, caused by delayed or lost video packets, can mislead the physician with respect to the neurologic disability of the patient. In order to view this video stream from the IP camera of the spoke hospital, physicians will require a similar broadband connection from their personal computer.

Additional audiovideo features should include the capacity to record and store consultations (with consent from patient and local staff). Video recordings could be used clinically (to document baseline deficits prior to treatment), for education, quality assurance, clinical trials (see Clinical Research using Telestroke 2.0 below) and to support billing documentation.

Mobility

Perhaps the most crucial advantage of web-based stroke care over traditional point-to-point telestroke systems is the ability of consults to be conducted from anywhere at anytime so long as the consultant has access to the WWW. This facilitates the flexibility of the stroke specialist to take consults from the hospital, office, home or even when he or she is out of town. Response to the consultation is accelerated, overcoming the delays inherent in having to travel either to the bedside or to a workstation, with the potential for shorter onset-to-treatment times for rt-PA administration. Web-based, mobile systems of telestroke have been shown to be feasible and to shorten overall treatment time [34].

Regional Coverage Networks

Implementation of WWW-based telestroke technology will facilitate the development of regional on-call networks to supply coverage in underserved areas. Physician supply companies could provide stroke specialty consultations with consultants located from within or outside the state as long as local licensure issues were handled and are now occurring [38]. Other models of telemedicine have already confronted these potential roadblocks. In fact, teleradiologists with NightHawk, the largest teleradiology firm, have licenses in an average of 38 states and privileges in 400 hospitals [39].

Decision Support

Moving beyond a simple two-way audiovideo link, Telestroke 2.0 systems should supplement the consultant and spoke hospitals with decision support capabilities. From the perspective of the stroke specialist, the web page should facilitate decision-making regarding the administration of IV rt-PA by providing a picture-archiving and communication system for CT viewing, real-time patient information including blood pressure and other vital signs and laboratory results, access to current stroke guidelines as well as interactivity, allowing the consultant to easily input data including NIHSS through dropdown menus without having to reload each screen (for example using Asynchronous JavaScript and XML (Ajax) [40]). Further, stroke diagnostic algorithms and prevention education strategies can be integrated into the encounter. From the spoke perspective, the decision to administer IV rt-PA should result in a printout of directions for dosing and administering thrombolytic therapy based on the individual patient's weight as well as post-tPA orders for neurological monitoring, and blood pressure control.

Physician Note

The final result of any web-based stroke consultation should be a 'billable' physician note which includes the required history, exam, review of radiology and laboratory data and medical decision-making components. To promote ease of note construction by the consultant, a basic template can be designed extracting patient demographics supplied by the ED staff and complemented by data (e.g. key historical elements, NIHSS, diagnosis, and decision in favor of or against rt-PA) entered by the consultant on web page utilizing Ajax design techniques. Voice recognition software may be interwoven to facilitate note construction.

Integrated EMR

Web-based connectivity with the patient's EMR will enhance the utility of the remote consultation. Ideally, such interoperability between the stroke specialist and community hospital EMR will be bidirectional; the consultant will have access to prior notes and imaging, for example, from the local hospital to enhance medical decision-making and the consultation note will be directly inserted into the EMR of the community hospital. There is a national push to implement health information technologies [41], and the development of international standards (HL7) for interfacing and exchanging electronic health information should facilitate translation of patient records between Telestroke 2.0 systems and local hospital networks. As opposed to the previously listed '2.0' elements which are readily available using current technologies, telestroke integration with EMR may still be several years away.

Clinical Research Using Telestroke 2.0

Telestroke 2.0 may be useful to modernize the quality and efficiency of acute stroke clinical trials. Web-based telestroke systems would allow the relatively small number of acute stroke researchers access to a larger pool of potential study candidates, to include both those who present to their institution, as well as to those who initially arrive at smaller secondary hospitals. This could ameliorate the enrolling inefficiency of individual investigators and centers and allow for inclusion of subjects who would have otherwise not been eligible. Also, incorporation of small centers into trial design could improve generalization of trial results and hasten the translation from study drug to standard clinical practice of beneficial treatments in these more community-based settings. A system of tertiary hospital enrolling center 'hubs' and secondary rural, selected urban, or community hospital 'spokes' is now feasible. Based on clinical and research capabilities for acute stroke trials, we propose that hospitals could be divided into four types (table 3).

Web-based audiovisual recording of the baseline and follow-up encounters could be used for centralized analysis of the NIHSS and other neurological scales similar to the routinely employed central analysis used for neuroimaging in stroke clinical trials. Although the interobserver reliability of the NIHSS *in person* is generally very good, certain elements of the exam (ataxia, dysarthria, facial weakness, and level of consciousness) demonstrate lower interclass correlation coefficients [42, 43]. The use

Table 3. Classification scheme for Telestroke 2.0 based clinical trial recruitment

Type 1

Identify and Ship. It is anticipated that the very small EDs, with total ED volumes of less than 10,000 patients per year and stroke volumes of less than 50 patients per year will be low yield for trial recruitment. In addition, these institutions will likely have a limited pharmacy capacity to administer novel agents. As a result, it may be determined that these institutions would not be included in acute trial research. Alternatively, if telemedicine can be carried out at low cost and these hospitals are relatively proximate to an enrolling center (Type 4, see below) they may at most be capable of identifying a potential candidate and transfer to the tertiary center in time for inclusion.

Type 2

Identify, Enroll, Randomize, Drug Administration, and Ship. Slightly larger institutions, with ED volumes above 10,000 annually, with more developed and 24 h/day pharmacies may be capable of enrollment of study patients within their own ED. Following study drug administration these patients will be transferred to the enrolling center for inpatient care.

Type 3

Identify, Enroll, Randomize, Drug Administration, and Keep. Hospitals with greater than 100 beds, ED volumes of greater than 30,000, with neurologists on staff, and more advanced monitoring capabilities (intensive care units) will be able to conduct all critical phases of an acute stroke trial. These patients will not require transfer to a tertiary center; however, a study nurse may be needed to travel to these sites to ensure documentation of study components.

Type 4

Tertiary Stroke Center. These hospitals would be the main telestroke trial hub for a rural or community network. Stroke trial experts in these institutions could orchestrate subject identification from Type 1 centers, and trial enrollment at Type 2 and 3 centers. In addition, patients presenting directly to these hospitals could be enrolled using traditional, 'non-telemedicine' means.

of a centralized server with videorecordings of subjects' exams with a small number of vascular neurologists to assess all baseline and outcome NIHSS would reduce interobserver variability and could result in greater reliability across all exam items.

Although the NIHSS performed via telemedicine correlates with bedside evaluation, other components required for telestroke-mediated clinical trials have not been validated. For example, key process measures (onset to enrollment time, informed consent, serum biomarker collection, study drug administration, and long-term follow-up) and outcomes (neurologic deterioration at 24 h) in acute stroke clinical trials need to be compared be-

tween telestroke and in-person to determine feasibility and reliability of data and documentation and to establish safety. In addition, the adequacy of a remote informed consent (via telemedicine) has not been tested. Also, 90-day follow-up visits for patients enrolled at rural hospitals and transferred to the hub may be difficult to obtain after the subject has returned home unless the evaluation can also be conducted via telemedicine. Finally, many small and rural hospitals do not have an institutional review board in place. In this situation, hospitals may defer to the hub's institutional review board or contract with a commercial institutional review board.

Where Do We Go from Here? Obstacles to Telestroke 2.0

The greatest impediment to further diffusion of web-based stroke care is its financial sustainability independent of grant support. Recognized within the stroke community has been the increase in hospital reimbursement for acute ischemic stroke with thrombolysis initially under DRG 559 and now using the Medicare Severity-DRG 061. These codes were introduced by the Centers for Medicare and Medicaid Services (CMS) to reflect the greater resource allocation and immediate hospital costs (including but beyond rt-PA alone) required for care of this patient population. However, for patients treated with thrombolysis for acute stroke in a remote ED prior to transfer to a stroke center, CMS precludes the use of these higher reimbursing codes. The American Academy of Neurology is currently lobbying CMS to correct this oversight and extend the reimbursement afforded to patients who receive IV rt-PA at the admitting institution to those who are treated via 'drip and ship'. In response, beginning in October, 2008, CMS is adding a new ICD-9 'v' code to track the number of patients for whom rt-PA is administered at one hospital and then transferred to a second institution. Depending on the frequency of use of the 'v' code over the next year, CMS will determine what changes to the current DRG codes are warranted [44]. A reimbursement scheme for these 'drip-and-ship' patients would properly proportion payments between the community hospital and stroke center to incentivize rt-PA use for appropriate remotely identified candidates via telestroke.

However, independent of increased hospital reimbursement for acute stroke patients treated with thrombolysis, web-based stroke consultations can be profitable for the 'hub' [45]. Although rural patient populations

may have an unfavorable payer mix, profitability may result from creation of a feeder system that includes all payers and transfer of other cerebrovascular diagnoses besides ischemic stroke (i.e. subarachnoid hemorrhage) which may require an intervention. In addition, ischemic stroke patients initially treated with rt-PA over the web, can be transferred to the hub in time for an additional endovascular reperfusion strategy if recanalization has not been successful, further improving 'hub' compensation.

Current Medicare policy already permits physician reimbursement for remote telehealth services including consultations for acute stroke therapy. A real-time, face-to-face interaction is required which is provided via a two-way audiovideo system across the Internet. One limitation of reimbursement is that the facility originating the consultation cannot be located in a metropolitan statistical area defined by the US Census as an urban area containing a population of 50,000 or greater. Unfortunately, as stated previously, many urban areas are as equally underserved with neurologists involved in acute stroke care as rural counties. Extension of telemedicine reimbursement to these settings could potentially boost on-call coverage. Insufficient reimbursement for acute stroke consultations (including those that result in thrombolysis) has been cited as a factor in low utilization of rt-PA in the community [5]. To augment physician reimbursement, the use of critical care coding is advocated by the American Academy of Neurology [46], and as of July 1, 2008, the American Medical Association has approved two new Category III CPT codes (0188T and 0189T) for the reporting of remote physician critical care services via telemedicine [47]. Category III codes are used to collect data for validation of widespread use. In addition, on-call stipends may be necessary to supplement the reimbursement obtained using CPT codes alone. The increased 'hub' revenue from web-based stroke care might provide a financial source to fund on-call stipends for Telestroke 2.0 consultants.

Conclusion

There is an impending crisis of physician shortage for acute stroke care. Few stroke patients are evaluated by vascular or general neurologists, resulting in low treatment rates with rt-PA, suboptimal care and slow clinical trial recruitment. Telestroke is one mechanism to expand stroke expertise from tertiary centers to hospitals with inadequate coverage. Many telestroke systems have lever-

aged fixed-line communications using ISDN or similar technologies to allow physicians to interact with patients using sophisticated but proprietary audiovisual communication equipment. Physicians can review CT scans and interact with patients and caregivers in remote EDs. However, the need to use specific workstations from which to conduct consults (i.e. point-to-point systems) has proved to be a barrier to the rapid adoption of telestroke systems in general.

The evolution of the Web 2.0 computing paradigm has enabled the possibility of a 100% web-based stroke care. Web 2.0 permits the creation of rich Internet applications with data, audio, video and graphical components which provide for an easy-to-use, optimized interface for complex applications such as telestroke. For example, Google™ and Salesforce.com™ leveraged Web 2.0 based technologies and platforms to remove the need for desktop-based software and allowed users to access information stored on servers that physically reside in the Internet 'cloud' [48]. The convergence of telestroke and Web 2.0 enables a 100% web-based application for telestroke, which we have called Telestroke 2.0. With Telestroke 2.0, neurologists can use any computer anywhere in the world

with a broadband Internet connection for the secure remote evaluation of stroke patients. Telestroke 2.0 maintains HIPPA compliance while integrating decision support algorithms with real-time synchronized two-way audiovideo, CT scan review capabilities and complete, on-demand documentation of consults for real-time submission for billing and reimbursement. In addition, the timely placement of data into hospital, state, regional or national databases (e.g. American Stroke Associations' Get with the Guidelines) would be facilitated. Similar, Telestroke 2.0 could accelerate the recruitment and performance of clinical trials and allow for centralized neurologic assessment by recording enrollment and subsequent exams to eliminate interobserver variability.

Financial sustainability remains the most significant barrier to the implementation of this next generation of telestroke. However, future CMS approval of higher reimbursement for the 'drip-and-ship' treatment paradigm, extension of physician reimbursement by Medicare to non-metropolitan statistical areas, and incorporation of endovascular reperfusion therapies by the hub hospital may work together to overcome this obstacle.

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