Remote Evaluation of Acute Ischemic Stroke in Rural Community Hospitals in Georgia

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Background and Purpose—Despite Food and Drug Administration approval of tissue-type plasminogen activator (tPA) for stroke, obstacles in the US health care system prevent widespread use. The Remote Evaluation for Acute Ischemic Stroke (REACH) program was developed to address these obstacles in rural settings. We have previously shown the reliability of the REACH system in performing a valid National Institutes of Health Stroke Scale (NIHSS) evaluation at the Medical College of Georgia (MCG). We now report on the performance of the system since its deployment in 5 rural hospitals in east Georgia.

Methods—The rural emergency department (ED) staff can activate a Code REACH protocol 24 hours per day, 7 days per week by calling the Emergency Communications Center (ECC, an in-house dispatch center) at MCG, who pages the on-call consultant. The consultant calls back the ECC and is connected to the waiting ED. Simultaneously, using any broadband-connected workstation, the consultant logs in to the REACH system, allowing performance of an NIHSS evaluation, review of the computerized tomography (CT) images transmitted by the local radiology staff, and then the consultant can speak to the patient and family to verify time of onset.

Results—The REACH system has evaluated 75 patients from March 2003 to April 2004, and 12 have received tPA, all without intracranial hemorrhage complications. NIHSS scores ranged from 0 to 30, with a mean of 14.3 (SD=8.7, median 11.5). The mean onset to door time was 70.9 minutes (SD=70.8, median 50), the mean door to consult time was 45.1 minutes (SD=39.8, median 34), and the mean door to NIHSS completion was 62.9 minutes (SD=50.8, median 51). The mean onset to needle time was 135.3 minutes (SD=51.45, median 134.5).

Conclusion—The REACH system enables remote stroke physicians to direct the local ED staff to administer tPA in rural settings where thrombolytics were not previously used. REACH may be used as a rapid consult tool to provide the same quality of stroke care to patients in rural hospitals as is given in tertiary stroke centers. This supports our endeavor to bring stroke expertise to rural community hospitals. (Stroke. 2004;35:1763-1768.)

Key Words: stroke assessment stroke, ischemic telemedicine

The thrombolytic tissue-type plasminogen activator (tPA) was approved in 1996 by the Federal Drug Administration for treatment of acute ischemic stroke. However, therapeutic intervention in rural Georgia with tPA is virtually nonexistent because of the lack of neurologists in rural hospitals. Eligibility for treatment is also restricted to a 3-hour window, further reducing the chances of emergent stroke patients receiving therapy in outlying areas. The Remote Evaluation of Acute Ischemic Stroke (REACH) began as a collaborative effort between the Departments of Neurology and Emergency Medicine at the Medical College of Georgia (MCG) and community hospitals in Georgia to address the lack of access to stroke specialists in these rural communities. The project seeks to enable MCG-based stroke specialists to remotely examine patients in outlying emergency departments (EDs), to review computed tomography (CT) scans in real time, and to make a recommendation regarding tPA treatment from any broadband-connected workstation while using the latest low-cost, off-the-shelf wireless equipment. We have previously reported that the National Institutes of Health Stroke Scale (NIHSS) could be reliably performed over the REACH system. Subsequently, we have successfully deployed the system in 7 community hospitals, with plans to expand to 14 or 15 sites within the next 24 months. We have successfully evaluated 75 patients, and 12 have received tPA, all without complications such as intracranial hemorrhages.

Subjects and Methods

The REACH system allows the medical staff in the emergency department to activate the REACH protocol on triaging an acute stroke patient who may be eligible for tPA by contacting the tertiary medical center emergency communication center (ECC). The tertiary
medical center ECC will contact the on-call faculty consultant, 1 of 3 neurologists or 1 emergency physician, who will call back the ECC and log onto the REACH system to conduct the NIHSS evaluation via the REACH cart, interpret the transmitted CT scans, obtain additional history from the patient and family, and converse with and evaluate the patient. The REACH consultant then makes a recommendation for or against tPA treatment and any other needed therapy. This recommendation is conveyed electronically to the cart. If tPA is recommended, then the software calculates the appropriate dosage (0.9 mg/kg intravenous, 90 mg maximum, 10% bolus, remainder infused over 60 minutes) according to the weight entered by the ED staff, and it can be printed and included in the patient’s chart (shown in Figure 1).

REACH Sites
Installation of the REACH system began in February of 2003, allowing Emanuel Medical Center in Swainsboro, Georgia (76 miles from MCG) and McDuffie Regional Medical Center in Thomson, Georgia (36 miles) to begin requesting REACH consults in late March of 2003. Subsequently, 5 additional hospitals, Wills Memorial Hospital in Washington, Georgia (55 miles, active May 2003), Jenkins Hospital in Millen, Georgia (50 miles, active July 2003), Washington County Regional Medical Center in Sandersville, Georgia (62 miles, active August 2003), Jefferson Hospital (40 miles, active December 2003), and Morgan Memorial Hospital (100 miles, active February 2004) have come online. In conjunction with technical installation of REACH equipment, a 2-hour educational training course is provided to all staff involved in the care of the stroke patient (ED physicians, nurses, emergency medical technicians, and radiology technicians) before activation at each site. Emergency Management of Stroke covers: (1) triage and medical stabilization; (2) expediting treatment; (3) tPA usage and therapy; (4) emergency treatment of intracranial hemorrhage; (5) activating the REACH protocol; and (6) monitoring after tPA. A mock consult is also performed at the end of each session, allowing all parties involved to become familiar with the user interface and their roles during their consult.

Feedback from community staff has been positive, as reflected by follow-up questionnaires returned in subsequent days by the nurse and physician who activated the REACH protocol. The 1-page questionnaire asks for a yes/no or check-box response to the following:

1. Were there problems with wireless phone?
2. Satisfied with REACH response?
3. Was cart on when you needed it?
4. Was log-in to site easy?
5. Was site easy to navigate?
6. Were there any problems with your consult encounter? (Web site) (Entering patient info) (Printout)
7. Overall, how was REACH experience? (Good) (No Opinion) (Bad)

Results for questionnaires have been positive, with all overall experiences qualified as “good.” Constructive criticisms have included requests for improvements in the audibility of the wireless phone, as well as streamlining of navigation through fields during data entry.

Hardware
The remote evaluation cart is comprised of an Axis 2130 Pan/Tilt/Zoom camera (Axis Communications) providing 15 to 25 fps, a 1.5-Ghz Dell PC workstation and LCD monitor (Dell Corp) running Microsoft Windows 2000 with Internet Explorer 5.5 (Microsoft Corp), a Linksys WET11 wireless bridge (Linksys), Netgear 5 port switch (Netgear Inc), and universal power supply (UPS), all housed on a mobile, ergonomic, medical cart. The computer workstation and camera are connected to the ethernet switch and wireless-networked to the hospital local area network (LAN) via a Linksys WAP11 802.11b wireless access point (Linksys). The UPS and wireless bridge allow the cart to be maneuvered anywhere in the emergency
room (ER) without the need for a wired infrastructure. The system is on constant standby.

CT images are sent directly from the scanner via DICOM Transmit protocol to a Sonicwall SSL Appliance (Sonicwall Inc) inside the hospital firewall, encrypting the images with a 128-bit certificate, and transmitting it over the Internet to a mini-PACS server at MCG.

Software
A database-driven SSL encrypted web application was developed to present multiple patients from various locations to the consulting physician in real time, allowing the consultant to use any accessible browser to locate the appropriate patient. It presents the patient video feed, the CT images, vitals and remaining tPA time window, and the NIHSS evaluation form to the consultant in 1 concise screen (Figure 2).

Remote Radiology
To rapidly provide consultants with the CT scans needed to rule out intracranial hemorrhage or other significant pathology, the patients’ CT scans are delivered digitally to a ConQuest DICOM server version 1.4.1 (released March 3, 2003) directly from the CT scanner. This server has been developed within the EU. ConQuest project as a small image archive. It is used to connect ConQuest imaging applications to the CT scanner that sends out images conforming to the DICOM standard (C-STORE). This allows the images to be incorporated directly into the REACH consult page.

The server accepts DICOM image data files, stored in chapter 10 DICOM (uncompressed) format, and converted as they are received using DCM2PNG, a command line tool, to batch-convert the DICOM images to PNG format. This lossless compression produces a final image that is one-tenth the size of the original image while removing none of the detail and introducing no compression artifacts (16-bit images will retain all raw data). The command tool will extract the function from the headers in the image to calibrate the raw data and discard irrelevant data.

To establish that the quality of CT images being read by consulting physicians are of appropriate quality for clinical decisions, 2 test patterns used by the Society of Motion Picture and Television Engineers are displayed before each CT viewing. This solution has been advocated by the American College of Radiology. Studies by Tobin et al have suggested that evaluations can be performed using these standard test images and further demonstrated that monitors that have discernible loss of resolution on these test patterns also have detectable loss of image quality on clinical images. Thus, a physician who can detect the brightness and contrast differences, spatial resolution and aliasing, and continuous gray-scale subtleties should reliably read a CT image digitally delivered by the community hospital’s radiology department.
Results
Since March 2003, the REACH system has evaluated 75 patients and has qualified 12 for tPA treatment. The remaining 63 patients did not qualify for tPA for the following reasons: 13 were brought to the ED outside the 3-hour window, 10 had hemorrhagic strokes, 3 had seizures, 33 had “rapidly improving” deficits, 2 had conversion disorder diagnosed, and 2 were found to be using anticoagulants (Table 1). Of the 75 patients evaluated, 54 were transferred to MCG. During 2 consults with rapidly improving patients, there were technical difficulties with the network connection to the cart, making the video feed unavailable. For those patients who were scored, the mean NIHSS value was 9.5 (SD 9.1, median 5.5). Mean values for onset to ED door times, defined as the length of time from estimated onset (as verified by family, friends, emergency medical technicians) to the time the patient was brought into the ED before the end of the 3-hour window was 70.9 minutes (SD = 50.8 minutes, median 51 minutes). Mean values for door to NIHSS, defined as the length of time once patient is brought into the ED to the time the REACH consultant submits an NIHSS evaluation into the system and the go/no-go recommendation is delivered to the cart in the rural ER was 62.9 minutes (SD = 50.8 minutes, median 51 minutes) (Table 2). Relevant times for all tPA-treated patients, as well as discharge dispositions, are listed in Table 3. None had intracranial hemorrhage complications. The mean door to needle time for these patients was 104.92 minutes (SD = 32.3 minutes, median 104.5 minutes), and mean onset to needle time was 135.3 minutes (SD = 51.4 minutes, median 134.5 minutes) (Table 4).

A number of patients evaluated through REACH were found to have intracranial hemorrhages, both subarachnoid and intracerebral. Patient 4, in March 2003, a 38-year-old black woman, presented to a REACH site after fainting in the yard while washing her car. The patient reported a severe headache, and the REACH protocol was activated. The remote consultant performed a 6-minute NIHSS evaluation within 40 minutes of door presentation, evaluated the CT (Figure 2), and diagnosed a subarachnoid hemorrhage. The patient was immediately transferred to MCG and found to have an anterior communicating artery aneurysm; the aneurysm was subsequently coiled.

Discussion
Guidelines by the American Heart Association state, “Thrombolytic therapy is not recommended unless the diagnosis is
TABLE 4. Analysis of Patients Treated With tPA Using the REACH System

<table>
<thead>
<tr>
<th>(N) Date Patient Presented</th>
<th>NIH SS</th>
<th>Onset to Door</th>
<th>Door to ECC Call</th>
<th>Door to Consult Callback</th>
<th>Door to NIHSS</th>
<th>Door to Needle</th>
<th>Onset to Needle</th>
<th>Discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>(3) March 6, 2003*</td>
<td>5</td>
<td>0:00</td>
<td>1:45</td>
<td>1:50</td>
<td>2:01</td>
<td>2:10</td>
<td>2:15</td>
<td>Home</td>
</tr>
<tr>
<td>(7) June 2, 2003</td>
<td>6</td>
<td>0:15</td>
<td>0:50</td>
<td>0:55</td>
<td>1:10</td>
<td>1:35</td>
<td>1:50</td>
<td>Home</td>
</tr>
<tr>
<td>(15) August 19, 2003</td>
<td>25</td>
<td>0:20</td>
<td>0:57</td>
<td>0:59</td>
<td>1:12</td>
<td>1:39</td>
<td>3:00</td>
<td>Rehab</td>
</tr>
<tr>
<td>(22) September 23, 2003</td>
<td>7</td>
<td>0:30</td>
<td>0:40</td>
<td>0:42</td>
<td>1:18</td>
<td>1:20</td>
<td>1:50</td>
<td>Home</td>
</tr>
<tr>
<td>(30) November 22, 2003</td>
<td>24</td>
<td>0:50</td>
<td>0:46</td>
<td>0:49</td>
<td>1:13</td>
<td>1:50</td>
<td>2:40</td>
<td>Rehab</td>
</tr>
<tr>
<td>(35) December 3, 2003</td>
<td>30†</td>
<td>0:40</td>
<td>1:23</td>
<td>1:26</td>
<td>—</td>
<td>2:45</td>
<td>3:25</td>
<td>Nurs Home</td>
</tr>
<tr>
<td>(36) December 22, 2003</td>
<td>7</td>
<td>0:20</td>
<td>0:27</td>
<td>0:28</td>
<td>1:00</td>
<td>2:05</td>
<td>2:25</td>
<td>Rehab</td>
</tr>
<tr>
<td>(42) January 12, 2004</td>
<td>9</td>
<td>1:00</td>
<td>0:40</td>
<td>0:47</td>
<td>1:08</td>
<td>1:20</td>
<td>2:20</td>
<td>Home</td>
</tr>
<tr>
<td>(43) January 13, 2004</td>
<td>11</td>
<td>0:30</td>
<td>1:25</td>
<td>1:33</td>
<td>1:33</td>
<td>1:50</td>
<td>2:20</td>
<td>Home</td>
</tr>
<tr>
<td>(50) February 19, 2004</td>
<td>23</td>
<td>0:30</td>
<td>0:32</td>
<td>0:34</td>
<td>1:00</td>
<td>1:01</td>
<td>1:30</td>
<td>—</td>
</tr>
<tr>
<td>(61) March 23, 2004</td>
<td>12</td>
<td>1:00</td>
<td>0:30</td>
<td>0:34</td>
<td>0:57</td>
<td>1:10</td>
<td>2:10</td>
<td>—</td>
</tr>
<tr>
<td>(63) March 24, 2004</td>
<td>13</td>
<td>0:10</td>
<td>0:30</td>
<td>0:35</td>
<td>0:58</td>
<td>1:09</td>
<td>1:19</td>
<td>—</td>
</tr>
</tbody>
</table>

Time span in hours:minutes. Rehab indicates rehabilitation; Nurs Home, nursing home.
*Patient had onset of stroke symptoms after entering ED.
†NIHSS estimated.

TABLE 3. Patients Treated With tPA Using the REACH System in 5 Rural Hospitals

<table>
<thead>
<tr>
<th>Time Span</th>
<th>Door to NIHSS</th>
<th>Door to Needles</th>
<th>Onset to Discharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-hour window</td>
<td>30 minutes</td>
<td>45 minutes</td>
<td>120 minutes</td>
</tr>
</tbody>
</table>

Established by a physician with expertise in diagnosis of stroke and CT of the brain is assessed by physicians with expertise in reading this imaging study.75 The REACH system allows remote consultants to provide acute consultations on patients with acute stroke to rural community hospitals that lack stroke physician expertise. REACH permits an evaluation of the NIHSS, review of the CT scan, and allows for interaction between the patient, family, the local ED physician and the remote stroke specialist. As a result, tPA is now being administered in rural community hospitals in Georgia where it was not used previously.

Conventional strategies to improve administration rates of tPA have used phone consultations and helicopter or professional ground transport to a tertiary care stroke hospital. Wang et al provided 24-hour phone consultation to 20 regional stroke network hospitals with on-site individuals certified in NIHSS evaluation.6 Twenty of 57 patients were remotely treated with tPA. Merino et al studied 82 patients treated with tPA in a London, Ontario, ER and found that 23 were transferred from outlying rural communities, suggesting that transfer and treatment of patients with tPA from rural communities was feasible, although symptom onset to London ED time was quite long (123 minutes).7 Silfman et al reported the experiences of the Shands-Jacksonville Acute Stroke Transport Program that serves the rural northeastern Florida/southeastern Georgia region without 24-hour CT capabilities.8 This study suggested that "patients who delayed their 911 call by >90 minutes after symptom onset may not arrive at the tertiary care hospital" in time to receive tPA, with average round-trip flight distances of 59 miles. Sillbergfelt et al have shown that helicopter transfer of patients for tPA treatment of suspected acute strokes is cost-effective but that "treatment at the initial hospital without transport, when possible, is inherently less expensive and more effective than transport for treatment."9 It has been shown that patients treated with intravenous tPA in the first 90 minutes after the onset of an acute stroke have a predictably better outcome than patients treated in the last 90 minutes of the 3-hour window.10 Patients will likely still require transfer from the rural site after receiving tPA, although after the time urgency has been lifted.

Other telestroke strategies have been developed to administer tPA at the local site. The teleconsultation system developed by LaMonte et al delivers expert stroke care to patients in the rural region of southern Maryland.11,12 It has found the administration of tPA during telemedicine consultation to be safe and feasible. Nonetheless, it is a fixed point-to-point consult system dependent on fixed ISDN lines, in contrast to the REACH system, which allows a consult through any broadband-connected workstation over the Internet.

Although there are advantages to using the Internet, this may be a potential point of failure because it is a network connection to the public Internet, in contrast to a dedicated line provided by an Internet service provider (ISP). Congestion and dropped packets are inherent problems when using the Internet, although bandwidth has been upgraded at each community hospital to 748 kbps downstream and 512 kbps upstream to minimize these issues. Using the public Internet as the vehicle for delivering telestroke consults in a geographically rural area has allowed the community hospitals to use existing lines to rapidly implement the program with minimal cost increase.
Further familiarity with the REACH system and protocol should lead to earlier consult requests and shorter evaluations. An important attribute of the REACH system is the ability to rapidly assist the local ED in other diagnoses that also need urgent attention. The consultants have been able to assist the rural staff in confirming the diagnosis of intracerebral or subarachnoid hemorrhage, with subsequent rapid transfer to MCG. The REACH system has evolved into much more than a “tPA” treatment tool. REACH may be used as a multisite consultation tool to provide the same quality of stroke care to patients in rural hospitals as is given in tertiary stroke centers.

Acknowledgments
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References
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