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A Review of the Evidence for the Use of Telemedicine Within Stroke Systems of Care: A Scientific Statement From the American Heart Association/American Stroke Association

Lee H. Schwamm, Robert G. Holloway, Pierre Amarenco, Heinrich J. Audebert, Tamilyn Bakas, Neale R. Chumbler, Rene Handschu, Edward C. Jauch, William A. Knight, IV, Steven R. Levine, Marc Mayberg, Brett C. Meyer, Philip M. Meyers, Elaine Skalabrin, Lawrence R. Wechsler and on behalf of the American Heart Association Stroke Council and the Interdisciplinary Council on Peripheral Vascular Disease

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AHA/ASA Scientific Statement

A Review of the Evidence for the Use of Telemedicine Within Stroke Systems of Care

A Scientific Statement From the American Heart Association/American Stroke Association

The American Academy of Neurology (AAN) affirms the value of this paper as an educational tool for neurologists.

Lee H. Schwamm, MD, FAHA, Co-Chair; Robert G. Holloway, MD, MPH, Co-Chair; Pierre Amarenco, MD, FAHA; Heinrich J. Audebert, MD; Tamilyn Bakas, RN, DNS, FAHA, FAAN; Neale R. Chumbler, PhD; Rene Handschu, MD; Edward C. Jauch, MD, MS, FAHA; William A. Knight IV, MD; Steven R. Levine, MD, FAHA; Marc Mayberg, MD, FAHA; Brett C. Meyer, MD; Philip M. Meyers, MD, FAHA; Elaine Skalabrin, MD; Lawrence R. Wechsler, MD, FAHA; on behalf of the American Heart Association Stroke Council and the Interdisciplinary Council on Peripheral Vascular Disease

Abstract**—**The aim of this new statement is to provide a comprehensive and evidence-based review of the scientific data evaluating the use of telemedicine for stroke care delivery and to provide consensus recommendations based on the available evidence. The evidence is organized and presented within the context of the American Heart Association's Stroke Systems of Care framework and is classified according to the joint American Heart Association/American College of Cardiology Foundation and supplementary American Heart Association Stroke Council methods of classifying the level of certainty and the class of evidence. Evidence-based recommendations are included for the use of telemedicine in general neurological assessment and primary prevention of stroke; notification and response of emergency medical services; acute stroke treatment, including the hyperacute and emergency department phases; hospital-based subacute stroke treatment and secondary prevention; and rehabilitation. **(*Stroke*. 2009;40:2616-2634.)**

Key Words: AHA Scientific Statements ■ stroke care ■ stroke management ■ telemedicine

The field of acute stroke care is evolving rapidly, and many states and communities are establishing designated stroke centers as a means to improve acute stroke care delivery.[1] Specialized stroke and brain imaging expertise is often required to facilitate delivery of advanced therapies, including intravenous tissue plasminogen activator (tPA). Access to this expertise is limited, often to larger urban centers, and there are significant disparities in access to specialty care across the United States. Telemedicine has been proposed as a method to increase access to limited specialty expertise in a cost-effective manner, especially for geographically remote areas. tPA is recommended for use in appropriate stroke patients by major professional societies and nursing organizations (American Heart Association [AHA], National Stroke Association, American Academy of Neurology, American College of Chest Physicians) and

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endorsed by the federal government (US Food and Drug Administration, Centers for Medicare and Medicaid Services, Agency for Healthcare Research and Quality) and multispecialty organizations (Brain Attack Coalition). Despite evidence of the benefit of intravenous tPA for treatment of stroke within 3 hours of stroke onset and recommendations for the use of tPA, only a small percentage of stroke patients receive this therapy.[2] One of the barriers to intravenous tPA treatment is the lack of availability of neurological expertise on an emergent basis. Emergency physicians are often not comfortable making the decision to institute tPA treatment without this guidance. Patients who might benefit from tPA may not receive treatment because of the treating physician's lack of familiarity with the appropriate inclusion and exclusion criteria or because of delays in evaluation and treatment resulting from inexperience. In addition, patients and families may not clearly understand the benefits and risks of intravenous tPA. It has been recommended that telemedicine be implemented within the Stroke Systems of Care Model to address these deficiencies.

In addition, teleconsultation can lead to many other changes in care apart from IV tPA decisions that are beneficial to the patient. Involvement of a neurologist in the care of the stroke patient has been shown to be associated with better outcomes in non–lytic-treated patients. Management of intracerebral hemorrhage is improved by selected triage to centers with neurosurgical capability. More rapid diagnosis of the underlying mechanism of ischemic stroke may lead to more rapid institution of secondary prevention therapy. We reviewed the available literature to evaluate the levels of scientific evidence that support the use of this telemedicine technology.

Of note, an important part of the application of a new technology depends on human factors and the ability to apply the new technology in a variety of scenarios, from research proof-of-concept environments to real-time acute stroke interventions. Whenever possible, we have attempted to distinguish between evidence of feasibility (ie, technically achievable in a proof-of-concept design) and effectiveness (ie, demonstrated benefit in a real clinical practice environment). Because telemedicine is not a treatment modality in and of itself but rather a technology that may enable the delivery of previously validated interventions, many of the studies reviewed assessed agreement between observers using traditional versus telemedicine-enabled methods of performing key tasks in the delivery of acute stroke care.

The aim of this new statement is to provide a comprehensive and evidence-based review of the scientific evidence supporting the use of telemedicine in acute stroke care delivery. The evidence is organized and presented within the context of the American Heart Association's Stroke Systems of Care framework and is classified according to the joint AHA/American College of Cardiology Foundation and supplementary AHA Stroke Council methods of classifying the level of certainty and the class of evidence (Tables 1 and 2).[3] Evidence-based recommendations are included for the use of telemedicine in general neurological assessment and primary prevention of stroke; notification and response of emergency medical services (EMS); acute stroke treatment, including the hyperacute and emergency department phases; hospital-based subacute stroke treatment and secondary prevention; and rehabilitation.

Two writing committee co-chairs were designated by the Stroke Council Manuscript Oversight Committee. A writing committee roster was developed by the AHA Stroke Council and approved by the AHA Manuscript Oversight Committee with representatives from emergency medicine, neurology, health services research, stroke telemedicine, radiology, neurosurgery, rehabilitation, and nursing. The committee met in person and held several teleconferences to develop the outline and text of the recommendations. The writing group conducted a comprehensive review of the relevant literature. Although a complete list of key words is beyond the scope of this section, the committee reviewed all compiled reports from computerized searches and conducted additional searching by hand. Searches were limited to English language sources and to human subjects. Literature citations were generally restricted to published manuscripts appearing in journals listed in Index Medicus and reflect literature published as of June 30, 2007, although selected articles of high relevance published in other languages or up until September 2008 were also included. Because of the scope and importance of certain ongoing clinical trials and other emerging information, published abstracts were cited when they were the only published information available; however, the levels of evidence and recommendations are based solely on full-length published peer-reviewed reports. The references selected for this document are exclusively from peer-reviewed papers that are representative but not all inclusive. All members of the committee had frequent opportunities to review drafts of the document, comment in writing or during teleconference discussions, and reach consensus with the final recommendations.

Technology and Technical Standards

Telemedicine has been broadly defined as *the use of telecommunications technologies to provide medical information and services*.[4] Use of interactive full-motion audio and video for acute stroke care was first reported in the early 1990s, but Levine and Gorman[5] were the first to coin the term *telestroke* for the use of telemedicine in the form of videoteleconferencing (VTC) to support acute stroke intervention. This type of VTC, also called videoconferencing, is characterized by the use of dedicated, high-quality, interactive, bidirectional audiovisual systems, coupled with the use of teleradiology for remote review of brain images. In this review, we have focused on this telestroke type of telemedicine activity and have identified whenever studies did not use this high-quality videoconferencing (HQ-VTC) methodology.

Interactive videoconferencing allows the patient and/or family and both the bedside and distant healthcare providers to see and hear each other in full color using cameras with various degrees of remote control (eg, pan, tilt, or zoom) connected to a display screen (video graphics array [VGA] or television monitor) (see Figures 1 and 2 and full-motion video clips viewable in the online Data Supplement). Unless otherwise noted in the text, all telemedicine systems reviewed met certain minimum quality standards for HQ-VTC, including transmission rates and algorithms of sufficient quality to

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Table 1. Applying Classification of Recommendations and Level of Evidence

ESTIMATE OF CERTAINTY (PRECISION) OF TREATMENT EFFECT	SIZE OF TREATMENT EFFECT →			
	CLASS I *Benefit >>> Risk* Procedure/Treatment **SHOULD** be performed/administered	**CLASS IIa** *Benefit >> Risk* *Additional studies with focused objectives needed* **IT IS REASONABLE** to perform procedure/administer treatment	**CLASS IIb** *Benefit ≥ Risk* *Additional studies with broad objectives needed; additional registry data would be helpful* Procedure/Treatment **MAY BE CONSIDERED**	**CLASS III** *Risk ≥ Benefit* Procedure/Treatment should **NOT** be performed/administered **SINCE IT IS NOT HELPFUL AND MAY BE HARMFUL**
LEVEL A Multiple populations evaluated* Data derived from multiple randomized clinical trials or meta-analyses	■ Recommendation that procedure or treatment is useful/effective ■ Sufficient evidence from multiple randomized trials or meta-analyses	■ Recommendation in favor of treatment or procedure being useful/effective ■ Some conflicting evidence from multiple randomized trials or meta-analyses	■ Recommendation's usefulness/efficacy less well established ■ Greater conflicting evidence from multiple randomized trials or meta-analyses	■ Recommendation that procedure or treatment is not useful/effective and may be harmful ■ Sufficient evidence from multiple randomized trials or meta-analyses
LEVEL B Limited populations evaluated* Data derived from a single randomized trial or nonrandomized studies	■ Recommendation that procedure or treatment is useful/effective ■ Evidence from single randomized trial or nonrandomized studies	■ Recommendation in favor of treatment or procedure being useful/effective ■ Some conflicting evidence from single randomized trial or nonrandomized studies	■ Recommendation's usefulness/efficacy less well established ■ Greater conflicting evidence from single randomized trial or nonrandomized studies	■ Recommendation that procedure or treatment is not useful/effective and may be harmful ■ Evidence from single randomized trial or nonrandomized studies
LEVEL C Very limited populations evaluated* Only consensus opinion of experts, case studies, or standard of care	■ Recommendation that procedure or treatment is useful/effective ■ Only expert opinion, case studies, or standard of care	■ Recommendation in favor of treatment or procedure being useful/effective ■ Only diverging expert opinion, case studies, or standard of care	■ Recommendation's usefulness/efficacy less well established ■ Only diverging expert opinion, case studies, or standard of care	■ Recommendation that procedure or treatment is not useful/effective and may be harmful ■ Only expert opinion, case studies, or standard of care
Suggested phrases for writing recommendations†	should is recommended is indicated is useful/effective/beneficial	is reasonable can be useful/effective/beneficial is probably recommended or indicated	may/might be considered may/might be reasonable usefulness/effectiveness is unknown/unclear/uncertain or not well established	is not recommended is not indicated should not is not useful/effective/beneficial may be harmful

*Data available from clinical trials or registries about the usefulness/efficacy in different subpopulations such as gender, age, history of diabetes, history of prior myocardial infarction, history of heart failure, and prior aspirin use. A recommendation with Level of Evidence B or C does not imply that the recommendation is weak. Many important clinical questions addressed in the guidelines do not lend themselves to clinical trials. Even though randomized trials are not available, there may be a very clear clinical consensus that a particular test or therapy is useful or effective.

†In 2003, the American College of Cardiology/American Heart Association Task Force on Practice Guidelines developed a list of suggested phrases to use when writing recommendations. All guideline recommendations have been written in full sentences that express a complete thought so that a recommendation, even if separated and presented apart from the rest of the document (including headings above sets of recommendations), would still convey the full intent of the recommendation. It is hoped that this will increase readers' comprehension of the guidelines and will allow queries at the individual recommendation level.

support >20 frames per second of bidirectional synchronized audio and video at a resolution capable of being accurately displayed on monitors of ≥13 in. These parameters reflect the consensus expert opinion of the writing group, and no published articles were excluded from review because of these criteria. They are incorporated here to help define appropriate minimum standards of video transmission below which the quality of information transfer may be insufficient for the recommendations to apply. Because we can comment only on the parameters specified in the published reports, many of the systems used are described in terms of bandwidth rather than video quality.

Common intermediate format (CIF), also known as full CIF, is a format used to standardize the horizontal and vertical resolutions in pixels in video signals, commonly used in HQ-VTC systems. CIF was designed to be easy to convert to European or American video format standards. CIF defines a video sequence with a resolution of 352×288 at a frame rate of 30 frames per second in full color. Multiples of CIF are commonly used. Source input format is practically identical to CIF but is taken from Moving Pictures Expert Group—Phase 1 (MPEG-1) rather than international telecommunications union standards.

Early systems used dedicated high-speed telecommunications lines, usually integrated services digital network (ISDN) lines, at rates of 256 to 384 kilobits per second to achieve CIF transmission. However, with recent developments in the quality of private fiberoptic networks and public Internet providers and with different vendors using different video processing and error-checking algorithms, simple numeric statements about transmission rates (eg, 384 kilobits per second) may not reflect comparable image quality across vendors. Therefore, we have chosen to focus on visual resolution and latency (eg, CIF standards), which are psycho-

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Table 2. Definition of Classes and Levels of Evidence Used in AHA Stroke Council Recommendations

Class I	Conditions for which there is evidence for and/or general agreement that the procedure or treatment is useful and effective
Class II	Conditions for which there is conflicting evidence and/or a divergence of opinion about the usefulness/efficacy of a procedure or treatment
Class IIa	The weight of evidence or opinion is in favor of the procedure or treatment
Class IIb	Usefulness/efficacy is less well established by evidence or opinion
Class III	Conditions for which there is evidence and/or general agreement that the procedure or treatment is not useful/effective and in some cases may be harmful
Therapeutic recommendation	
Level of Evidence A	Data derived from multiple randomized clinical trials
Level of Evidence B	Data derived from a single randomized trial or nonrandomized studies
Level of Evidence C	Consensus opinion of experts
Diagnostic recommendation	
Level of Evidence A	Data derived from multiple prospective cohort studies using a reference standard applied by a masked evaluator
Level of Evidence B	Data derived from a single level A study or ≥1 case-control studies or studies using a reference standard applied by an unmasked evaluator
Level of Evidence C	Consensus opinion of experts
Classifying evidence for agreement studies	
Level of Evidence A	Prospective
	Masked
	Broad/representative subject spectrum
	Complete assessment
	Adequate description of test method/reference standard
	Adequate description of test results/study finding
Level of Evidence B	≥1 of the following:
	Retrospective
	Unmasked
	Narrow spectrum
	Incomplete assessment
	Inadequate description of test method/reference standard
	Inadequate description of test results/study finding
Level of Evidence C	≥2 of the following:
	Retrospective
	Unmasked
	Narrow spectrum
	Incomplete assessment
	Inadequate description of test method/reference standard
	Inadequate description of test results/study finding

physical properties that will continue to be meaningful over time even as technology continues to evolve. Systems that do not meet these minimum standards may not perform in a manner sufficient to be consistent with these guideline recommendations; therefore, caution should be used when these recommendations are applied to such systems.

Many of the studies compared the assessment of acute or subacute stroke severity among patients using the National Institutes of Health Stroke Scale (NIHSS) performed at the bedside (NIHSS-bedside) with that performed via HQ-VTC (NIHSS-telestroke). When evidence was available, studies comparing telestroke intervention with low-cost telephonic communication were also reviewed.

Teleradiology is the ability to obtain radiographic images at 1 location and transmit them remotely to another location for diagnostic and consultative purposes[6]; this is critical to the telestroke encounter. In 1982, the American College of Radiology and the National Electric Manufacturers Association published standards for digital imaging and communications in medicine, now the standard for transmissible medical images.[7] In 1994, the American College of Radiology published standards for teleradiology applications.[8] Equipment used for teleradiology systems must be approved by the US Food and Drug Administration (FDA).[9,10] The Joint Commission and other accrediting bodies play an important role in the performance appraisal and credentialing of teleradiology systems.[11] According to these standards of practice, the Centers for Medicare and Medicaid Services provide reimbursement for both intrastate and interstate teleradiology services.[12,13]

Primary Prevention of Stroke

There are no published articles on the use of HQ-VTC for the primary prevention of stroke or management of risk factors per se. There are some reports on the use of other means of telemedicine to improve control of risk factors such as blood pressure or diabetes. None of these studies investigated stroke as an outcome event. Further study is warranted to determine whether such systems may be useful for remote staffing of prevention clinics or specialized centers for management of transient ischemic attacks.

Notification and Response of EMS

If EMS providers could identify potential stroke patients and transport them to designated stroke centers, more patients might be able to receive appropriate therapies. Prehospital stroke assessment tools have been developed to help EMS personnel identify potential stroke patients, but even in the emergency department, stroke may be difficult to diagnose.[14,15] Providing stroke expertise to the ambulance via HQ-VTC or lower-quality technology may increase diagnostic accuracy, provide earlier resource mobilization, and increase appropriate triage. Furthermore, if effective prehospital neuroprotective interventions are available in the future, telemedicine may increase their appropriate use.

Available Technology

The spectrum of telemedicine technology for EMS use ranges from cellular phone technology to primitive 2-way

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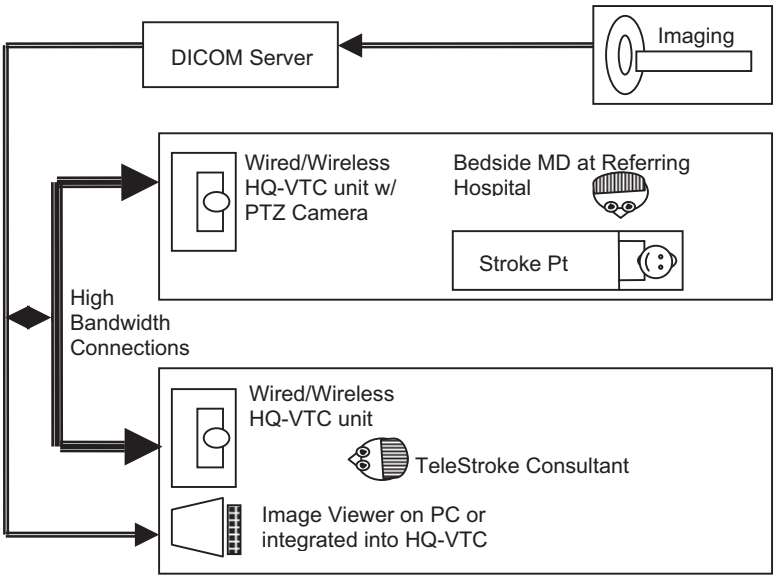

Figure 1. Telestroke schematic illustration. (Adapted from Rosenthal E, Schwamm LH. Telemedicine and stroke. In: Wooton R, Patterson V, eds. *Teleneurology*. London, England: Royal Society of Medicine Press, Ltd; 2005.)

audio and video. More recent developments in emergency video-multiplexing transport systems provide live video transmission with high spatial and temporal resolution and biotelemetry data using low-data-transmission-rate networks on satellite communications and cellular phone networks.[16] Current technology can provide real-time video with video frame rates of 15 frames per second at a video resolution of 360×240 pixels. Evolution-data optimized or evolution-data only is a telecommunications standard for the wireless transmission of data through radio signals, typically for broadband Internet access. It uses cellular telephone multiplexing techniques, including code division multiple access and time division multiple access, to maximize both individual user's throughput and the overall system throughput. This emerging telecommunications standard has been adopted by many mobile phone service providers around the world, particularly those previously using code division multiple access networks. As such broadband wireless networks from the major carriers become more available, transmission rates of >2 megabytes per second are possible, but this high bandwidth is often asymmetrical and therefore does not support bidirectional video at full capability. Application of wireless and satellite data transmission of video, audio, and device data from the prehospital and ambulance setting includes video examination and focused abdominal sonography for trauma.[17]

EMS Telemedicine for Stroke

The only 2-way ambulance-based telemedicine system for stroke assessment reported in the literature is the integrated telecommunications system (TeleBAT) developed by the Maryland Brain Attack Team.[18,19] The TeleBAT system

Figure 2. Representative still images from telestroke consultations. Actual clarity of full-motion video is greater than that shown in these single-frame still images. (Images courtesy of Partners TeleStroke Center, with permission from all individuals depicted.)

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Table 3. NIHSS Reliability Studies

NIHSS Item	Goldstein	Brott	Shafqat	Meyer	Meyer	Handschu	Handschu	LaMonte	LaMonte
	Bedside vs. Bedside	Bedside vs. Bedside	Telemed vs. Bedside non-acute	Telemed vs. Bedside non-acute	Telemed vs. Bedside-untrained non-acute	Telemed vs. Bedside (0-36 hrs)	Telemed vs. Bedside (0-6 hrs)	Lab Simulation vs. Videotape (1 LS vs. 2 VT)	Lab Simulation vs. Videotape (2 LS vs. 1 VT)
LOC	0.50	0.49	100% Agree	100% Agree	0.87	0.99	0.97	100% Agree	100% Agree
LOC Q	0.64	0.80	0.75	0.93	0.96	0.90	0.88	0.58	0.58
LOC C	0.41	0.58	0.29	100% Agree	100% Agree	0.93	0.89	100% Agree	100% Agree
Gaze	0.33	0.82	0.41	100% Agree	0.60	0.95	0.88	100% Agree	100% Agree
Visual Fields	0.57	0.81	0.60	0.93	0.78	0.89	0.83	100% Agree	0.44
Facial Palsy	0.22	0.57	0.40	0.22	0.62	0.85	0.62	-0.11	0.69
Motor Arm	0.77	0.85	0.82	0.88 0.82	0.94 0.97	0.90	0.74	0.74 100% Agree	100% Agree 100% Agree
Motor Leg	0.78	0.83	0.83	0.74 0.80	0.95 0.89	0.92	0.72	0.72 0.44	0.44 0.58
Ataxia	-0.16	0.57	-0.07	0.34	0.65	0.95	0.94	100% Agree	100% Agree
Sensory	0.50	0.60	0.48	0.80	100% Agree	0.91	0.83	0.58	100% Agree
Language	0.79	0.64	0.65	0.73	0.89	0.98	0.97	0.58	0.67
Dysarthria	0.32	0.55	0.55	0.61	0.60	0.92	0.93	0.58	0.38
Neglect	0.61	0.58	0.77	0.80	0.72	0.96	1.00	0.62	0.58
Study Specific Kappa Scoring	> 0.60 = Excellent	>0.80 = Excellent	>0.75 = Excellent	>0.75 = Excellent	≥0.75 = Excellent	Weighted	Weighted	r > 0.5 = good	r > 0.5 = good
% Excellent	5/13 (38%)	4/13 (31%)	4/13 (31%)	10/15 (67%)	10/15 (67%)	13/13 (100%)	12/13 (92%)	6/15 (40%)	7/15 (47%)
% Moderate	4/13 (31%)	9/13 (69%)	7/13 (54%)	3/15 (20%)	5/15 (33%)	0/13 (0%)	1/13 (8%)	7/15 (47%)	5/15 (33%)
% Poor	4/13 (31%)	0/13 (0%)	2/13 (15%)	2/15 (13%)	0/15 (0%)	0/13 (0%)	0/13 (0%)	2/15 (13%)	3/15 (20%)

Green= excellent agreement *Yellow= moderate agreement* *Red= poor agreement*

consists of an ambulance unit using cellular technologies (4 simultaneous cellular phone connections) to communicate with the hospital base station via the hospital's intranet. The TeleBAT system provides a bandwidth of 9.6 kilobytes per second, producing a 320×240-pixel image at 2 frames per second and a voice channel. Using the TeleBAT system from a dedicated ambulance to remotely perform the NIHSS, investigators have shown the system to be feasible for evaluating prehospital neurological deficits.[19]

It is clear that existing technology can provide some degree of interactive video and audio communication with prehospital units in transport, although current published applications have unacceptably low frame rates, and broad application of this technology to large fleets of EMS vehicles is not yet practical. Real-time audiovisual telecommunication to perform a stroke screening assessment, including the NIHSS, in the prehospital setting is technically feasible. The usefulness of this intervention in real practice is uncertain, and further research is required. There are insufficient data to support a recommendation.

Acute Stroke Evaluation, Including the Hyperacute and Emergency Department Phases

Although numerous scales have been used in the evaluation of stroke patients,[20,21] the NIHSS is generally regarded as the reference standard for stroke clinical deficit scale assessments. The NIHSS is a 13-item graded neurological examination that assesses consciousness, visual field abnormalities, gaze disturbances, motor and sensory abilities, speech and language functions, and inattention. Only a few clinical signs relevant for stroke diagnosis like distal motor function and balance and gait disorders are not covered by this standardized examination tool. The scale, developed for use in acute stroke therapy trials,[22,23] requires only a limited time to perform (generally <8 minutes).[22] Overall interrater reliability for examinations performed by stroke specialists at the bedside has been reported.[22,23] The percentage of items with excellent interrater reliability ranges from 31% to 38%[22,23] (Table 3). This reliability of the NIHSS performed at the bedside extends to nonneurologist physicians and nonphysician study coordinators,[24] to community neurologists and nurses,[25] and to retrospective medical record NIHSS abstraction.[26] Although the NIHSS is a reliable stroke deficit scale, it includes items with redundancy and items with less-than-excellent reliability.[25,27] This reliability can be improved with training.[28,29] To ensure the adequacy of stroke evaluation by HQ-VTC, the feasibility and reliability of performing the NIHSS were demonstrated first in the nonacute and subsequently in the acute stroke environment. In these validation study paradigms in general, an NIHSS is performed by a stroke expert over HQ-VTC assisted by a nurse or physician (eg, emergency physician) at the bedside for elements that require a physical presence at the bedside such as sensory testing or presentation of stimulus cards for language assessment. This is compared with the score obtained by a stroke specialist who independently performs the NIHSS at the bedside. In clinical practice, personnel who assist during the telestroke consultation may not have had specific training in either the NIHSS or telestroke administration, but this variable of physician-extender experience during telestroke consultation has not been the subject of any of the reports.

Feasibility and Reliability of Performing Neurological Assessment Over Telestroke Systems

Nonacute Setting

There are data on the feasibility and reliability of conducting a general neurological evaluation over telemedicine compared with face-to-face consultation. One small study focusing on the feasibility and reliability of the neurological

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examination performed via telemedicine evaluated the interobserver agreement of the examination of eye movements, facial strength, tongue movements, motor strength, deep tendon reflexes, plantar responses, sensation, coordination, sitting balance, and gait as parts of the general neurological examination.[30] In 17 patients with a variety of neurological diseases, a standard face-to-face examination by neurological experts was compared with an HQ-VTC examination over a 384–kilobits per second ISDN system performed by house officers and scored by senior neurological trainees at a distance. It is not stated if the distant examiners could direct the bedside examination or ask for individual tests to be repeated. Interobserver agreement ranged from fair to nearly perfect (κ=0.21 to 1.00), with the poorest agreement in eye movements. They also compared the results of 2 face-to-face examinations. The level of agreement between HQ-VTC and face-to-face evaluations was almost identical to that between 2 face-to-face evaluations for all tested components of the examination except eye movements.

One study addressed patient and provider satisfaction with telemedicine outpatient consultation.[31] The majority of 86 patients felt confident with HQ-VTC examination, and only a few noted problems with audio quality or reported feeling "shy in front of the camera." In a similar study of 25 patients, the majority of users did not report difficulties in the use of the telemedicine equipment or interpretation of the findings and expressed confidence in the use of telemedicine.[32]

Class II Recommendation

1. HQ-VTC is reasonable for performing a general neurological examination by a remote examiner with interrater agreement that is comparable to that between different face-to-face examiners *(Class IIa, Level of Evidence B).*

Two studies addressed the feasibility and reliability of performing an NIHSS-telestroke in the nonacute setting, ie, patients who are beyond the time window for acute intervention. Shafqat et al[33] performed the first investigation of interrater agreement between NIHSS-bedside and NIHSS-telestroke when performed by stroke neurologists. Twenty patients with ischemic stroke (excluding unstable patients) were examined both at bedside and via HQ-VTC at full CIF of 30 frames per second using a point-to-point, ISDN telemedicine link at 384 kilobits per second and remote pan/tilt/zoom camera capability. The remote and bedside neurologists had no prior clinical knowledge of the patients, and each was kept blinded to the examinations and scores of the other. The telestroke examination was assisted by a bedside nurse. For the initial 10 patients, the remote assessment was performed first; for the remaining 10, the order was reversed. The NIHSS-telestroke was performed in an order designed to minimize the need for camera adjustments. NIHSS-bedside and NIHSS-telestroke scores ranged from 1 to 24. Thirty-one percent of NIHSS items showed excellent weighted κ agreement. This finding was consistent with prior clinical reports comparing 2 bedside examiners (see Table 3).[22,23] NIHSS-bedside and NIHSS-telestroke scores were strongly correlated (r=0.97, P<0.001). Mean telestroke examination time was slightly longer than bedside (9.70 versus 6.55 minutes; P<0.001).

Meyer et al[34] performed a study of interrater NIHSS-bedside and NIHSS-telestroke agreement using a videoconferencing system capable of either wired or wireless connectivity over public Internet with a pan/tilt/zoom-capable camera and performing the NIHSS-telestroke in the conventional order. Because of the ability to download and run the videoconferencing software on many personal computers with access to high bandwidth (either wired or wireless), the authors refer to this method as site independent. This Internet-based system allowed 400×300-pixel resolution at 750 kilobits per second. Junior and senior stroke neurologist examiners were compared to assess reliability. Twenty-five patients with stroke symptoms were examined both at bedside and via telemedicine by 2 NIHSS-certified neurologists. One examiner (bedside) examined the patients at the bedside; the second examiner (remote) performed scale evaluations via the STRokE DOC (Stroke Team Remote Evaluation using a Digital Observation Camera) system. The remote neurologist directed the examination assisted by the onsite neurologist rather than by a nonphysician assistant. Feasibility was shown with all NIHSS-telestroke examinations (25 of 25, 100%) performed successfully with wireless telemedicine. NIHSS-bedside and NIHSS-telestroke scores ranged from 1 to 16. Intraclass correlation coefficient was 0.94 for NIHSS and 0.95 for modified NIHSS. Using weighted κ coefficients, this trial showed the 67% of NIHSS items and 82% of modified NIHSS items had excellent agreement (Table 3).

Wiborg et al[35] demonstrated good to excellent agreement in testing 44 patients in a similar paradigm in which a remotely located stroke neurologist interviewed and examined the patient (depending on the patient's ability to cooperate) with the support of the local referring emergency physician. They used a standard HQ-VTC system and performed 2 other stroke severity scales used in Europe, the European Stroke Scale (weighted κ=0.72 to 0.95) and Scandinavian Stroke Scale (weighted κ=0.70 to 0.97). Some of these patients were examined within the first 24 hours of symptom onset.

In summary, stroke severity scales can be reliably administered over HQ-VTC. Items with the highest interrater reliability generally include level of consciousness and motor-related questions. Items with the lowest interrater reliability generally include facial palsy, ataxia, and dysarthria. These findings are similar to bedside reliability assessments.

Class I Recommendation

1. HQ-VTC systems are recommended for performing an NIHSS-telestroke examination in nonacute stroke patients, and this is comparable to an NIHSS-bedside assessment. Similar recommendations apply for the European and Scandinavian Stroke scales *(Class I, Level of Evidence A).*

Acute Stroke Setting, Including Thrombolytic Evaluation

The reliability of the NIHSS-telestroke in controlled environments such as the outpatient or nonacute setting does not necessarily imply reliability in the more chaotic environment

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in which acute stroke interventions such as thrombolytic therapy are provided. Wang et al[36] investigated the reliability of performing the NIHSS-telestroke in the acute setting either in the emergency department or during an inpatient hospital admission. A Web-based system using 1-way video transmitted from the bedside and plain old telephone service for audio communications was used to assess interrater reliability between neurologists. Twenty patients with acute ischemic stroke were examined at the bedside by a neurologist or via the telestroke system with the help of an assistant. The level of training of the assistant was not specified. The NIHSS-telestroke order was rearranged to reduce the need for camera manipulations, with items requiring close-ups performed before items requiring a zoomed-out view. NIHSS-telestroke scores ranged from 1 to 24. There was no difference of >3 points on total score between NIHSS and NIHSS-telestroke (r=0.9552, P=0.0001). This study suggests that performing the NIHSS-telestroke by this Internet-based technique is both feasible and reliable in the acute hospital and emergency department setting.

Handschu et al[37] assessed the German version of the NIHSS within 6 and 36 hours of stroke onset using a HQ-VTC system displaying 25 images per second in a view of a matrix made up of 384×288 pixels up to 768×576 pixels. NIHSS-bedside and NIHSS-telestroke scores were performed by stroke neurologists assisted by a trained medical student for the remote evaluations and ranged from 1 to 24 in 41 patients. Standard NIHSS sequencing was used, and ≈11.4 minutes was needed to perform the NIHSS-telestroke. Although no examination was aborted, there were minor issues with video (n=2), audio (n=5), and lighting (n=3), which required repetition of the NIHSS-telestroke in 2 cases. Weighted κ results showed excellent reliability for all 13 items in 41 patients examined within 36 hours of stroke onset (weighted κ=1.0) and in 12 patients examined within 6 hours (weighted κ=0.92). These 2 reports extended the feasibility and reliability of NIHSS-telestroke administered by telemedicine to the acute hospital environment and time period when therapeutic decisions are generally made.

Additional studies have been performed to assess the feasibility and reliability of NIHSS-telestroke during an actual acute stroke consultation when many additional human and environmental demands are present. Many hospitals struggle to complete the acute stroke evaluation in time for potential thrombolytic therapy, so it needed to be demonstrated that under these time-pressured conditions, the NIHSS-telestroke can still be performed swiftly and reliably. The feasibility of performing the NIHSS-telestroke during actual thrombolytic consultations has been demonstrated in multiple observational cases series. The originating sites (ie, clinical setting where the patient is physically located) include (1) a remote Maryland facility using ISDN connections and a restructured NIHSS-telestroke (23 telemedicine cases),[38] (2) an isolated Massachusetts island hospital (24 telemedicine cases),[39] (3) 12 German community hospitals within an ISDN network (1123 cases),[40] (4) 2 Texas community hospitals using a fiberoptic network (328 cases),[41] (5) 8 rural Georgia hospitals using a cell phone or regular telephone service for audio and a 1-way videoconferencing system (75 patients[42] and 194 patients[43]), and (6) 4 California community hospitals using HQ-VTC.[44]

Assessing NIHSS reliability during remote acute telestroke consultations is problematic because acute telestroke consults are generally performed when local neurological evaluations are unavailable. Without concurrent NIHSS-bedside examinations, interrater reliability cannot be directly assessed. Comparisons between patients examined by telestroke and others evaluated either at the bedside or by nontelemedicine techniques provide some insight into reliability in this setting. In a comparison of telestroke network hospitals and academic stroke centers, Audebert et al[45] recorded the NIHSS-telestroke (115 patients) in thrombolysis cases versus NIHSS-bedside (110 patients). Similar stroke severity scores were recorded in each group (median: NIHSS-telestroke, 12; NIHSS-bedside, 11). On the basis of these reports, performing the NIHSS during acute stroke consultation is feasible.

The recently reported STRokE DOC trial (design described previously[44]) compared decision making in acute stroke patients for thrombolytic eligibility using HQ-VTC with review of computed tomography (CT) images versus telephone consultation alone. It demonstrated that the accuracy of decision making by stroke neurologists via telestroke and assisted by the local referring physician is superior to that via telephone for patients with acute ischemic stroke when assessing their suitability for treatment with thrombolytics. Correct treatment decisions were made more often when telemedicine was used than telephone only (108 [98%] versus 91 [82%]; odds ratio, 10.9; 95% CI, 2.7 to 44.6; P=0.0009).[46] An ongoing clinical trial will further address the issue of reliability of the NIHSS-telestroke during acute stroke consultation (TRUST-tPA: Therapeutic Trial Evaluating Efficacy of Telemedicine [TELESTROKE] of Patients With Acute Stroke; NCT00279149).[47] We are not aware of any other published data that explore the reliability of other nonstroke experts performing an NIHSS-telestroke compared with a stroke specialist or a nonstroke expert at the bedside. Although this is fertile ground for further inquiry, we must limit our current recommendations to neurological assessments involving stroke specialists.

Class I Recommendation

1. The NIHSS-telestroke examination, when administered by a stroke specialist using HQ-VTC, is recommended when an NIHSS-bedside assessment by a stroke specialist is not immediately available for patients in the acute stroke setting, and this assessment is comparable to an NIHSS-bedside assessment *(Class I, Level of Evidence A).*

Feasibility and Reliability of Remote Assessment of Neuroimaging in Acute Stroke

All commercially available FDA-approved teleradiology systems produce images of sufficient quality for clinical interpretation. The application of teleradiology to acute stroke per se is a recent phenomenon. In 1990, the first mobile magnetic resonance imaging (MRI) scanner became available in the

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Netherlands, and teleradiology was used by MRI specialists to support local physicians. From 1992 to 1993, expert opinion was sought in 43 cases, or 3% of the total scanner volume, with suspected subacute cerebral ischemia or infarction listed by the expert reviewer as probably MRI artifact in 2 cases.[48] In 2000, Yamada et al[49] used a mobile phone system to analyze emergency department CT, MRI, and angiographic images in 100 patients to facilitate rapid triage. Among the 100 patients included, there was a broad range of neurological conditions, including, but not limited to, ischemic stroke. Although these authors found the system adequate to evaluate most conditions, they commented that localization of ischemic stroke on the transmitted images required knowledge of a patient's physical examination.[49]

Several studies have examined the reliability of CT interpretation in actual or simulated acute stroke encounters between different providers. In 2001, Johnston et al[50] compared blinded stroke neurologists' reading of CTs using 2 different methods (teleradiology and review of printed films on a light box) and the reference standard of a neuroradiologist review of printed films on a light box. Sixty head CTs obtained during consecutive acute stroke evaluations for thrombolytic therapy were used. Agreement among neurologists for eligibility for thrombolysis by image review on a light box versus teleradiology was excellent ($\kappa=1.0$). Compared with the neuroradiologist's review (ie, the reference standard), the neurologist's sensitivity was 100% (95% CI, 0.93 to 1.0) and specificity was 100% (95% CI, 0.40 to 0.98) using either teleradiology or light box. This pilot study provided evidence that neurologists with stroke expertise can assess head CT scans via teleradiology to determine eligibility for intravenous tPA eligibility.

In 2005, 12 hospitals in Bavaria established a stroke network with the stroke center in Munich-Harlaching and Regensburg.[51] The goal was to evaluate the safety and efficacy of using telestroke to increase the use of intravenous tPA for acute ischemic stroke in the community hospital setting. In this program, HQ-VTC was used in conjunction with review of the CT images. Hypodensity visible on CT was one of the primary reasons for withholding thrombolytic therapy in 250 of 356 ischemic stroke patients evaluated over a 13-month period.[51]

Schwamm et al[39] reported on data from 24 patients in whom compressed brain images were interpreted by the telestroke neurologist in a browser-based image viewer (AMICAS, Inc, Waltham, Mass) on a Pentium-based desktop personal computer equipped with a cathode-ray tube monitor set at 1024×768-pixel resolution. Independently, a neuroradiologist reviewed uncompressed images at a high-resolution (2000×2000 pixel) workstation for clinical interpretation (AGFA, Inc). Both readers were blinded to the other's interpretation. For the first 15 patients evaluated, a second neuroradiologist was later provided with a clinical summary and retrospectively performed an interpretation, blinded to all other interpretations. There was perfect agreement among all readers for detecting absolute imaging exclusions to intravenous tPA, although the number of exclusions was small. The potential exclusions included the presence of any intracranial hemorrhage (n=1; subtle subdural hematoma), brain tumor, or acute hypodensity greater than one third of the middle cerebral artery territory (n=0). The interrater agreement for subtler ischemic changes was more variable. Transmission of the head CT was delayed for technical reasons in 1 patient (4.1%), who presented beyond the time window for intravenous tPA.

However, these studies have not compared the accuracy of image interpretation by stroke neurologists or other nonradiologists as a function of their level of training and experience. Further high-quality studies are needed to define the minimum level of training and expertise required by an individual physician to achieve results in acute brain imaging interpretation similar to that of a stroke specialist.

Class I Recommendations

1. Teleradiology systems approved by the FDA (or equivalent organization) are recommended for timely review of brain CT scans in patients with suspected acute stroke *(Class I, Level of Evidence A).*
2. Review of brain CT scans by stroke specialists or radiologists using teleradiology systems approved by the FDA (or equivalent organization) is useful for identifying exclusions for thrombolytic therapy in acute stroke patients. *(Class I, Level of Evidence A).*
3. When implemented within a telestroke network, teleradiology systems approved by the FDA (or equivalent organization) can be effective in supporting rapid imaging interpretation in time for thrombolysis decision making *(Class I, Level of Evidence B).*

Feasibility and Effectiveness of Telemedicine Consultation for Enabling and Providing Recommendations in Favor of or Against the Use of Intravenous tPA in Patients With Suspected Acute Ischemic Stroke

Several groups have shown the feasibility of using telestroke consultation for enabling and providing recommendations in favor of or against the use of intravenous tPA in patients with suspected acute ischemic stroke, resulting in thousands of acute stroke evaluations and a substantially increased number of tPA administrations.[52] Many of these studies have been in small community hospitals without prior tPA experience or 24/7 neurology coverage.[38,39,41–45,47,53–56]

The number of centers using telestroke for acute stroke care, including recommendations regarding thrombolysis, is growing. Feasibility has been established using primarily uncontrolled case series from single or multiple sites. Most originating sites (ie, the facility where the patient is located) have been rural or community hospitals, with increasing adoption by urban centers that are without adequate onsite neurology coverage.

The safety of using telestroke consultation for providing recommendations in favor of or against the use of intravenous tPA in patients with suspected acute ischemic stroke has been studied generally via the safety of giving tPA to a patient with an acute ischemic stroke. The major safety outcome studied has been symptomatic intracerebral hemorrhage and in-hospital mortality. Safety has also been indirectly studied by determining a diagnosis other than acute ischemic stroke so

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that intravenous tPA would be contraindicated and thus potentially produce harm. The number of patients in whom tPA was overused or underused has not been reported.

The ability to identify stroke mimics in general and those patients with malingering, conversion reaction, or Munchausen's syndrome might be more difficult during telestroke evaluation than in person, but this has not been reported. By reviewing the video, Hess et al[43] recommended against treatment in 4 patients thought to have conversion disorders. There was no independent validation of this diagnosis. Recognition of nonvascular stroke-like syndromes has been evaluated in 3 studies. The rates of telestroke consultations yielding nonstroke diagnoses in these studies were 12%,[40] 16%,[53] and 30%.[39] In 1 study, the nonvascular origin was verified in the vast majority of identified cases.[40]

In 1 study, intravenous tPA protocol violations occurred in 15 of 106 cases (15%) during the first year of follow-up.[51] A second-year analysis found that patients who received tPA remotely after telestroke consultation had a nonsignificantly higher symptomatic intracerebral hemorrhage rate as defined by National Institute of Neurological Disorders and Stroke (NINDS) criteria (7.8% versus 2.7%; $P=0.14$) but a similar space-occupying parenchymal hemorrhage rate (PH2) as defined by the European Cooperative Acute Stroke Study (4.3% versus 2.7%; $P=0.72$) and similar in-hospital mortality rate compared with patients treated in established stroke centers (3.5 versus 4.5%; $P=0.74$).[45] On the basis of data from the Telemedic Pilot Project for Integrative Stroke Care (TEMPiS) study,[55] long-term mortality rates and functional outcomes (at 3 and 6 months) for patients at telestroke-enabled community hospitals using tPA were similar and comparable to the results of previous conventionally delivered tPA trials.[57] One hundred seventy patients were treated with tPA in the telestroke hospitals; 132 were treated in the stroke center hospitals. Mortality rates were 11.2% versus 11.5% at 3 months ($P=0.55$) and 14.2% versus 13% at 6 months ($P=0.45$). A good functional outcome after 6 months was found in 39.5% of patients at the telestroke hospitals versus 30.9% at the stroke centers ($P=0.10$) as defined by modified Rankin Scale (mRS) and 47.1% versus 44.8% ($P=0.44$) as defined by the Barthel Index (BI). These results reflect not just telestroke evaluation but also the formation of specialized stroke teams at the remote hospitals who underwent comprehensive stroke training, including thrombolysis management.

Limitations of the TEMPiS study include a cluster-control rather than randomized design and unblinded end-point assessment. Functional assessment at 6 months was missing in 1 of every 14 telestroke patients. Exclusion criteria included posterior circulation syndromes, very mild (NIHSS <5), or very severe strokes (NIHSS >20), thus limiting generalizability and comparability of their experience directly to published trials.

As described previously, the STRokE DOC trial compared HQ-VTC with telephone assessment for tPA eligibility assessment. Although the numbers of treated patients were small, intravenous thrombolytics were used at similar rates (28% telemedicine versus 23% telephone; $P=0.43$). The 90-day functional outcomes for the whole cohort were not different for the BI (95 to 100) (43% versus 54%; $P=0.13$) or mRS (34% versus 47%; $P=0.09$) score. There was no difference in overall mortality (19% versus 13%; $P=0.27$) or rates of intracerebral hemorrhage (7% versus 8%; $P=1.0$). Unadjusted mortality after treatment with thrombolytics was higher in the telemedicine group (39% versus 12%; $P=0.03$[17]), but this was no longer significant ($P=0.17$) when adjusted for the baseline NIHSS, which was much higher in the telemedicine group. Notably, there were more incomplete data in the telephone group than in the telemedicine group (12% versus 3%; $P=0.0001$). Only a portion of those treated with tPA were urgently transferred ("drip and ship"). No studies have specifically addressed the safety and efficacy of drip and ship versus drip and keep in a telestroke paradigm.

In summary, mortality after intravenous tPA recommended by a telestroke-supported stroke unit or by emergency department consultation appears to be similar to that in previous trials and clinical practice. A prospective, randomized controlled trial of telemedicine versus telephone suggests that similar intracerebral hemorrhage rate and functional outcomes can be achieved in comparable acute stroke populations.

Class I Recommendation

1. It is recommended that a stroke specialist using HQ-VTC provide a medical opinion in favor of or against the use of intravenous tPA in patients with suspected acute ischemic stroke when on-site stroke expertise is not immediately available *(Class I, Level of Evidence B).*

Telestroke Consultation Availability and Rates of Appropriate Use of Intravenous tPA

A report of the results of telemedicine consultation at 2 community hospitals in Houston compared rates of intravenous tPA over 13 months to the rate in the previous 13 months.[41] An *International Classification of Diseases*, ninth revision, clinical modification, review of ischemic strokes at these hospitals for the previous 13 months and during the telestroke project identified a prior treatment rate of 0.8%, increasing to 4.3% of all strokes during the telestroke project. Local programs highlighting telemedicine and stroke awareness, as well as stroke screenings, may have contributed to the improved treatment rates. The REACH (Remote Evaluation of Acute isCHemic stroke) program included telemedicine consultation to 8 hospitals in rural Georgia.[43] Over 15 months, 30 patients were treated with intravenous tPA from 194 acute telestroke consults. The total number of stroke patients at these hospitals during this interval was not reported. No prior monitoring of tPA treatment rates was noted, although the report suggests that tPA was not used previously at these sites.[42] Institution of telemedicine was accompanied by an educational course for the hospital staff involved in stroke care.

The TEMPiS project established HQ-VTC telestroke services to a network of 12 hospitals in Bavaria serviced by 2 hub stroke centers.[58] A report from the TEMPiS project reports a 10-fold relative increase in the thrombolysis treatment numbers at telestroke network hospitals compared with

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the 12-month period before the network was started (from 10 to 115 per year).[45] A similar increase was found in the prospective study of the same group in the telestroke network hospitals compared with hospitals without network implementation (4.6% versus 0.4% of all stroke patients during a 21-month period).[55]

The Telemedicine in Stroke in Swabia (TESS) project reported intravenous tPA treatment in 2 of 153 patients (1.3%) evaluated by HQ-VTC over 18 months but provided no prior treatment rate information.[53] A telemedicine service in Ontario treated 27 of 88 evaluated patients (31%) over 34 months but also provided no information regarding treatment rates before their telestroke project was started.[56]

LaMonte et al[38] compared treatment rates by HQ-VTC and telephone consultation at the same site over a 2-year period. Intravenous tPA was administered in 23.8% of 21 telemedicine consults and only 3.8% of 27 telephone consults. Assignment to the 2 different arms was biased and makes interpretation of differences difficult because telephone consults were used when the telemedicine system was not available but also when patients were outside the 3-hour time window or not considered eligible for acute stroke treatment. No information was provided regarding rate of treatments for all eligible patients or all stroke patients.

Schwamm et al[39] reported the results of telemedicine consultation services provided over 27 months to a hospital located on an island just off the Massachusetts coast. Twenty-four patients were evaluated by HQ-VTC. Intravenous tPA treatment was initiated in 6 of 10 patients (60%) presenting within 3 hours of stroke onset and in 6 of 8 (75%) in whom telestroke consultation was begun within 3 hours after onset. It is not stated whether this represents all the acute stroke patients evaluated at this hospital during this time. There were 106 admissions for ischemic stroke during the 27 months of intervention, with 6 of 106 (5.6%) of all patients treated with intravenous tPA. This was significantly increased compared with 0 of 100 patients with ischemic stroke admitted during the 2-year period before the intervention, despite emergency department availability of intravenous tPA and a written tPA protocol in place ($P=0.03$).

In many of these studies and in practice, significant education and training frequently accompany telemedicine services and may have contributed to a measured increase in tPA treatment. Specifically, there is limited evidence regarding the extent or duration of training of the bedside assistant and their levels of expertise. In some cases, these are physicians; in others, they may be licensed nurses, advanced practice nurses, or emergency medical technicians, and they may be trained specifically in the operation of the telestroke technology recognition or in the use of accepted scales for evaluation of suspected stroke. Further high-quality studies are needed to define the minimum educational requirements and level of medical and technology training necessary for the bedside assistant to be an effective partner in telestroke care delivery. This is especially important in light of the decreasing availability and increasing cost of providing trained physicians to staff emergency departments.

In addition, there are limited data on the impact of concerns by practitioners regarding medical liability on the implementation of telestroke support systems. This may also limit the rapid generalizability of telestroke, especially in the United States.

In summary, the rate of treatment of acute stroke patients treated with telemedicine is considerably higher than most reported intravenous tPA treatment rates at community hospitals. In most cases, the treatment rate applies only to patients evaluated by HQ-VTC rather than the total number of stroke patients or intravenous tPA–eligible patients presenting to those hospitals. Few studies recorded the total number of stroke patients evaluated at telestroke hospitals, making it impossible to calculate the rate of intravenous tPA treatment before and after the introduction of telestroke. However, it is unlikely that total ischemic stroke admissions increased dramatically during the intervention period compared with baseline; therefore, increases in raw rates of tPA use likely reflect increased percentages of all stroke admissions.

Class II Recommendation

1. Implementation of telestroke consultation in conjunction with stroke education and training for healthcare providers can be useful in increasing the use of intravenous tPA at community hospitals without access to adequate onsite stroke expertise *(Class IIa, Level of Evidence B).*

Telephone Consultation Availability and Rates of Appropriate Use of Intravenous tPA

Telephone contact with a neurologist or stroke team member is probably the most common means of acute stroke consultation currently in widespread use. The lack of adequate monetary compensation for emergency stroke evaluation and the limited number of stroke specialists available likely limit frequent or consistent 24/7 onsite consultation.

Frey et al[59] published a retrospective analysis of the use of telephonic consultation in acute stroke to select patients for intravenous tPA compared with a cohort of patients receiving tPA after in-person evaluation at the referral care center (53 tPA patients treated by telephone versus 73 tPA patients treated in person). In this experience, 43 community hospitals were provided with telephone assistance by the referral stroke center to select eligible patients for tPA thrombolysis on arrival in the emergency department. Patients treated by telephone were transported to the referral stroke center (mean distance, 277 miles) with infusion continued during flight transportation (flight time, 20 to 90 minutes). Treatment by telephone increased the number of patients treated with tPA at the referral stroke center by 72%. Although intravenous tPA use increased, the reported patient outcomes were poorer with telephone-based tPA care. There were similar rates of symptomatic intracerebral hemorrhage (6% versus 3%; $P=$NS) but significantly fewer discharges home, significantly more discharges to a skilled nursing facility, and a trend toward higher mortality (7% versus 1%; $P=0.08$).[59] The authors state that "stroke severity was lower in the in-house group, for which outcomes were more favorable, consistent with the difference in stroke types" (p 154). However, no initial stroke severity scores are reported, and there is no

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statistically significant difference in the stroke subtypes reported. The telephonically treated patients were older (67 versus 61 years; $P=0.04$), and it is possible that the differences in baseline characteristics in this retrospective cohort may account for part or all of the outcome differences.

Increased use of intravenous tPA has also been observed in a network of 20 hospitals.[60] In a third network of community hospitals located within 100 miles of Saint Luke's Stroke Center in Kansas City, 53 of 142 tPA-treated patients had tPA treatment initiated in the referring hospital after telephone consultation, and these patients had an acceptable hemorrhage rate.[61] Comparing the patients transferred after intravenous tPA with those receiving intravenous tPA at the tertiary referral center showed that there were no differences in mortality, percentage with NIHSS <6, or length of stay.[62] In a retrospective study of the safety of intravenous tPA using telephonic expert guidance in a rural community hospital linked to the University of Kentucky Medical Center,[63] symptomatic intracerebral hemorrhage occurred in 3 of 121 consecutive patients (2.5%), and mortality was 7.5%. Forty-seven percent of patients were discharged home. There were no controls in this study.

In summary, implementation of a stroke center telephone consultation service in conjunction with stroke education and training for healthcare providers may increase the use of intravenous tPA at community hospitals without access to adequate onsite stroke expertise. However, there are limited data on to the safety and efficacy of this approach.

Class II Recommendation

1. Compared with traditional bedside evaluation and use of intravenous tPA, the safety and efficacy of intravenous tPA administration based solely on telephone consultation without CT interpretation via teleradiology is not well established *(Class IIb, Level of Evidence C).*

Feasibility, Safety, and Effectiveness of Using Telemedicine Consultation for Enrollment Into Acute Stroke Clinical Trials

By increasing access to expert stroke specialists, a telemedicine videoconferencing system has the potential acutely and remotely to select patients for inclusion in clinical trials. Although there are several trials using telemedicine as part of the study intervention, to the best of our knowledge, there are currently no acute stroke clinical trials specifically testing the hypothesis of whether the use of HQ-VTC telestroke can increase enrollment into clinical trials. There are insufficient data to support a recommendation regarding the use of HQ-VTC. However, the completed Field Administration of Stroke Therapy–Magnesium (FAST-MAG) Pilot Trial has demonstrated the feasibility of enrolling patients via cellular telephone–based screening and consent into a hyperacute neuroprotective trial before hospital arrival.[64]

Class II Recommendation

1. Prehospital telephone-based contact between emergency medical personnel and stroke specialists for screening and consent can be effective in facilitating enrollment into hyperacute neuroprotective trials *(Class IIa, Level of Evidence B).*

Subacute Stroke Treatment and Secondary Prevention (Hospital Based)

Feasibility and Effectiveness of Telemedicine Within Organized Systems of Stroke Care

This section focuses on the use of HQ-VTC to support organized inpatient stroke care or stroke units, which are one of the most widely available and best supported evidence-based stroke recommendations.[65] Both primary and comprehensive stroke centers should have personnel, programs, expertise, and infrastructure to rapidly triage acute stroke patients, to implement acute therapies (such as intravenous tPA), and to admit stroke patients into dedicated stroke units.[66] For many rural areas, limited availability of physicians and therapists with stroke expertise may be a primary barrier to achieving and maintaining a specialized stroke center. Stroke specialists are needed to recognize stroke mimics and high-risk patients, to assist in selecting appropriate acute and subacute treatments, and to select patients who may benefit from interventions available only at comprehensive stroke centers. Expertise may also be needed for in-hospital subacute care to determine stroke origin and optimal secondary prevention, as well as guidance of a multidisciplinary approach to early stroke rehabilitation and prevention of complications.

The TEMPiS study reviews the experience of two comprehensive stroke centers that partnered with 12 regional hospitals that had no stroke units before network implementation.[40] In addition, data were collected from nonparticipating control hospitals. The formation of the stroke teams at each regional center was supported by the 2 comprehensive stroke centers through an intensive stroke education program and financial support from the regional insurance carriers to hire additional dedicated therapists and place them at the regional community hospitals. Because most of the regional hospitals had no inpatient neurology service, specific indications for inpatient telestroke unit consultations were defined in advance, and the telestroke program provided the neurological expertise required to run the stroke units at the smaller regional hospitals.

The high rate of patients presented for telestroke consultations (38%)[40] and the significant number of patients treated with thrombolysis[55] appear to support the mutually beneficial relationship between dedicated stroke care units and telestroke networks. Hospitals with telestroke access to stroke expertise and dedicated stroke units had significant improvements in quality of care and neurological outcomes compared with those hospitals that were not included in the telestroke network and did not have telestroke access or stroke units.[54] Patients in telestroke network hospitals had a 38% lower odds ratio of a poor outcome defined as severe disability, institutional care, or death.[54]

Class I Recommendation

1. When the lack of local physician stroke expertise is the only barrier to the implementation of inpatient stroke

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units, telestroke consultation via HQ-VTC is recommended *(Class I, Level of Evidence B).*

Rehabilitation

Feasibility and Effectiveness of Telemedicine Consultation for Performing Assessments of Disability After Stroke

Very little research has been published regarding the feasibility and reliability of disability scales in stroke patients via HQ-VTC. The few studies available are small pilot trials, generally use lower-quality video systems, and are generally not specific to stroke patient populations.

Occupational Therapy and Allied Health Providers

Dreyer et al[67] performed a feasibility study on 4 elderly volunteers with reported difficulties in independent living skills. They compared in-person and Internet-based assessment using 2 standardized evaluations tools: the Kohlman Evaluation of Living Skill and the Canadian Occupational Performance Measure. They used a low-bandwidth system (20 kilobits per second), a headset, a videocamera, a portable telephone, and a modem on the patient side. On the occupational therapy side were a video monitor, computer, and keyboard. For the Kohlman Evaluation of Living Skill, the offsite occupational therapist scored 1 subset differently, but the Canadian Occupational Performance Measure yielded identical scores. They concluded that the low-bandwidth video images were insufficient to measure fine motor movement but that the audio quality was excellent.[67]

Guilfoyle et al[68] investigated assessments across multiple allied health fields comparing in-person and videoconferencing assessments. In this study, a HQ-VTC videoconferencing unit connected by a 384–kilobit per second ISDN line was established in a rural long-term care facility. Twelve elderly volunteers and a nursing assistant participated in videoconference assessments. The scheduling of assessments was balanced (6 underwent in-person evaluations first and 6 underwent videoconferencing first). All subjects were assessed by allied health therapists specializing in dietetics, occupational therapy, physiotherapy, podiatry, and speech pathology. Assessment led to the generation of a care plan for each setting. In the absence of a standard reference, 2 independent, blinded raters compared the care plans. The 2 raters agreed that care plans were the same in only 35 of 60 assessments ($\kappa=0.31$). In addition, therapists rated the in-person assessments more efficient and suitable than the videoconference assessments. Although the correlation between settings was poor, interpretation of these findings is limited by several methodological flaws: One therapist performed both in-person and offsite assessments, and there was no training of the therapist to perform assessments by videoconferencing not needed in an agreement assessment.[68]

Physical Therapy

The majority of the telemedicine literature related to stroke uses in-person motor assessments to establish the efficacy of virtual reality–based interventions and does not address the use of HQ-VTC to administer standardized disability scales. Much of the literature focuses on the use of computer-generated virtual or simulated environments in which a subject's movements in real 3-dimensional space are represented on a display screen. These so-called virtual reality systems simulate a real-world environment via computer software, and movements are practiced by the user through a human-machine interface.[69]

In a normal volunteer study of disability, Russell et al[70] investigated the reliability of observational kinetic gait assessment performed via a low-bandwidth Internet link (using a personal computer with a Web camera connected at 18 or 128 kilobits per second). Twenty-four volunteers underwent evaluation by a modified Gait Assessment Rating Scale (a 17-item 4-point gait quality scale), which was recorded by full-resolution video. The video clips were then accessed online, establishing an interrater reliability (intraclass correlation of 0.92 and intrarater reliability of 0.96 comparable across different Internet speeds.[70]

A single study established the feasibility and accuracy of physical assessments for stroke patients via HQ-VTC. Physical therapists (PTs) administered the European Stroke Scale and the Functional Reach Test to 26 subjects with a history of stroke, both face to face and remotely, via an HQ-VTC connected at 384 kilobits per second. Patients were randomized to remote or face-to-face administration groups. Each patient was simultaneously rated by both the face-to-face and remote PTs blinded to the ratings. Equivalence was set at the 95% limits of agreement. When the face-to-face PT directed the patient, the 2 PTs reported equivalent values in >90% of the patients for the Functional Reach Test and for all European Stroke Scale components, with the exception of gait (83%) and maintaining leg position (85%). When the remote PT directed the patient, the 2 PTs reported equivalent values in >90% of the patients for the Functional Reach Test and >83% for all European Stroke Scale components.[71]

Speech and Language Pathology

In contrast to the fields of occupational therapy and physical therapy, the level of evidence for stroke-related speech and language assessments via HQ-VTC is more convincingly established. In 2004, Brennan et al[72] published one of the first studies comparing traditional face-to-face speech and language evaluation to HQ-VTC assessment using the story retelling procedure. Although there was a mixed patient population, this study included 14 right hemispheric and 14 left hemispheric stroke patients within 1 year of symptom onset. This study used real-time audio and HQ-VTC while using a computerized story retelling program via a 10–megabyte per second local area network connection. There was no significant difference between the ratings from the 2 settings ($P=0.05$ by paired t test).[72]

In a well-designed pilot study, Hill et al[73] assessed 19 speakers with dysarthria face to face and via an Internet-based application (real-time videoconferencing at 128 kilobits per second and the transfer of store and forward audio and video between patient and speech and language pathologist). Subjects were assessed with dysarthria ratings: Frenchay Dysarthria Assessment, dysarthria severity rating, perceptual speech battery, and the Assessment of Intelligibility of Dysarthric Speech.

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The interrater reliability for these measures is ρ=0.72, 0.90, 0.57 to 0.85, and r=0.90, respectively. However, because this study included only 2 stroke patients of 19 total subjects, its generalizability to the stroke population may be limited.[73]

In a separate study, Palsbo[74] used a randomized, double-crossover agreement study of 24 poststroke patients randomized to a remote or face-to-face administration of a subset of the Boston Diagnostic Aphasia Examination and to remote or face-to-face assessment of speech comprehension, speech expression, and motor speech. The HQ-VTC equipment was operated at a transmission speed of 384 kilobits per second. Each patient was simultaneously scored by both the face-to-face and remote speech and language pathologists in a blinded fashion. Percentage agreement within the 95% limits of agreement ranged from 92% to 100% for each functional communication measure.[74]

Class I Recommendation

1. Assessment of occupational, physical, or speech disability in stroke patients by allied health professionals via HQ-VTC systems using specific standardized assessments is recommended when in-person assessment is impractical, the standardized rating instruments have been validated for HQ-VTC use, and administration is by trained personnel using a structured interview *(Class I, Level of Evidence B).*

Feasibility and Effectiveness of Telephonic Consultation for Performing Assessments of Disability After Stroke

Many stroke patients undergoing rehabilitation often require a range of therapies over extended periods of time, which frequently necessitate changes in venue. A feasible and reliable assessment tool is essential to establishing effectiveness of therapy. The use of telephone follow-up to establish the level of disability can be helpful in clinical practice and research. Whereas a wide variety of stroke outcome scales have been developed and validated, only those high-quality studies establishing reliability for telephonic administration are discussed in detail.

Of the quoted references, only 2 studies that test the reliability of the BI in stroke patients when administered over the telephone have been published in full. The BI, 10-item scale that assesses the level of independence for activities of daily living, is a frequently used. An early small study in stroke patients yielded a positive correlation between raters in person and over the telephone but used trends rather than reliability statistics.[75] In another study of 391 subjects, more than half of whom were stroke patients, the BI performed well when administered on the telephone, with an intraclass correlation of 0.89 compared with in person.[76]

The mRS is widely used in stroke research as an outcome measure, not infrequently collected by the telephone.[77] In their editorial, Newcommon et al[78] emphasized that administering the mRS over the telephone may lead to low interrater reliability (κ=0.03). NINDS investigators found an improved interrater reliability when administered by an experienced rater using dichotomized outcomes (mRS≤1, κ=0.78; mRS≥2, κ=0.74).[79] Wilson et al[80] showed that the mRS given as a structured interview (which can be delivered via the telephone) results in a higher interrater reliability than when obtained in person without a structured approach (weighted κ=0.93).

The Functional Independence Measure (FIM), a validated disability rating scale, is generally used in the rehabilitation setting. This 18-item, 7-level scale is used to assess the need for assistance in activities of daily living in 6 areas: self-care, sphincter control, transfers, locomotion, communication, and social cognition. The FIM has good interrater agreement, test-retest reliability, and validity in stroke patients.[81,82] Smith et al[83] performed a blinded comparison of in-person versus telephone FIM ratings in patients with stroke, demonstrating a total FIM intraclass correlation of 0.97 and intraclass correlation ranging from 0.85 to 0.98 for FIM subscales (except for social cognition, which showed poor correlation). Very similar correlations were found when the FIM was administered to a patient proxy (caregiver) via the telephone.[84]

The Stroke Impact Scale was developed with extensive psychometric testing and has no significant floor or ceiling effect.[85] This 59-item questionnaire contains the following domains: strength, hand function, activities of daily living/instrumental activities of daily living mobility, emotion, memory, concentration, and social participation. Kwon et al[86] have shown that it is feasible to administer the Stroke Impact Scale at 12 weeks after stroke and the mRS at 16 weeks after stroke via telephone. Telephone survey administration yielded a higher response rate, less bias in responder selection, and higher test-retest reliability than a mail-in survey.[87]

In summary, the feasibility and reliability of telephonically administered stroke disability scales have been established to a reasonably high level of evidence for the BI, mRS, and Stroke Impact Scale. The interrater reliability may be improved by the use of experienced raters and structured interviews. The use of a patient proxy may add considerable variability.

Class I Recommendation

1. Telephonic assessment for measuring functional disability after stroke is recommended when in-person assessment is impractical, the standardized rating instruments have been validated for telephonic use, and administration is by trained personnel using a structured interview *(Class I, Level of Evidence B).*

Feasibility, Safety, and Effectiveness of Providing Telemedicine-Enabled Poststroke Rehabilitation

Telerehabilitation is defined as the ability to provide distance support, evaluation, and intervention to persons who are disabled via telecommunication and is a subcategory of the wider area of telemedicine.[88] Access to services and quality of care were key factors in the development of telerehabilitation. The unfortunate reality is that many stroke survivors who complete inpatient rehabilitation have restricted access to outpatient rehabilitation services, especially those who reside in rural locations.[89] Telerehabilitation has the potential to provide timely and efficient postacute care for stroke patients beyond the hospital and into an individual's home so that clinicians are able to monitor the patient's health status

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and to identify conditions that need improvement before complications or adverse complications ensue, eventually improving patient function while reducing long-term disability and costs.[88] A few nursing studies have emerged in the literature that explored the use of videoconferencing and telemedicine technologies with stroke survivors and their caregivers.[90–93] Although these studies provide some preliminary evidence of satisfaction and feasibility of these technologies, more work is needed to demonstrate the efficacy of these methods in promoting in home rehabilitation. A recent systematic review of the application of telerehabilitation services for stroke patients yielded only a small number of studies. This small number of studies, discussed in detail below, delineates the extent to which telerehabilitation is feasible for stroke patients.

Feasibility of Telemedicine by PTs/Occupational Therapists in Community-Based Rehabilitation

Videoconferencing applications have been found to be feasible in community-based stroke rehabilitation. In a sample of 21 stroke patients living at home in Hong Kong, Lai et al[88] developed an 8-week intervention program—1 session per week and 1.5 hours per session that consisted of conversations about education, exercise, and social support—at a community center for community-dwelling stroke patients. The program was performed by a PT through a videoconference link, and a nonprofessional assistant was located at a community center to operate the equipment. The education element included signs and symptoms of stroke and the pathophysiology of stroke; the exercise program focused on improving balance and strength, involving mainly leg muscles. The study participants were asked to exercise at their home ≥3 times per week.[88] After the 8-week intervention, a significant improvement was found in the Berg Balance Test (mean improved score, 42.2 to 49.0), all subscales of the Medical Outcomes Study 36-Item Short Form, the State Self-Esteem Scale, and a stroke knowledge test. These findings demonstrated the feasibility and safety of using videoconferencing for community-based stroke rehabilitation.

Similarly, a separate study demonstrated the feasibility of using videoconferencing technology for delivering multifactorial, in-home rehabilitation intervention for community-dwelling adults who had recently been prescribed a mobility aid.[94] The intervention used regular telephone service to provide low-quality 2-way video and audio interaction between the occupational therapist and patient regarding prescription and/or training in functionally based exercises,

Table 4. Summary of Recommendations

Class I recommendations

1. High-quality videoconferencing systems are recommended for performing an NIHSS-telestroke examination in nonacute stroke patients, and this is comparable to an NIHSS-bedside assessment. Similar recommendations apply for the European and Scandinavian Stroke scales (Class I, Level of Evidence A).
2. The NIHSS-telestroke examination, when administered by a stroke specialist using high-quality videoconferencing, is recommended when an NIHSS-bedside assessment by a stroke specialist is not immediately available for patients in the acute stroke setting, and this assessment is comparable to an NIHSS-bedside assessment (Class I, Level of Evidence A).
3. Teleradiology systems approved by the FDA (or equivalent organization) are recommended for timely review of brain CT scans in patients with suspected acute stroke (Class I, Level of Evidence A).
4. Review of brain CT scans by stroke specialists or radiologists using teleradiology systems approved by the FDA (or equivalent organization) is useful for identifying exclusions for thrombolytic therapy in acute stroke patients (Class I, Level of Evidence A).
5. When implemented within a telestroke network, teleradiology systems approved by the FDA (or equivalent organization) are useful in supporting rapid imaging interpretation in time for thrombolysis decision making (Class I, Level of Evidence B).
6. It is recommended that a stroke specialist using high-quality videoconferencing provide a medical opinion in favor of or against the use of intravenous tPA in patients with suspected acute ischemic stroke when on-site stroke expertise is not immediately available (Class I, Level of Evidence B).
7. When the lack of local physician stroke expertise is the only barrier to the implementation of inpatient stroke units, telestroke consultation via high-quality videoconferencing is recommended (Class I, Level of Evidence B).
8. Assessment of occupational, physical, or speech disability in stroke patients by allied health professionals via high-quality videoconferencing systems using specific standardized assessments is recommended when in-person assessment is impractical, the standardized rating instruments have been validated for high-quality videoconferencing use, and administration is by trained personnel using a structured interview (Class I, Level of Evidence B).
9. Telephonic assessment for measuring functional disability after stroke is recommended when in-person assessment is impractical, the standardized rating instruments have been validated for telephonic use, and administration is by trained personnel using a structured interview (Class I, Level of Evidence B).

Class II recommendations

1. High-quality videoconferencing is reasonable for performing a general neurological examination by a remote examiner with interrater agreement comparable to that between different face-to-face examiners (Class IIa, Level of Evidence B).
2. Implementation of telestroke consultation in conjunction with stroke education and training for healthcare providers can be useful for increasing the use of intravenous tPA at community hospitals without access to adequate onsite stroke expertise (Class IIa, Level of Evidence B).
3. Compared with traditional bedside evaluation and use of intravenous tPA, the safety and efficacy of intravenous tPA administration based solely on telephone consultation without CT interpretation via teleradiology are not well established (Class IIb, Level of Evidence C).
4. Prehospital telephone-based contact between emergency medical personnel and stroke specialists for screening and consent can be effective in facilitating enrollment into hyperacute neuroprotective trials (Class IIa, Level of Evidence B).
5. Delivery of occupational or physical therapy to stroke patients by allied health professionals via high-quality videoconferencing systems is reasonable when in-person assessment is impractical (Class IIa, Level of Evidence B).

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environmental modifications, and assistive technology. Data presented on 13 patients (mean age, 58.2 years) indicated that on average 13.1 mobility/self-care problems per patient were identified and an average of 12.5 recommendations per patient were made to address these problems.[94]

In summary, the findings suggest that HQ-VTC for telerehabilitation is feasible for delivery of in-home rehabilitation care.

Class II Recommendation

1. Delivery of occupational or physical therapy to stroke patients by allied health professionals via an HQ-VTC systems is reasonable when in-person assessment is impractical *(Class IIa, Level of Evidence B).*

Conclusion

This new statement provides a comprehensive and evidence-based review of the scientific evidence supporting the use of telemedicine for stroke care delivery organized by the stroke systems of care model. A summary of the recommendations organized by Class of Evidence is presented in Table 4.

Disclosures

Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honoraria	Expert Witness	Ownership Interest	Consultant/Advisory Board	Other
Lee H. Schwamm	Massachusetts General Hospital	Site PI for Forrest (multicenter clinical trials in thrombolysis)†; NIH-IMS3*; CDC†	None	None	Occasional expert review of medical records* None are related to telemedicine	None	Massachusetts Department of Public Health Stroke Systems Consultant†; CoAxia, Inc†; CryoCath, Inc*; RTI*; Phreesia, Inc† No commercial activities related to telemedicine	None
Robert G. Holloway	University of Rochester Medical Center (NY)	NIH†	None	None	None	None	Milliman, Inc* (review neurological guidelines for content and accuracy)	None
Pierre Amarenco	Denis Dierot University–Paris VII	Boehringer Ingelheim† (drug supply for the TRUST-tPA Trial)	None	Pfizer,* Sanofi-Aventis *	None	None	Pfizer*; Sanofi-Aventis*; Daiichi-Sankyo*	None
Heinrich J. Audebert	Center for Stroke Research, Charité Universitätsmedizin Berlin, Campus Benjamin Franklin, Berlin, Germany	German Federal Ministry of Research to Hospital,† Boehringer Ingelheim,* Meytec GmbH*	None	Boehringer Ingelheim Pharma GmbH* (manufacturer of thrombolysis agent and platelet inhibitor for secondary prevention of stroke), Meytec Gmbh* (manufacturer of telemedicine equipment), BMS* (manufacturer of platelet inhibitor for secondary prevention of stroke)	None	None	German Competence Network Stroke Board of Directors* (funded by the German Federal Ministry for Education and Research– BMBF) (role is coordinator of the subnet "Telemedicine in Acute Stroke"), no conflicts of interest with this activity	None
Tamilyn Bakas	Indiana University School of Nursing	None	None	None	None	None	None	None
Neale R. Chumbler	Department of Veterans Affairs, HSR&D Center for Implementing Evidence-Based Practice, Indianapolis VAMC and Department of Sociology, Indiana University School of Liberal Arts	PI of investigator-initiated grant funded by Rehabilitation Research & Development Division of Department of Veterans Affairs, "Home-Based Tele-Health Stroke Care: A Randomized Trial for Veterans"† (components of this grant do not conflict with duties on this committee)	None	None	None	None	None	None
Rene Handschu	Friedrich Alexander Universitaet	None	None	Boehringer Ingelheim,* Sanofi Aventis*	None	Siemens Co*	None	None
Edward C. Jauch	Medical University of South Carolina	Novo Nordisk*	None	Genentech*	None	None	Genentech*; Novo Nordisk*	None
William A. Knight IV	University of Cincinnati	None	None	None	None	None	None	None

(*Continued*)

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Writing Group Disclosures, Continued

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honoraria	Expert Witness	Ownership Interest	Consultant/Advisory Board	Other
Steven R. Levine	Mount Sinai School of Medicine	Gaisman Aware Grant for telestroke research (Gaisman Foundation)*	None	American Academy of Neurology Annual Meeting Course* (telemedicine for stroke)	Expert witness in medicolegal case involving stroke Medlink*	None	NXY 059 AstraZeneca* (no longer active)	None
Marc Mayberg	SwedishNeuroscience Institute	NIH–Mechanisms of Blood Brain Barrier Disruption,† NINDS R01, NS046513-01*	Swedish Foundation Grant to establish collaborative MGH–Swedish Telestroke Program† (these funds support capital equipment acquisition to develop regional telestroke network)	None	None	Cerevision† (this company is developing workflow software to facilitate rapid stroke diagnosis and treatment, $10 000 stock option)	None	None
Brett C. Meyer	University of California, San Diego, School of Medicine	PI of NIH-funded Stroke Team Remote Evaluation Using a Digital Observation Camera (STRokE DOC) clinical trial, NIH (P50 NS044148)†	None	Boehringer Ingelheim (past)*	None	None	Boehringer Ingelheim*; Genentech*	None
Philip M. Meyers	Columbia University, College of Physicians and Surgeons–New York Presbyterian Hospitals	None	None	None	None	None	None	None
Elaine Skalabrin	University of Utah	None	None	Genentech*; Boehringer Ingelheim*	None	None	None	None
Lawrence R. Wechsler	University of Pittsburgh Medical Center	AstraZeneca*; Boehringer Ingelheim*; Boston Scientific*; NMT Medical*	None	Bristol Myers Squibb*	None	None	AstraZeneca*; Atherosys*; ImaRx*; NMT Medical*; Nuvelo*; ReNeuron*; Sage Medical*	None

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

*Modest.

†Significant.

Reviewer Disclosures

Reviewer	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honoraria	Expert Witness	Ownership Interest	Consultant/ Advisory Board	Other
Seemant Chaturvedi	Wayne State University	None	None	None	None	None	None	None
Scott Kasner	Hospital of the University of Pennsylvania	None	None	None	None	None	None	None
Paul McMullan	Ochsner Medical Center	None	None	None	None	None	None	None
Karen Rheuban	University of Virginia	FCC grant for rural broadband for acute stroke access†	Medicare Health IT grant for acute stroke telehealth program†	None	None	None	None	None

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

*Modest.

†Significant.

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