Background—Time is of the essence for effective intervention in acute ischemic stroke. Efforts including stroke teams that are “on call” around-the-clock are emerging to reduce the time from emergency room arrival to evaluation and treatment.

Summary of Comment—Based on the results of the NINDS rt-PA Stroke Trial, which demonstrated both clinical effectiveness in reducing neurological deficits and disability and cost savings to health care systems, many community hospitals and managed-care organizations are exploring methods to enhance and expedite acute stroke care in their local communities. Only a small fraction of acute stroke victims is currently treated with thrombolytics (<1.5% nationally), and few benefit from the expertise and experience of the stroke teams. It is essential to develop new paradigms to improve acute stroke care in all settings, rural and urban. Rapid linkages to expert stroke care can help the underserved areas. Telemedicine for stroke, “Telestroke,” uses state-of-the-art video telecommunications that may be a potential solution and may maximize the number of patients given effective acute stroke treatment across the country and across the world. Telestroke could facilitate remote cerebrovascular specialty consults from virtually any location within minutes of attempted contact, adding greater expertise to the care of any individual patient. This model also has the potential to enhance patient entry into clinical trials. Telestroke would enhance stroke education through the creation of telecommunication-linked classes providing interactive information on stroke care and prevention to places where they are otherwise not available. Health-care professionals will gain experience and expertise through the interaction with a remote expert—telementoring. Telestroke provides an excellent medium for data collection and an unprecedented opportunity for quality assurance. Monitoring of an entire tele-interaction can offer real-time assessments, which can then be analyzed in-depth at a later date for unique insights into health-care delivery. Prehospital use of telemedicine for stroke is already being piloted, linking patients in the ambulance to the emergency department. Legal and economic parameters must be established for telemedicine in the areas of reimbursement, liability, malpractice insurance, licensing, and credentialing. Issues of protection of privacy and confidentiality, informed consent, product liability, and industry standards must be addressed to facilitate the use of this new and potentially useful technology.

Conclusions—Computer-based technology can now be used to integrate electronic medical information, clinical assessment tools, neuroradiology, laboratory data, and clinical pathways to bring state-of-the-art expert stroke care to underserved areas. (Stroke. 1999;30:464-469.)

Key Words: telemedicine ■ stroke, acute ■ stroke, ischemic ■ thrombolytic therapy ■ stroke management

Time is brain1 carries a new meaning and imperative with the advent of a clinically effective treatment protocol for acute ischemic stroke.2 The use of rtPA, as approved by the Food and Drug Administration (FDA), currently requires a very narrow time window of only 3 hours.3 More than 16 000 acute stroke patients were screened for the NINDS rt-PA Stroke Trial, and approximately 50% of these patients arrived too late to be treated.4 Within the 8 clinical centers participating in the NINDS rt-PA Stroke Trial, labor-intensive stroke teams provided around-the-clock coverage. These teams provide local care in their immediate region. How can more acute stroke patients benefit from the expertise and experience of these stroke teams?5 How can we improve on the common acute stroke care scenarios (Figure 1A)?

Based on the results of the NINDS rt-PA Stroke Trial,2 many health-care systems are exploring ways to enhance and expedite acute stroke care in their local communities. Rapid linkages to experts will be needed in areas served by physicians not schooled in acute stroke management. Reverse gatekeeping in a managed-care environment to allow complete access to stroke experts early in the course of an acute
A stroke may prove to be an effective model for stroke care on a national basis. It is time to consider using state-of-the-art video telecommunication technology to maximize the number of patients given effective acute stroke treatment across the United States (and eventually in other underserved countries). Telemedicine for stroke, "Telestroke," is currently unproven but holds promise as a technology intensive, rather than manpower-intensive, method of providing rapid acute stroke expertise to local hospitals with available head CT scanning (Table 1). Telestroke could allow consultation with remote cerebrovascular specialists from virtually any location within minutes of attempted contact, enhancing the care of any individual patient. It may also be used to train emergency room physicians as they treat the patient. This model also has the potential to enhance patient entry into clinical trials.

Current video telecommunication technology could complement the slow but necessary process of training stroke specialists and other physicians to become competent and experienced in the use of rtPA for stroke and aid in the more general management of the acute stroke patient. One could envision regional stroke centers as hubs providing service to hospitals/health systems/health maintenance organizations (HMOs)/individual patients via telemedicine, analogous to other medical specialties. Telestroke and telemedicine, in general, offers managed-care organizations a method to centralize medical specialists and may allow academic integrated health systems and universities an opportunity to develop new regional, national, and even international access to patients in need of such care.6

Current video telecommunication technology could complement the slow but necessary process of training stroke specialists and other physicians to become competent and experienced in the use of rtPA for stroke and aid in the more general management of the acute stroke patient. One could envision regional stroke centers as hubs providing service to hospitals/health systems/health maintenance organizations (HMOs)/individual patients via telemedicine, analogous to other medical specialties. Telestroke and telemedicine, in general, offers managed-care organizations a method to centralize medical specialists and may allow academic integrated health systems and universities an opportunity to develop new regional, national, and even international access to patients in need of such care.6

Envision a "stat" page that establishes a video-telecommunication link connecting the stroke physician on call to the local emergency room (ER). This technical link provides capabilities for assisting the local ER physician to perform a standardized stroke scale, such as the National Institutes of Health Stroke Scale (NIHSS),18 to review inclusion/exclusion criteria,19,20 to obtain and interpret a stat head CT scan (teleradiology),18 to review laboratory studies, and to discuss the risk/benefits with patient/family/local physicians. Medications could then be dosed per protocol, care monitored,21 and cardinal signs discussed, thereby identifying potential changes in neurological status quickly. Protocols would be reviewed and discussed. The stroke team would be available at any time subsequently for follow-up questions or discussions. Care of acute stroke patients, not just patients eligible for thrombolytic therapy, could be enhanced by remote physicians with stroke expertise.

### Table 1. The Promise and Potential of Telemedicine for Stroke

<table>
<thead>
<tr>
<th>Potential Benefit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Remote &quot;stat&quot; expert stroke diagnosis</td>
</tr>
<tr>
<td>Secondary prevention (expert decisions on stroke prevention and risk assessment)</td>
</tr>
<tr>
<td>Opportunity to offer clinical trial participation to patients in remote sites</td>
</tr>
<tr>
<td>Immediate &quot;remote&quot; surgical opinions</td>
</tr>
<tr>
<td>Greater number of patients treated acutely with or without rtPA/other potential interventions</td>
</tr>
<tr>
<td>Greater number of patients receiving &quot;expert&quot; stroke outpatient/inpatient consultations</td>
</tr>
<tr>
<td>Greater number of patients enrolled in promising acute stroke therapies</td>
</tr>
</tbody>
</table>

---

**A.** Patient seen by ER physician. History, Exam, EKG, laboratories, other studies. CT ordered. Admitted. Neurology consult next day. (No acute interventional treatment plan.) Generally unable to provide 60-minute "door-to-needle" time. Hospitals map acute stroke care pathways and flow charts, identify a Stroke Team and leader.

**B.** EMS or triage nurse identifies acute stroke victim and notifies ER physician. Future potential to perform and transmit acute CT, echocardiogram, carotid doppler to identify mechanisms subtype.

**C.** ER physician dictates pertinent history and performs brief physical exam confirming acute stroke.

**D.** ECG, lab, studies. CT notified and patient transported to scanner.

**E.** Telestroke system activated and on-line connection established leading to 2-way viewing between patient, local physician, patient’s family, and stroke “expert” at a remote site from the patient.

- Risk/benefit discussed. CT/labs reviewed.
- rt-PA given if appropriate/viable acute management decided.
- Monitored care plan set up.
- On-line connections ended.
- Patient treated locally in consultation and collaboration with stroke “expert” remote from the patient.

Further details of the actual protocol to be carried out can be found in references 5 and 6.

---

1 On call beeper/cell phone access to regional stroke "hub" (center).

---

A common acute stroke scenario. **B.** Possible "Telestroke" scenario. Schematic views of hardware needed for Telestroke (C, D, and E). **C.** Acute stroke patient in ER with treating physician. Video camera captures care, and computer screen can be turned on to view remote "stroke expert." **D.** Acute stroke patient in CT scanner with images to be transmitted to remote "stroke expert" (teleradiology). **E.** Remote "stroke expert" views patient and physician at treatment site and head CT films on computer screen with interactive software and video telecommunication.
This acute care strategy in regions without on-site acute stroke coverage would supplement rather than compete with local physicians. Local physician management for further diagnostic refinement and subsequent care and decision making would continue. (This strategy would facilitate working toward complementary services, not competing care.) This concept would be consistent with the spirit of the National Stroke Association Stroke Center Network recommendations.22 Such stroke center network initiatives could use Telestroke as part of their “state-of-the-art” initiatives for connection to local and regionally affiliated hospitals.

**Historical Aspects of Telemedicine and Its Potential Problems**

Interactive video telemedicine began approximately 40 years ago with initial applications to psychiatry23 and radiology.24 Despite the involvement of national agencies, the subsequent decades saw a general lack of sustainability of many pilot telemedicine projects beyond the funding phase, due in part to programs failing to become financially independent and profitable. A regrowth of telemedicine programs has occurred in the past 10 years. Evolving economic and political issues in health care have contributed to the growth. New medical applications (remote telepsychiatry, teleradiology for x-ray, CT, and MRI) and technologies such as digitized and compressed data, narrow bandwidth information transfer, better industry standards, and desktop units have driven the growth of telemedicine.7 There has been approximately a 2- to 3-fold increase annually in the number of video telemedicine consults in the United States since 1994.

**Telemedicine Progress To Date**

Recently, the University of Iowa has received funding from the National Library of Medicine to develop telemedicine for stroke in rural areas of Iowa.25 Several states have been awarded grants by the Department of Health and Human Services (HHS) for several different rural pilot telemedicine projects. In the past federal grants have tended to encourage the use of low-cost technologies such as telephones, fax machines, and existing telephone lines as opposed to privately funded projects, which may shoot for high-end cutting-edge technologies. Medicare has already established a reimbursement fee schedule for teleradiology. The government’s Health Care Financing Administration is studying pilot programs using telemedicine in 5 states to determine if they should reimburse for these services.26 California State Bill 1665 mandated a telemedicine reimbursement fee schedule to be in place in 1997.27 Almost one third of 2472 rural hospitals surveyed have initiated expansion of telemedicine services to provide specialty health care services. Approximately 15% to 25% of Americans live in underserved or nonurban areas,28 and less than 5% of the population of the state of New Mexico could get to a facility in time for thrombolytic therapy for acute ischemic stroke (according to American Medical Association Press Conference on Stroke, New York City, January 30, 1997). However, 5 factors were identified that may limit the use of telemedicine: high costs, current lack of reimbursement by insurers, lack of clinical standards, scheduling difficulties, and time limitations.

A recent review of prospective controlled clinical trials involving distant medical technology (including telephone contacts and consults) concluded that electronic communication with patients enables greater continuity of care by improving access between physicians and patients, in areas of preventive care, and in the monitoring of several chronic conditions.29 Relevant to stroke, beneficial effects in controlling several risk factors (diabetes, cigarette smoking, and hyperlipidemia) were also demonstrated.

To be able to reimburse for telemedicine clinically, such as for an acute stroke consultation to a remote “stroke expert” (who will help decide whether thrombolytic therapy should or should not be given), we should see “medical necessity” as a consideration governing federal payment schedules and state legislative initiatives. There are already payment mechanisms in place for ECG, radiology, and pathology slides. This could be used as a template by third-party payers in establishing a schedule for interactive television and case conference, for example. Administration, medical education and training, research, medical record compilation and access (including pharmacy), scheduling of services, telephone calls, faxes, and e-mails may not be covered. There may be payment for mobile units and selected physical examinations (including standardized stroke scales and functional stroke scales)30–32 in the future. Telemedicine for stroke provides an exciting opportunity to carry out the clinical mission of stroke clinicians.33 A pilot study of telemedicine for patients with Parkinson’s disease has demonstrated dependable and valid assessment of motor function in these patients34,35 with Spearman ρ correlation coefficients on 2 standardized scales r>0.88 (P<0.001). Patients also viewed this technology as accessing better health care.

Legal barriers must be addressed in the arenas of reimbursement, liability and malpractice insurance, licensure, credentialing, and technological product liability and standards.36 Precautions should be considered so that telemedicine does not promote misuse or piracy or violate confidentiality of the medical record or privacy laws. The Center for Telemedicine Law Licensure Task Force has recommended examination of strategies to adopt uniform standards and administrative requirements for licensure and local responsibility for quality assurance.

Interstate licensure is another issue to be addressed if Telestroke care is to be provided across state lines.37 Several states have already adopted legislation that has required out-of-state physicians to obtain a license within the state in which the patient is being treated through telemedicine. In general, strict restrictions have been placed on physician-to-physician consultations.

Other potential barriers that will need to be addressed38 include cost-effectiveness, possible negative patient and physician attitudes, institutional strategic plans for telemedicine including the development of successful partnerships with other health-care providers, lack of education among involved personnel, and need to demonstrate a positive effect on patient outcome.

**Rationale for Change**

There is a stroke approximately every 40 to 50 seconds in the United States, with the new estimate of new strokes at
TABLE 2. Objectives of Telemedicine for Stroke (Telestroke) Care

| Facilitation—rapid care, collaborative networking |
| Teaching and training—students, residents, fellows, staff, emergency physicians, and acute stroke care personnel |
| Video databases of actual patient encounters |
| Cognition—awareness of benefits and limitations of the technology |
| User and payer (reimbursement) acceptance—physicians, nurses, HMOs, patients, hospital administrators, third party health cost financiers |

>700,000 annually, and stroke is 1 of our nation’s most expensive diseases to treat, estimated at $41 billion/y. Treatment of ischemic stroke with rtPA reduces neurological impairment and disability, hospital length of stay, and percentage of patients going to rehabilitation and nursing homes, thus having the capacity to yield major cost savings nationally to health systems and health-care financiers. Telemedicine would also enhance physician contact with colleagues from around the country and other countries to undertake collaborative protocols and research projects and to improve clinical trial efficiency.

Impact of Telemedicine on Stroke Care

A New Approach to Stroke Education and Data Collection

Compact disk interactives (CD-I) or Internet-based interactives can be developed to enhance the education of physicians in the area of treatment protocols and CT interpretation in early ischemic stroke (and the occasional subtle signs of intracranial hemorrhage). These CD-I may help supplement the services of acute stroke teams, facilitating local acute care. This technology with enhancement from digital video display (DVD) technology could also supplant telemedicine in some locations.

Patient education via CD-I and Telestroke classes (interactively via remote video access to multiple sites simultaneously) can also enhance the number of high-risk patients exposed to stroke risk-factor reduction, warning sign awareness programs, and the importance of accessing acute stroke care (911 emergency) urgently. HMOs can provide their patients with stroke teleclasses as part of their “member services.” Video telecommunications (Table 2) and video interactive nursing care and education could also be incorporated into more real-time comprehensive stroke care and prevention.

Data collection, by linking a Telestroke system to a computerized database, could facilitate data analysis of all aspects of stroke care. Comprehensive demographic information and highly accurate chronological data (eg, team response time and time to other specific aspects of the care protocol) can be more easily compiled and compared with other hospitals and medical centers. This could aid in the collection of outcomes data to improve the quality of stroke care in the future.

Telementoring

Telementoring is an additional aspect of telemedicine that trains and guides assessment and treatment of a new procedure or technique when the local physician has limited experience with the technique. This concept could also be applied to acute stroke care. There are specific technological requirements, documentation of skill levels, and requirements for standardized protocols. Hence, telementoring may be more sophisticated and in a higher risk (liability) category than standard telemedicine applications. A standard training protocol should be formulated and tested to maintain quality assurance. Training to learn the NIHSS can be carried out via real-time video telecommunication, building on the NIHSS certification process that was carried out for the TOAST and NINDS rt-PA stroke trials.

Potential New Aspects of Stroke Care

Acute stroke care is in its infancy regarding the potential growth and vast benefits from telemedicine. Telemedicine offers the promise of greater efficiency and more consistent application of protocols and medications. Telemedicine will facilitate high ER quality, with more standardized treatment within this narrow time frame.

The use of telemedicine in the ambulance for more precise and rapid prehospital/emergency medical services care of acute stroke patients, including performing an NIHSS analysis, is currently under evaluation, Tele-BAT. This novel approach may shorten the time to treatment because emergency medical technicians can transmit their videotaped assessment to the ER, providing emergency physicians and neuroradiologists with earlier viewing of the stroke patient’s condition. Relay of visual and audio patient neurological data, vital signs, and blood data, many components of the clinical pathway (except head CT scanning) that lead to rtPA therapy, can be performed in the prehospital setting. Protocols can also be downloaded from the Internet and used in the ER and ambulance. This integrated approach may lead to highly accurate clinical judgments once reliability and validity issues are addressed.

Issues of Telestroke’s accuracy, validity, reliability, safety, cost, effectiveness, and patient and provider satisfaction should be compared directly with conventional stroke care. Measurable outcomes (health and economic) will need to be documented and analyzed. Pilot studies should be funded to initiate these important scientific questions.

As we strive to treat as many eligible stroke patients with rtPA as possible without sacrificing careful and accurate assessments of the clinical and radiological data, many practical issues now challenge us. Medical expertise is required for the diagnosis and management of acute stroke. Physicians with experience treating stroke can mirror the results of the NINDS rt-PA Stroke Trial in their clinical practices (Ref. 59 and D. Tanne et al, for the t-PA in Clinical Practice Stroke Survey Group, unpublished observations, 1998) with strict adherence to the protocol. This clinical experience can now be linked with the hardware and second- and third-generation software that can integrate interactive electronic patient medical information such as clinical assessments and stroke scales, neuroradiology, still images, video clips, and laboratory data. In the United States, the number of video interactive patient-practitioner consultations has...
grown from 6134 in 1995 to 19 380 in 1996 and was estimated to be 36 000 in 1997.60

A rapid response system for acute stroke treatment61 will be necessary for all hospitals that treat acute stroke patients as part of their emergency care practice.5,21,62,63 This is also consonant with new standards placed on HMOs regarding whether the patients get better.64 Measuring the quality of care and service delivered will be important because rtPA improves outcome without increasing mortality.2 HMOs will be striving to be sure that this service is available to as many of their patients as possible.61

Conclusions

Telemedicine for stroke has the promise to become a key revolutionary component of an integrated health-care delivery system (Figure 1B through 1E). It can link rural hospitals65 and under-resourced urban hospitals66 with regional acute stroke centers of excellence, enhancing standardized streamlined care throughout a system’s care facilities. It may be important to link isolated lower stroke volume hospitals to a larger stroke network.

Telestroke is a new application for existing technology.67 Therefore, rigorously designed studies demonstrating validity, accuracy, and reliability of telemedicine68–71 for stroke are urgently needed to decide whether this avenue should become widespread in clinical acute stroke care.72 A state-by-state analysis for Telemedicine 1997 through 1998 can be purchased over the Internet.73 Investigating telemedicine’s role in acute stroke care should now be facilitated by the recent congressional approval of reimbursement for telemedicine consultations (effective January 1, 1999) for rural Health Personnel Shortage Areas.74

Acknowledgments

We thank Harry H. Mansbach, MD, for critically reviewing earlier manuscript drafts and Lalaine Castillo and Shirley Sian for their assistance in manuscript preparation.

References

"Telestroke": The Application of Telemedicine for Stroke
Steven R. Levine and Mark Gorman

Stroke. 1999;30:464-469
doi: 10.1161/01.STR.30.2.464

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://stroke.ahajournals.org/content/30/2/464

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Stroke can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Stroke is online at:
http://stroke.ahajournals.org//subscriptions/