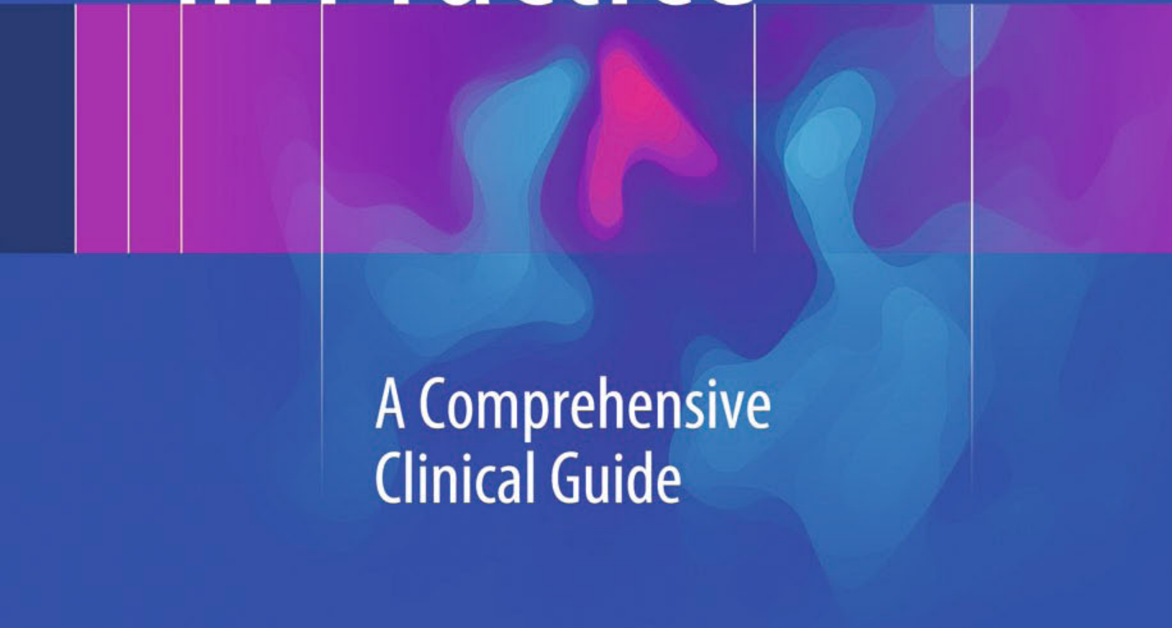
Jack W. Tsao
Bart M. Demaerschalk *Editors*

Teleneurology in Practice

A Comprehensive Clinical Guide



Springer

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For our families (Joan, Emmanuel, and Veronica Tsao and Sherry and Nicholas Demaerschalk)

Preface

Teleneurology in Practice: A Comprehensive Clinical Guide was inspired by the faculty and learner discourse which occurred during the annual courses on teleneurology we directed for the American Academy of Neurology from 2012 to 2014. The book was written with the objective of enabling medical professionals practicing in the broad field of the clinical neurological sciences to swiftly learn about the existing evidence, proven applications, operational methods, and the latest trends in the rapidly growing and evolving practice method of leveraging technology to care for patients at a distance. The field of neurology, even more quickly than other disciplines of medicine, is implementing the technological advances and discoveries of the science of healthcare delivery to address issues of access, efficiency, timeliness, quality, outcomes, and cost.

For patients in remote and underserved areas, having an acute or chronic neurological condition may necessitate lengthy and costly travel to obtain specialist evaluation. Telemedicine has the capability to deliver such care directly to a patient's local community. Neurology telemedicine for acute stroke has already demonstrated reliability, validity, efficacy, safety, and both clinical and cost effectiveness by preventing unnecessary ground and air ambulance transfer, by increasing the thrombolysis treatment for eligible patients, and by reducing the resulting neurologic disability. The US military has a limited number of neurologists. Development of a store and forward consultation system has enabled military neurologists to deliver far-forward battlefield care for service members deployed overseas and to combat zones. The chapters in this book will review the use of telemedicine for the evaluation and treatment of patients with many common neurological conditions and will provide a practical guide for neurologists seeking to incorporate telemedicine into their daily practices.

Readers will note that chapters discuss subspecialty areas within neurology and neurosurgery where telemedicine is already making or is anticipated to make an impact. The chapter authors were asked to summarize the existing evidence, current practice, key findings, central issues, and common operations for telemedicine in their areas of expertise in order to enable this book to serve as a guide for busy clinicians managing patients using telemedicine. To address a wide readership, initial chapters focus on the practice of neurology telemedicine in the USA, other countries in the world, the US military, and technology which can be used to establish a teleneurology practice. The subsequent chapters focus on accepted telemedicine sub-specialty areas of neurological practice, including stroke, neurocritical care, interventional neuroradiology, neurosurgery, hospitalist neurology, Parkinson's disease, and neuropathology. This is followed by chapters addressing emerging areas of practice, including epilepsy, sleep medicine, dementia, and concussion. The final chapters address telemedicine in neurological education, legal aspects of practice, and reimbursement.

We would like to thank our respective families for their support in the writing and editing process and Richard Lansing, who was the initial publishing editor on other books we have edited and who convinced us to become the editors for this book.

The readers will recognize that the authors and coauthors were carefully selected for their leadership, expertise, experience, and early contributions to this emerging field of practice. We thank each of them for their valuable contributions. Finally, as some of the authors of this book are US military officers or government employees, it remains for us to issue a blanket disclaimer:

The opinions or assertions contained herein are the private views of the authors and are not to be construed as official or as reflecting the views of the Departments of the Navy or Army, the Department of Defense, or the Department of Veterans Affairs.

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Teleneurology in the US Veteran Health Administration

Larry E. Davis, Nina I. Garga, Molly K. King, Stephanie Chen and Karen L. Parko

Abbreviations

CVT	Clinical video telehealth
CCHT	Care coordination/home telehealth
HAT	Home automated telemanagement
SCAN-ECHO	Specialty care access network-extension for community healthcare outcomes
CBOC	Community-based outpatient clinic
VA	Veterans administration
VHA	Veterans Health Administration
ER	Emergency room

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ECoE	Epilepsy Centers of Excellence
MSCoE	Multiple Sclerosis Centers of Excellence
PADRECC	Parkinson Disease, Research, Education, and Clinical Centers
PNES	Psychogenic non-epileptic seizures
MS HAT	Multiple sclerosis home automated telemanagement
CPRS	Computerized patient record system
MRI	Magnetic resonance imaging
CT	Computed tomography
UPDRS	Unified Parkinson's disease rating scale

Introduction

Enormous progress has been made in telemedicine in the past 108 years since Willem Einthoven demonstrated the feasibility of transmitting heart sounds by telephone [10]. Today all US states and many countries have telehealth programs. Telehealth programs use electronic information and telecommunication technologies to deliver distant clinical health care, patient and professional health-related education, and information about public health and health administration. In the USA, most large telemedicine programs are located in major academic medical centers, military, and the Veteran Health Administration (VHA). This chapter will focus on the VHA.

The VHA is the largest integrated health care system in the USA [6]. (It provides care to over 5.6 million eligible veteran patients annually via 152 veterans administration (VA) medical centers [7]). Since the VA is responsible for delivery of health care to all eligible veterans, there is a challenge to deliver care to those that reside at a distance from a major VA medical center. Currently, over 3.4 million enrolled eligible veterans live in rural areas representing 41 % of all veterans enrolled in the VA health care system [21, 22]. Chronic medical conditions or disabilities are present in 27 % of these veterans [4]. Old age is another factor in rural veterans as 68 % of veterans are older than 55 years, 41 % are 65 years or older [21], and 1.4 million were aged 85 years or more [6].

Studies demonstrate many of these veterans' health care needs are not being adequately met [33]. To address the rural needs, the VA expanded its outreach health programs and added 1100 community-based outpatient clinics (CBOCs) located mainly in the rural parts of each state [7].

In addition, VHA embraced telehealth and extended the scope of telemedicine to include patient and provider educational instruction and electronically transmitted images from distant sites to a major medical center called store and forward telehealth. Telemedicine was expanded to include both clinical video and home telehealth patient encounters. For fiscal year 2012, VA delivered over 250,000 clinical video telehealth visits, over 70,000 VA home telehealth encounters, and about 250,000 VA store and forward activities. [7].

Neurologists, along with other medical specialists, also face this largely unmet challenge to deliver quality medical care to individuals living remotely in the USA. In the USA, over 2500 rural counties have an unacceptable ratio of both primary care providers and medical specialists (projection of physician supply in the USA: Rockville, MD: US Department of Health and Human Services [25]). In 2005, urban towns had a ratio of 1 medical specialist to 2.4 general physicians. However, small and isolated rural communities had a ratio of only 1 specialist to 12 generalists [13]. Neurology, a specialty largely concentrated in major cities, makes it difficult for rural patients to receive good continued care for chronic neurologic problems. As such, they often rely on local general providers for ongoing care.

Does the lack of neurologists affect the quality of care to patients with neurologic problems? The UK performed a study comparing patients from the same area seen by either remote general practitioners or neurologists. The study showed neurologists made fewer uncertain diagnoses, caused fewer hospital admissions, ordered fewer diagnostic tests, prescribed fewer drugs, requested fewer other specialty consultations, and requested fewer follow-up visits. The study concluded that neurologists provided better, more efficient, and less expensive management [24]. In the USA, the American Board of Medical Specialties no longer requires internal medicine or family medicine residents to complete training in neurology. Thus, many primary care physicians are less prepared to make neurological diagnoses and manage their treatment.

VHA neurologists have a similar challenge. Although most large VHA medical centers house excellent neurologists, they are located in major cities and seldom travel to rural CBOCs to see patients. In addition, many veterans have chronic neurologic conditions requiring continued follow-up visits by neurologists for ideal care. VHA is meeting this challenge in several ways.

Clinical Video Telehealth (CVT) The CVT system enables a veteran at their local CBOC to talk with and be examined directly by a neurologist. The ability to use CVT communication with neurological patients is important as neurologists depend heavily on accurate interpretation of the history and neurologic exam to establish a diagnosis and management plan [23]. Over the past 5 years, televideo equipment has been purchased by the VHA and placed at most of the CBOCs. Scheduling requires that the CVT equipment, patients, and specialists all be available simultaneously. Due to increasing demand to see patients by CVT, more than one set of televideo equipment is now often located at many CBOCs.

The equipment used by most VHAs include a Tandberg or Jabber camera system at the neurology clinic and one of three Tandberg camera systems (table top, conferencing, or global media cart) at the CBOC site. ISDN lines securely transmit the information between the two sites at 548 kbps. No recordings are made of the sessions.

Neurologists wishing to see patients by CVT must complete specialized training conducted by several videos available through the VA intranet [7]. Since the provider is not in the room with the patient, training for emergencies is necessary. In addition, there is a comprehensive quality management program that supports national telehealth networks [7]. For the 2012 fiscal year, 50 VA neurology services saw patients by teleneurology.

Fig. 1 Teleneurology Tandberg system used by neurologist at VA major medical center to see the distant veteran and the patient's electronic medical record

When patients arrived at the CBOC, a clerk checks the patient into the electronic medical record system for both the originating (local) and destination (specialty care center) sites as each appointment uses specific stop codes that denote the specialty and type of CVT visit. The nursing staff usually obtains vital signs and escorts the patient and family into the room with the telehealth camera. Specified telehealth assistants are often assigned to the CBOC to assist. This assistant may perform elements of the history or exam when trained by the neurologist and may be present during the entire teleneurology session, part of the session, or be called back for special problems that develop. The CBOC primary provider is seldom in the room during the interview. At most telehealth sites, the patient sits in a room the size of an exam room facing a camera with a microphone and speaker. The neurologist's room, variable in size and/or type, also contains a monitor with camera, microphone, and speaker in order to see the patient, and often a second monitor with access to the computerized patient record system (Fig. 1).

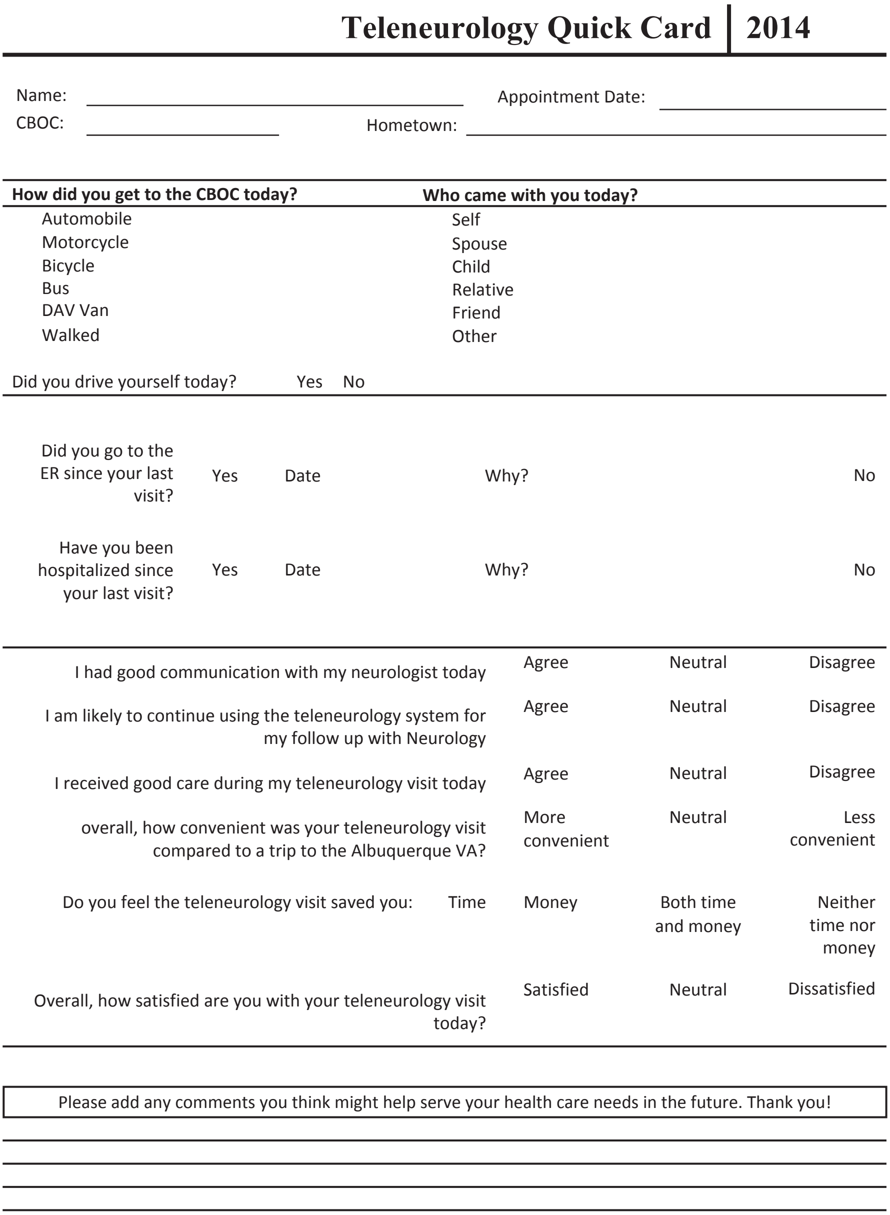
CVT in neurology serves several purposes. The first is to see, by teleneurology at their CBOC, patients with chronic neurologic diseases. Most commonly, teleneurology visits are for follow-up patients. As an example, telehealth was adopted early by the Neurology Service at the New Mexico Veterans Affair Health Care System in Albuquerque, NM as New Mexico is a large state with many veterans living rurally. Albuquerque neurology draws from a wide area of veterans in New Mexico, Southern Colorado, Eastern Arizona, and Western Texas in all 11 rural CBOCs. They have now seen by teleneurology over 500 patients with disorders such as Parkinson's disease (36 %), seizures (26 %), chronic headaches, (13 %), multiple sclerosis (7 %), dementia (6 %), and miscellaneous (12 %) including dizziness, benign tremors, peripheral neuropathies, transient ischemic attacks, and post-acute encephalopathy. All patients are first seen in the Albuquerque VA neurology clinic where a thorough history, neurologic exam, and necessary laboratory, electrophysiologic tests, and neuroimaging tests are completed. Once the diagnosis and treatment plan requiring neurologic follow-up are established, a decision is made whether a rural veteran is suitable for teleneurology. If the patient consents, they are scheduled for a follow-up teleneurology appointment. Only occasionally (5 %) does a patient have neurologic conditions so complex that they are not suitable for teleneurology. Those excluded have rapidly deteriorating conditions such as brain tumors or have multiple neurologic problems whose signs and symptoms overlap.

Each follow-up neurology visit lasts 30 min with about 15 min for history and examination and 15 min for patient discussion regarding results, education on their disease, answering questions, ordering lab tests or medication changes and reviewing the treatment plan.

The examination conducted by the neurology provider is limited and usually consists of a mental status exam similar to one done face to face. The patient is asked to move closer to their camera to allow examination for pupil symmetry, full movement of extra ocular muscles, presence of nystagmus, ability for strong eye closure and symmetrical smile, protrusion of the tongue midline without atrophy, speaking clearly, and full range of neck motion. For motor evaluation, we ask the patient to hold out their arms for one minute looking for downward drifting, rapidly open and close their fists, stand up from their chair without using their arms, walk around the room normally and on heels and toes. We find it is difficult to grade subtle differences between sides, to measure muscle tone and to evaluate for cogwheeling. However, bradykinesia and abnormal limb movements can be easily observed. Coordination is assessed by finger-to-nose and finger-tap or rapid alternating movements. Gait and balance testing such as tandem, Romberg, and station, stride and arm swing are observable but in patients with abnormal gait, the presence of a companion or health care professional is advised. Limitations regarding deep tendon reflexes, a careful sensory exam, retinal exam or complete oral exam of palate movement can be overcome with a trained assistant present [5, 16, 29].

At the end of every session, patients are asked to notify the CBOC staff they are done, obtain any blood tests ordered, and fill out a performance improvement satisfaction questionnaire (Fig. 2). The satisfaction quick card seeks feedback and ideas from the patient and family as well as the CBOC staff to improve the teleneurology experience. An electronic progress note, written by the neurology provider, is available to the CBOC provider shortly. If a general medical problem is identified during the session, the primary provider is alerted in order to address the general medical concern.

Educating the patient and family about their neurologic disease is accomplished in two ways. In about half the visits, patient educational materials regarding their disease are mailed. Albuquerque also supplies individual education classes using separate 60 min teleneurology sessions given by a nurse trained in patient education. Feedback regarding these teleneurology education sessions to veterans with Parkinson's disease has been highly positive.



Teleneurology Quick Card | 2014

Name: ____________________ Appointment Date: ____________

CBOC: ____________ Hometown: ____________________

How did you get to the CBOC today?	Who came with you today?
Automobile	Self
Motorcycle	Spouse
Bicycle	Child
Bus	Relative
DAV Van	Friend
Walked	Other

Did you drive yourself today? Yes No

Did you go to the ER since your last visit?	Yes	Date	Why?	No
Have you been hospitalized since your last visit?	Yes	Date	Why?	No

I had good communication with my neurologist today		Agree	Neutral	Disagree
I am likely to continue using the teleneurology system for my follow up with Neurology		Agree	Neutral	Disagree
I received good care during my teleneurology visit today		Agree	Neutral	Disagree
overall, how convenient was your teleneurology visit compared to a trip to the Albuquerque VA?		More convenient	Neutral	Less convenient
Do you feel the teleneurology visit saved you:	Time	Money	Both time and money	Neither time nor money
Overall, how satisfied are you with your teleneurology visit today?		Satisfied	Neutral	Dissatisfied

Please add any comments you think might help serve your health care needs in the future. Thank you!

Fig. 2 Teleneurology performance improvement satisfaction questionnaire

To place the value of New Mexico's teleneurology experience into a patient perspective, experience of the first 354 patients was published [8]. Ninety percent reported they were fully satisfied with their visit, 7 % were neutral, and only 3 % were dissatisfied. Over 95 % reported that they wanted to continue their neurology care by teleneurology. The median age of the patients was 64 years with a range of 23–90 years. Fifty-four percent of the patients required a companion who drove because of patient physical impairments (such as from Parkinson's disease or multiple sclerosis), cognitive impairments (from dementia or head trauma), poor stamina (elderly), or having no driver's license (epilepsy). Many of the companions had to take time off work.

To assess the quality of teleneurology care, patients were asked if since the last visit they had visited an emergency room (ER). Fifteen patients said they had whereas only three had visits related to the illness being followed by teleneurology. Two additional patients required hospitalization. One hospitalization was for seizures and the second patient with Parkinson's disease developed a skin infection following a previous battery change for a deep brain stimulator. The rate of ER visits or hospitalizations for their neurologic condition was similar to that experienced by follow-up patients attending regular Albuquerque neurology clinics. During their teleneurology visits only two patients had unexpected worsening of their condition sufficient to require face-to-face evaluation in an Albuquerque neurology clinic over the next several days.

Eighty percent of patients completed their patient satisfaction questionnaire. Ninety-two percent reported that they experienced good communication with the neurologist using the teleneurology equipment; 87 % reported that they felt they received good care during the visit; and 89 % expressed it was much more convenient than traveling to Albuquerque. Over 115,000 miles in travel was saved as veterans spent an average of 5 h and drove 325 miles round trip to reach the Albuquerque clinic. By not traveling to Albuquerque patients also saved the cost of gas, wear on their car, food, often lodging and the expense of a companion having to take a day off from work to drive. Thus, 92 % reported they felt teleneurology saved them time, money, or both. No patients reported concerns about safety or privacy issues.

The teleneurology "no-show" rate was 12 %, comparable to neurology clinics in Albuquerque. Reasons for their "no-show" included unexpected unavailability of the designated driver, bad weather preventing travel even to the CBOC, hospitalization, acute general illnesses, and forgetting the appointment.

Telehealth Services in Neurology Subspecialty Centers of Excellence

In VA neurology, three outstanding specialty groups have been formed: Epilepsy Centers of Excellence (ECoE), Multiple Sclerosis Centers of Excellence (MSCoE), and Parkinson's Disease, Research, Education, and Clinical Centers (PADRECC). These three groups are national Centers of Excellence whose purpose is to improve the medical care of veterans with these illnesses. All have extensively developed the use of telehealth to reach both patients and providers throughout the USA. They utilize a variety of synchronous and asynchronous telehealth technologies and

Table 1 Telehealth Services, VA Neurology Subspecialty Centers of Excellence

Clinical video telehealth
Standard to CBOC or distant medical center
Video-to-home
Mentored
Patient/caregiver education and support groups
Home automated telemanagement (HAT)
Multidisciplinary videoconferencing with mentored providers (SCAN-ECHO)
Electronic consults (virtual care)
Remote real-time interpretation of video EEG telemetry
Store and Forward technology

platforms to provide consultation, diagnosis, monitoring, and mentoring in the care of veterans primarily in the outpatient and home settings. The technologies employed are listed in Table 1. An overview of these services follows.

Clinical Video Telehealth (CVT): Additional Applications and Experience

The ECoEs, MSCoEs, and PADRECCs all provide standard CVT to patients at CBOCs and at distant medical centers lacking subspecialists. Although mostly offered to established patients for follow-up care, PADRECC utilizes CVT for initial screening evaluations of patients referred for possible deep brain stimulation (DBS) surgical therapy. This screening program successfully identified a substantial percentage of patients ineligible for DBS, and thereby saved lengthy and costly trips to distant PADRECC clinics. In addition, each program piloted CVT delivered directly to the patient's home, overcoming barriers such as immobility and driving restrictions that frequently reduce access to care.

A number of retrospective and prospective pilot studies have proven that CVT is feasible for these three disease states, with respect to validated neurological examination, patient satisfaction, and clinical outcomes [1, 9, 26, 35]. However, there remain few larger scale prospective randomized trials evaluating the efficacy of this modality in multiple neurologic subspecialties [28].

The Philadelphia PADRECC has initiated two randomized controlled trials to evaluate patient satisfaction, clinical outcomes, and economic impact of CVT. The first compares standard CVT to traditional outpatient care, and the second compares video-to-home CVT to traditional outpatient care (Jayne Wilkinson, personal communication). For the patients undergoing standard CVT, a clinical technician at the patient site receives extensive training from PADRECC in performing the unified Parkinson's disease rating scale (UPDRS) assessment, and assists with this part of the evaluation during the visit. For those undergoing video-to-home CVT, a visual-only modified UPDRS assessment is made by the provider and has yielded reliable results in other studies [29]. The results of these two trials are not yet published but have the potential to provide rigorous evidence about CVT's efficacy in Parkinson's disease.

The ECoEs have expanded standard CVT further to create a novel platform for providing cognitive-behavioral therapy to patients with psychogenic non-epileptic seizures (PNES) through mentored video telehealth sessions. Management of PNES is complex but typically includes psychotherapy to gain control of seizures. The psychotherapy employed by the ECoE is a standardized 12-session therapy tailored specifically for patients with PNES [18] and directly addresses both the seizures and the comorbidities that commonly occur in this disorder [19].

In the clinical telehealth model, the patient arrives at a clinic to be seen by a mentored provider at a distant site. The mentor is also connected to the same video telehealth session, either as a visible participant or an invisible observer during later sessions in the 12-session series. After the session, the mentor gives feedback to the mentored provider. The mentor continues to provide oversight for 6–12 months, or until the mentee is adequately trained to independently provide the therapy. This model increases veteran access to a highly specialized, time-intensive treatment while simultaneously increasing the pool of skilled providers.

PADRECCs have also utilized multisite video teleconferencing for patient support groups. Attendance at a Parkinson's disease support group at one urban medical center had been poor due to traffic, limited parking, and difficulty obtaining transportation. When they converted to multisite video conferencing, patients connected from their local CBOC, improving attendance and access to this resource (Jayne Wilkinson, personal communication). Patient and caregiver educational programs are conducted similarly, enhancing outreach to rural veterans.

Care Coordination/Home Telehealth (CCHT) or Home Automated Telemanagement

Care coordination/home telehealth (CCHT) or home automated telemanagement (HAT) systems are Internet-based platforms linking patients with chronic disease to care providers for the purposes of improving patient education, self-management, and clinical outcomes. A system consists of a patient unit, a secure HAT server, and a provider clinical unit [6]. The types of patient units can range from a basic smartphone to a laptop computer, sometimes with medical device attachments that can be used to make measurements and directly upload data. Examples include a blood pressure cuff, a glucometer, or more sophisticated tools.

The patient interacts with the HAT system and inputs data, which is then transmitted to a secure server, processed and delivered to a provider's device. The provider typically accesses a web-based platform to review trended data and sends back recommendations to the patient, often utilizing specialty-developed clinical decision support tools. The goal is to enhance patient and provider tracking of clinical progress, intervene promptly to improve patient health, and avoid deterioration and/or hospitalization. The tools may also be used for individualized patient education about their disease, including testing to assess their understanding. A key feature of the HAT system is employing an iterative development process to optimize the functions and interface [12].

HAT systems have been successfully implemented in a variety of chronic diseases [31]. The MSCoE in Baltimore partnered with Johns Hopkins University and the University of Maryland to develop a targeted system for patients with MS [11]. The system includes an interactive patient education and counseling tool, physical telerehabilitation, and patient home care management tools. The telerehabilitation program consists of a face-to-face or video-to-home visit with a therapist, followed by watching educational videos on assigned exercises, patients keeping exercise diaries, reminders to patients to perform exercises when there is a gap in adherence, including alerts to physical therapists, and access to quick written or diagrammed exercise instructions for review [12].

Based on the initial success of the pilot program [12], a larger randomized controlled trial is underway evaluating the efficacy of the MS HAT program at the Baltimore MSCoE. One hundred patients will be randomized to either MS HAT telerehabilitation or traditional outpatient physical therapy, and functional outcomes at 6 months will be compared. There are also plans to evaluate whether HAT can improve adherence to medications using reminders and educational tools. A long term goal is to integrate HAT into the existing electronic health portal for patients in order to streamline clinician efforts for accessing data and documenting therapeutic plans.

A HAT system for epilepsy is currently in the early stages of development at the Baltimore ECoE. PADRECC is exploring a research study to evaluate a home automated technology to quantify functional on/off states in patients with Parkinson's disease over a week-long interval (Jayne Wilkinson, personal communication). These data could be used for more objective measurements for medication titration or adjustment of DBS settings.

SCAN-ECHO (Specialty Care Access Network-Extension for Community Health Care Outcomes)

A new model of health care and education delivery, Project ECHO, was developed in 2003 at the University of New Mexico [2], and expanded to VA in 2010 under the acronym SCAN-ECHO. Its purpose is to provide equitable and accessible specialty care for all veterans, especially those living in rural areas where specialty care is not readily available [27].

The ECoE and the PADRECC programs have integrated SCAN-ECHO into the spectrum of telehealth services provided to veterans. As of December 2013, 11 SCAN-ECHO centers within the VA health care system are funded by the Office of Specialty Care Transformation, with 5 of the 11 providing neurology SCAN-ECHOs.

Fig. 3 SCAN-ECHO session showing epilepsy experts communicating with other VA sites through teleconferencing

The goal of Epilepsy and PADRECC SCAN-ECHOs is to provide consultation and clinical support from neurology subspecialists to other health care providers through video-teleconferencing. Traditional video-telehealth clinics visually and audibly link one medical provider to one patient. SCAN-ECHO leverages telehealth technology by connecting mentoring subspecialists to multiple primary and specialty health care providers from different VA CBOCs and medical centers, often across VISN lines. Not only does SCAN-ECHO provide consultation support to referring providers, it also imparts knowledge and skills to help the referring provider manage similar patients over time. A force multiplier effect is achieved through this dissemination of knowledge and skills (VA SCAN-ECHO website, accessed Nov 12, 2013) [30].

SCAN-ECHO sessions take place during a set day and time every month, and comprise of patient case discussions and didactic presentations. Referring providers request a SCAN-ECHO consult in the computerized patient record system (CPRS). During the scheduled SCAN-ECHO clinic, referring providers and the multidisciplinary specialist team meet virtually via video-teleconferencing (Fig. 3). The multidisciplinary team often includes a physician specialist, a mental health clinician, an advanced practice nurse, a clinical pharmacist, and an administrative staff. The referring clinicians present their patients and clinical questions to the specialist team. The team then delivers recommendations to the referring clinicians immediately and also summarizes the recommendations in a consultation note in CPRS. Other health care providers also join the conference to listen and learn from the discussion of patient cases, and may contribute by offering additional perspectives and experience. In addition to interactive case discussions, the specialist team presents a short 10–15 min "clinical pearls" didactic that updates participants on current standards of care. The didactic presentations form a recurring 12–24 month educational curriculum.

The Epilepsy SCAN-ECHO offered by the Epilepsy Centers of Excellence is unique in that it uses cutting edge video-teleconferencing equipment to share electroencephalographs (EEGs), epilepsy monitoring unit data, and magnetic resonance imaging (MRI) scans with clinicians. Also, all Epilepsy SCAN-ECHO sessions are accredited, allowing providers to earn continuing medical education/continuing education unit credits for participating.

The PADRECCs use SCAN-ECHO to spread knowledge and best practices on deep brain stimulation, a surgical treatment for Parkinson’s disease that involves implanting a device in a specific part of the brain to control symptoms.

There are innumerable benefits from the SCAN-ECHO program. Veterans are saved from traveling long distances to see a specialist and they benefit from a multidisciplinary review of their cases. Both referring providers and specialist teams report that SCAN-ECHO creates a more straightforward channel of communication between providers that helps build rapport between different sites. There is also increased provider satisfaction with the ability to virtually network with colleagues nationwide. The VA health care system as a whole benefits from reduction of overall travel and fee-basis costs.

The most significant benefit of SCAN-ECHO may be to the participating health care providers. SCAN-ECHO creates a resource-rich forum and an opportunity for discussion with subspecialty experts, colleagues, and collateral health care professionals. The virtual learning environment of SCAN-ECHO fits with the learning needs of practicing clinicians. While students in the health care field primarily learn through “intake of knowledge” [20] and memorizing of facts, practicing clinicians often move past “recall of facts, principles or correct procedures, and into the area of creativity, problem solving, analysis, or evaluation … learners need interpersonal communications, the opportunity to question, challenge and discuss ” [3]. SCAN-ECHO moves beyond the “passive transmission of factual information” [14] and creates a unique educational opportunity based in case discussions and active interaction.

Clinicians who participate in SCAN-ECHO give overwhelmingly positive feedback. Information learned during SCAN-ECHO sessions allow better management of their patients and reduce variation in care. Over time, with skills and knowledge learned from SCAN-ECHO, the expectation is that the referring provider can better independently manage their patients.

Other Telehealth and Virtual Care Services

In addition to CVT, HAT, and SCAN-ECHO programs, the neurology subspecialty clinics have implemented several additional telehealth services [15]. Electronic consults (e-consults) are offered in specific circumstances to referring providers when inquires allow for a chart review by the specialist to amass pertinent data and generate a consultation response. This service is similar to SCAN-ECHO but is performed electronically without directly interfacing with the referring provider and without the associated educational content. It may have value in specific clinical circumstances.

Store and Forward services and remote real-time interpretation of video electroencephalography telemetry are also offered by ECoEs.

Store and Forward Communication

Store and Forward technology is the practice in which the initial care provider stores images or medical information and then asynchronously sends data to an expert at a distant medical center using audio, visual, or data communication for review and interpretation. Currently this technology is widely utilized by CBOC clinics to transmit retinal photographs of their diabetic patients for interpretation by an ophthalmologist regarding possible diabetic retinopathy [17]. If identified, the patient is referred to an ophthalmologist at the major VA medical center. CBOC providers also photograph skin lesions and transmit the image to dermatologist for decisions as to whether the lesion is benign or the patient requires referral to a dermatology clinic for skin biopsy, etc. [34].

The simplest Store and Forward method is to send an electronic image, such as a photograph of a retina or skin lesion, along with a patient history by encrypted email. VA Store and Forward technology has advanced to where the images or video are transmitted using high bandwidth and “cloud technology” to the data storage unit of a consulted specialist at a major medical center. Some VA medical centers transmit cranial MRI and computed tomography (CT) scans obtained when their local radiologists are not available for immediate interpretations to radiology centers having a 24-h coverage. General pathologists now transmit micrographs of unusual brain lesions to neuropathologists at major medical centers for their interpretation.

The advantage of store and forward communication is that it does not require the patient to be present and the experts can review the transmitted information at their convenience. The major disadvantage is that the patient is not available to answer questions from the expert.

Store and forward technology is being used by VA neurologists to transmit retinal photographs of possible papilledema, skin photographs of unusual lesions, and CT/MRI neuroimaging. VA technology also allows the transmission of entire video EEGs, voice recordings, and clinical videos of atypical seizures, limb tremors, movements, dystonic posturing, speech disturbances, etc. Store and forward data can also be transmitted to experts during SCAN-ECHO conference sessions which would make their interpretation in real time.

Private neurologists use similar store and forward systems in local emergency rooms without neurologists. Neuroimaging is forwarded a stroke specialist in order to evaluate patients and determine whether the patient has an acute stroke requiring tissue plasminogen activator (tPA) administration [32]. Currently, VA neurologists seldom participate because the acute patients are seldom veterans and would not be transferred to a VA medical center.

Summary

In the past decade, VHA has taken enormous strides toward improved delivery of patient care from major VA medical centers to veterans living remotely. Teleneurology now offers veterans a variety of telehealth services that include CVT, CCHT or home automated telemanagement, SCAN-ECHO, and store and forward technology to many of their rural or home bound veterans. With advances in telehealth technology continuing, the future looks promising for rural veterans to receive easier and better neurologic care.

References

1. Ahmed S, Mann C, Sinclair DB, Heino A, Iskiw B, Quigley D, Ohinmaa A. Feasibility of epilepsy follow-up care through telemedicine: a pilot study on the patient's perspective. Epilepsia. 2008;49:573–85.
2. Arora S, Thornton K, Komaromy M, Kalishman S, Katzman J, Duhigg D. Demonopolizing medical knowledge. Acad Med. 2013;89:30–2.
3. Bates AW. Technology, open learning and distance education. New York: Routledge; 1995.
4. Bloch C. Federal agencies: activities in telemedicine, telehealth, and health technology. Potomac: Bloch Consulting group; 2010. pp. 165–s85.
5. Craig JJ, McConville JP, Patterson VH, Wootton R. Neurological examination is possible using telemedicine. J Telemed Telecare. 1999;5:177–81.
6. Darkins A, Ryan P, Kobb R, Foster L, Edmonson E, Wakefield B, Lancaster AE. Care coordination/home telehealth: the systematic implementation of heath informatics, home telehealth, and disease management to support the care of veteran patients with chronic conditions. Telemed J E Health. 2008;14:1118–26.
7. Darkins A, Foster L, Anderson C, Goldschmidt L, Selvin G. The design, implementation, and operational management of a comprehensive quality management program to support national telehealth networks. Telemed J E Health. 2013;19:557–64.
8. Davis LE, Coleman J, Harnar J, King MK. Teleneurology: successful delivery of chronic neurologic care to 354 patients living remotely in a rural state. Telemed J E Health. In press 2014.
9. Dorsey ER, Deuel LM, Voss TS, Finnigan K, George BP, Eason S, Miller D, Reminick JI, Appler A, Polanowicz J, Viti L, Smith S, Joseph A, Biglan KM. Increasing access to specialty care: a pilot, randomized controlled trial of telemedicine for Parkinson's disease. Mov Disord. 2010;25:1652–9.
10. Einthoven W. The telecardiogram. Ned Tijdischr Greeneskd. 1906;50:1517–47.
11. Finkelstein J, Wood J. Design and implementation of home automated telemanagement system for patients with multiple sclerosis. Conf Proc IEEE Eng Med Biol Soc. 2009;2009:6091–94.
12. Finkelstein J, Lapshin O, Castro H, Cha E, Provance PG. Home-based physical telerehabilitation in patients with multiple sclerosis: a pilot study. J Rehabil Res Dev. 2008;45:1361–73.
13. Fordyce MA, Chen FM, Doescher MP, Hart LG. 2005 physician supply and distribution in rural areas of the United States. Final report #116. Seattle, WA;WWAMI Rural Health Research Center, University of Washington 2007.
14. Gibson, CC. When disruptive approaches meet disruptive technologies: learning at a distance. J Contin Educ Health Prof. 2000;20:69–75.
15. Harnar J, King MK, Coleman J, Davis L. Overview of teleneurology in the VA. Report to VA Office of Telehealth Services, Washington DC October 26, 2013.

16. Kane RL, Bever CT, Ehrmantraut M, Forte A, Culpepper WJ, Wallin MT. Teleneurology in patients with multiple sclerosis: EDDS ratings derived remotely and from hands-on-examination. J Telemed Telecare. 2008;14:190–4.
17. Kirkizlar E, Serban N, Sisson JA, Swann JL, Barnes CS, Williams MD. Evaluation of telemedicine for screening of diabetic retinopathy in the Veterans Health Administration. Ophthalmology. 2013;120:2604–10.
18. LaFrance WC Jr, Miller IW, Ryan CE, Blum AS, Solomon DA, Kelley JE, Keitner GI. Cognitive behavioral therapy for psychogenic nonepileptic seizures. Epilepsy Behav. 2009;14:591–6.
19. LaFrance WC Jr, Reuber M, Goldstein LH. Management of psychogenic nonepileptic seizures. Epilepsia. 2013;54(Suppl 1):53–67.
20. Lonka K, Lindblom-Ylanne S. Epistemologies, conceptions of learning and study practices in medicine and psychology. Higher Educ. 1996;31:5–24.
21. National Center for Veterans Analysis and Statistics. Characteristics of Rural Veterans: 2010: data from the American Community Survey. US Department of Veterans Affairs. http://WWW.teleheath.va.gov website (July 2012). Accessed 16 Jan 2013.
22. Office of Rural Health. Fact sheet 3(2). http://WWW.ruralhealth.va.gov website (November 2012). Assessed 2 May 2013.
23. Patterson V. Teleneurology. J Telemed Telecare. 2005;11:55–9.
24. Patterson VH, Esmonde TFG. Comparison of the handling of neurologic outpatient referrals by general physicians and a neurologist. J Neurol Neurosurg Psychiatr. 1993;56:830.
25. Projection of physician supply in the United States: Rockville, MD: US Dept of Health and Human Services. Office of data analysis and management report. 1985. pp. 3–85.
26. Rasmusson KA, Hartshorn JC. A comparison of epilepsy patients in a traditional ambulatory clinic and a telemedicine clinic. Epilepsia. 2005;46:767–70.
27. Rongey, C. VISN 21 SCAN ECHO: expanding access to specialty care. San Francisco, CA: San Francisco VA Medical Center. 2013.
28. Rubin MN, Wellik KE, Channer DD, Demaerschalk BM. Role of telemedicine in providing tertiary neurological care. Curr Treat Options Neurol. 2013;15:567–582.
29. Samii A, Ryan-Dykes R, Tsukuda RA, Zink C, Franks R, Nichol WP. Telemedicine for delivery of health care in Parkinson's disease. J Telemed Telecare. 2006;12:16–8.
30. Specialty Care Access Network Extension for Community Healthcare Outcomes. (SCAN-ECHO). SCAN ECHO. 2012. http://vaww.infoshare.va.gov/sites/specialtycare/SCSTransformation/SCANECHO/default.aspx. Accessed 12 Nov 2013.
31. Wallin MT. Integrated multiple sclerosis care: new approaches and paradigm shifts. J Rehabil Res Dev. 2010;47(5):ix–xiv.
32. Wechsler LR, Tsao JW, Levine SR, Swain-Eng RJ, Adams RJ, Demaerschalk BM, Hess DC, Moro E, Schwamm LH, Steffensen S, Stern BJ, Bhattacharya P, Davis LE, Yurkiewicz IR, Alphonso AL. Teleneurology applications. Report of the teleneurology work group of the American Academy of Neurology. Neurology. 2013;80:670–6.
33. Weeks W, Wallace A, West A, Heady HR, Hawthorne K. Research on rural veterans. J Rural Health. 2008;24:337–44.
34. Whited JD, Warshaw EM, Edison KE, Kapur K, Thottapurathu L, Raju S, Cook B, Engasser H, Pullen S, Parks P, Sindowski T, Motyka D, Brown R, Moritz TE, Datta SK, Chren MM, Marty L, Reda DJ. Effect of store and forward teledermatology on quality of life: a randomized controlled trial. JAMA Dermatol. 2013;149:584–91.
35. Wood J, Wallin M, Finkelstein J. Can a low-cost webcam be used for a remote neurological exam? Stud Health Technol Inform. 2013;190:30–2.

International Teleneurology

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Teleneurology

Teleneurology refers to the transfer of medical information from one site to another, using information and communications technology (ICT) for the management of neurological disorders. In this chapter, we discuss the rationale behind using teleneurology in different parts of the world, review work done in this field, and describe the various barriers affecting its widespread use.

Why Do We Need International Teleneurology?

In a survey performed in 2006, the World Health Organization/World Federation of Neurology Atlas of Country Resources for Neurological Disorders showed inadequate resources for neurological disorders around the world. The survey included 109 countries and more than 90 % of the world population. The survey showed disparities in access to neurology care, especially affecting low-income and developing countries [15]. Neurological and mental health disorders also have broader economic consequences. The cumulative global impact in terms of lost economic output from these disorders will amount to US$ 16.3 trillion between 2011 and 2030 according to the World Health Organization [39]. The shortage of neurological

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services, experts, and treatment delays increases morbidity and mortality in this field. It is generally accepted that increasing the number of neuroscience specialists and providing them with the required infrastructure are not possible throughout the world [11]. The use of telemedicine to overcome some of the problems encountered by this shortage has been promising. Telemedicine enables more inpatient neurology consultations, provides effective treatment of acute stroke patients, optimizes treatment of epilepsy patients in hospitals, and gives better access to neurologists in developing countries [28]. The European Commission perceives that eHealth (providing health-care services through the use of information technology) and the broader application, ICT, can be used as a valuable tool to promote high-level neurological services, improve outreach, and make them more cost effective [7]. Government officials in the developing world have acknowledged the importance of this system in bridging the gap between need and supply of medical care [9, 36].

International Telestroke Networks

Health systems are not well equipped to treat stroke patients in underdeveloped and developing countries. In a survey conducted across 25 European countries, with 448 of the 886 hospitals studied admitting at least 1 stroke per day, only 11.4 % met the criteria for primary stroke center certification, showing ineffectiveness of stroke care, even in developed countries [21]. Majority of the suburban hospitals lacked stroke specialists, diagnostic equipment, and stroke treatment protocols in another survey from Beijing [38]. Telestroke has been used to great advantage in different parts of the world to overcome these obstacles in stroke care. Our experience, as part of the Michigan Stroke Network, has confirmed that telemedicine is an effective method for acute stroke care, especially for patients living in rural areas of Michigan, where there is a shortage of neurologists. This has been demonstrated by multiple different networks across the USA. Telestroke networks have also operated successfully in the Canadian provinces of Alberta and Ontario. Ontario has a single network with five consulting centers dedicated for acute stroke management [27]. In a report of 210 patients managed by the University of Alberta telestroke network, 44 (21 %) received thrombolysis at 7 distant spoke hospitals. Over 2 years, the number of acute stroke transfers decreased from 144 to 15 at one of the “spoke” sites, a 92.5 % decline [17]. This study indicates the importance of the increasing use of teletechnology in decreasing unnecessary transfers.

Telemedic Pilot Project for Integrative Stroke Care (TEMPiS) was the first pilot teleneurology network, outside the USA dedicated for stroke management established in 2002, supported by a Bavarian state grant. TEMPiS has since transitioned to be supported by a regular health insurance and is built around two comprehensive stroke centers in Eastern Bavaria. The network provided 10,239 neurology consultations between February 2003 and December 2006 and about 5.8 % of the ischemic stroke patients were given thrombolytic therapy during this period [37]. Stroke Eastern Saxony Network (SOS-NET) is another large German telestroke network in rural Eastern Saxony with approximately 1,600,000 residents. Over 3000 teleconsultations during July 2007 to December 2012 helped a quarter of the strokes to be transferred for comprehensive care and 43 % received recommendations for intravenous (IV) tissue plasminogen activator (tPA) administration [3]. Similar networks have also been established in other European countries including the UK, where there are now more than 30 acute trusts using telemedicine to provide prompt treatment to acute stroke patients [13]. The Lancashire and Cambria stroke network is the largest network among these, and serves about 2.2 million people with annual stroke rates of 4500/year [19]. The Helsinki University Central Hospital (HUCH) ran a network in Finland, and 57.5 % of the ischemic stroke patients were given thrombolysis during the 2007–2009 period with an acceptable incidence of intracranial hemorrhage rate (6.7 %) [33].

A pilot videoconferencing telestroke system was setup in Australia in 2009. It was established between Royal Melbourne Hospital (hub) and Northeast Health Wangaratta Hospital (spoke). The Northeast Health Wangaratta Hospital is 235 km from Melbourne and has a catchment population of approximately 90,000. Thrombolysis was not offered at this hospitaI as there are no on-site neurologists The establishment of the telestroke system led to eight patients being offered thrombolysis in the first year without any complication of intracranial hemorrhage [26].

International Teleneurology in Other Subspecialties

The use of teleneurology in other subspecialties is uncommon outside the USA. A systemic review in 2008, that included 15 papers, evaluated 5 ICT (information and communication technology) applications in dementia care around the world. The projects included ComputerLink, AlzOnline, Caring for Others, and two studies from the REACH project (TLC and CTIS). The results suggest that ICT interventions have moderate effects on improving caretaker stress and depression. All of these projects were based in the USA highlighting the rarity of ICT use for dementia care outside the USA [30].

Epilepsy remains an undertreated condition around the world though efforts to improve epilepsy care have been promising in the Western countries. There are over 50 million epilepsy patients in the world with 85 % living in developing countries according to WHO [6]. In developing countries, 75 % may not be receiving adequate treatment, while nine out of ten patients in Africa go untreated altogether [40]. Median number of neurologists in sub-Saharan Africa is estimated at 0.3 per 1 million populations with 11 countries having no neurologists. A collaboration with developed countries for neurological consultations [4] and teleneurology can be helpful in bridging the gap between the primary doctors in developing countries and neurologists in the developed world.

Epilepsy care presents with its own inherent problems, as these patients are restricted or unable to drive in most parts of the world. In nations with large rural populations, access to an epilepsy specialist can be difficult. The application of store-and-forward technology for electroencephalography (EEG) interpretation is a reasonable alternative in some countries where neurophysiologists are not readily available. The feasibility of an EEG service between a community hospital and a tertiary hospital was tested in Spain. Most of the patients (98 %) were satisfied with tele-EEG system in a 116-patient study. Seventy-five percent preferred it over the conventional consult, due to reduced traveling expenses and the total invested time in the EEG test [20]. Similarly, tele-EEG has been a timely and effective method of providing EEG services in the UK, especially for hospitals who are not able to recruit neurophysiologists [5].

In North America, the feasibility of epilepsy care follow-up through teleneurology was tested in a study conducted by the University of Alberta hospital epilepsy clinic [1]. Follow-up care through teleneurology videoconferencing was compared to traditional clinic follow-ups in out-of-town patients. Teleneurology production costs were similar to the patients' savings in traveling and lost productivity. About 90 % of patients in both groups were satisfied with the quality of the service. A Canadian survey reported that a large number of neurologists (79.5 %) had access to videoconferencing equipment. In this 2008 report, majority (64.1 %) of the neurologists did not use teleneurology for epilepsy care, though 61.5 % acknowledged the need for teleneurology for epilepsy care. The most common obstacles for broader use of teleneurology were reported to be the lack of infrastructure support and remuneration problems [2].

Intercontinental Teleneurology

Intercontinental teleneurology or cross-border teleneurology refers to collaboration between providers in a country with the lack of access to a neurologist and the neurologist in a different country. Neurologists in the developed countries can help primary doctors, trainees, and mid-level providers through video links and store-and-forward technology. These systems can support education and training as well. The Swinfen Charitable Trust, UK, was established in 1998 with the policy to provide telemedicine links between medical practitioners in developing world and experts abroad who would give free advice via the Internet. Most of the consultations are done through secure e-mail links. An e-mail link communication with the facility to send high-resolution digital images is an inexpensive and simple form of telemedicine. A link established in Bangladesh was one of the original projects where still images captured at the Center for the Rehabilitation of the Paralysed, Dhaka, were transmitted by e-mail to medical consultants abroad. Most of the 27 referrals done were for neurology and orthopedics. These consultations were judged to be beneficial for the establishment of the diagnosis, the provision of reassurance to the patient and referring doctor, and appropriate change of management. The Swinfen Charitable Trust also helped establish similar e-mail links in Patan Hospital, Kathmandu, Nepal, in March 2000. Over a period of 12 months, 42 telemedicine referrals were sent to specialists throughout the world; 21 % of which were neurology referrals.

All replies from specialists were judged to be helpful for diagnosis, management, and education [12]. The studies published about the trust work have shown that a low-cost telemedicine link is technically feasible and can be of significant benefit for diagnosis, management, and education in a developing world setting. Over the years, the trust has expanded its work to many developing and poor countries. Patterson et al. reviewed the expanded work of Swinfen Charitable Trust in four Middle Eastern countries with 283 referrals and 22 other countries with 500 cases. One of the consultant neurologists received 26 referrals including 9 inpatients from Iraq, Afghanistan, Kuwait, and Pakistan. Radiological images were attached to the referring e-mail for ten patients and clinical images for eight patients. The neurologist requested video clips for a further three patients. Most of the cases (77 %) were completed through e-mail communications between doctors of these countries and the neurologist. These consultations were helpful in the diagnosis of brain tumors, demyelinating disease, conversion disorders, etc. Some cases were referred to for neuroradiologist and neurosurgery opinions too [29].

Similar charitable works have also been established through in USA. Children's National Medical Center, Washington, DC in collaboration with Mosaic Foundation has developed projects in Africa, the Middle East, and Germany covering a number of specialties, including cardiac surgery, neurology, and genetics. The medical center performs mission-driven work in African countries such as Uganda and Morocco. It has also made business arrangements in Qatar, Kuwait, and the United Arab Emirates, where it focuses primarily on treating neurodevelopmental disorders [18].

Teleneurology consultations for overseas combat forces have been successfully used for better triage and remote management of traumatic brain injury (TBI) patients in remote areas. High rates of neurologic injuries combined with a limited number of practicing neurologists' overseas mandate other alternatives. Teleneurology can potentially cover this gap effectively. The US Army Medical Department approved the use of the army knowledge online (AKO) electronic e-mail system as a teleconsultation service in 2004. It was originally used to provide teledermatology consultation to health-care providers in Iraq, Kuwait, and Afghanistan. Later on, it was expanded to other subspecialties including teleneurology [22]. Teleneurology group of AKO can be perceived as a form of intercontinental teleneurology. Deployed providers generate teleconsultation requests into the AKO system by entering a patient's history and physical examination, clinical photographs, radiographs, and laboratory results into the Internet link. It is mandatory by the Office of the Surgeon General of the Army that all consultations are responded within 24 h. A retrospective analysis of AKO teleneurology from October 2006 to December 2010 is reported. The analysis included TBI consults from March 2008 to December 2010. It is difficult to judge the effectiveness of this program with limited outcome data and comparisons to other health-care models. But this chapter supports the aim for the creation of a more robust program and continued research in this aspect of teleneurology [42].

Another example of intercontinental teleneurology is the collaboration between neurology teams of the developing and developed countries. King Hussein Cancer Center, Jordan, and the Hospital for Sick Children, Canada, collaborated between

December 2004 and May 2006 to discuss 72 cases of pediatric neuro-oncology. Experts from two sides had 20 sessions through videoconference. In 23 patients (36 %), major changes from original management plan were recommended on different aspects of the care. In 21 patients (91 %), those recommendations were followed, with potentially significant positive impact on patients' care [31]. These twinning programs can serve as an important educational tool in addition to better patient management. Similar programs have been used in India at a national level. Sanjay Gandhi Post-Graduate Institute of Medical Sciences used videoconferences between 2001 and 2004 to discuss neurological cases. Patient management issues, radiology images, and neurophysiology examinations were discussed in 30 sessions during this period; two to three cases were discussed in each session. These conferences improved the knowledge of participants, provided an opportunity for a second opinion as well as modified the treatment decisions in some cases [25].

Internet Referral System

An Internet referral system has been used in Ireland, as an alternative method of teleneurology to overcome the shortage in neurological expertise. National health project, Ireland and St. Vincent's University Hospital launched a pilot project Neurolink in 2006. It was a form of Internet referral system, and 710 consultations were performed until January 2011. General physicians filled out an electronic template using a series of drop-down menus for each patient they wanted a neurologist's opinion for. The referring general physician entered patient's information including clinical presentation and suspected diagnosis. The neurologist then logged on and viewed the referral after he or she was notified through e-mail. Consultant neurologists send a reply via the web-based application. The general physician was advised about further investigations to be ordered, and the need for neurology outpatient consultations. About 19 % of the patients did not require further care with the neurologist. Ireland has the lowest number of consultant neurologists per capita in Europe and this method could help reduce the number of unnecessary outpatient neurology consultations, and allow for the better use of the neurologists' time for much needed patient care [41].

Challenges

Telemedicine faces significant challenges worldwide due to several reasons. These include a lack of reimbursement, physician licensure or credentialing, language commonality, technological availability, trained support staff, and patient privacy and security assurances [16]. The nature of these challenges is different in various parts of the world.

The lack of reimbursement for teleneurology has been a universal problem [8, 14]. The primary method of financing neurological care is “out-of-pocket payments” in 83 % of countries from Africa, “tax based” in Eastern Mediterranean (58 % countries), Western Pacific (50 % countries), and Southeast Asia (40 %), while in 29 % of the countries in the American continent, private health insurance plans are the primary source for reimbursement. This represents a challenge for teleneurology, where the initial setup and cost for consult services could be deemed high. Telestroke programs in the Western world often look to the government or foundations to help with these significant upfront capital expenses [27]. Telemedicine research grants, spoke, hub or hub-and-spoke subsidization, spoke subscription-based revenue stream, health insurance reimbursement (government and nongovernment insurers), or a combination of the above are start-up options for telestroke networks [10]. These options are successful for telestroke networks and can be applied to other teleneurology subspecialties worldwide as business models. The new teleneurology models should provide cheaper alternatives to traditional models and be regarded more acceptable. A new telehealth system to be implemented by the Wayne State University Physician Group is both simple and unique. The system is based on an interactive, encrypted patient data exchange on a cloud server using tablet-based format. The specially formatted tablet computers are designed to accept input from a range of medical devices—stethoscope, blood pressure, ECG, respiration, weight, and height. In the proposed Michigan Specialty Network, the service will enable rural providers to connect regarding neurological diseases with medical specialists miles away. Picture archiving and communication system (PACS) technology hosted in addition to the ICT will provide economical storage and convenient access to images from X-rays, magnetic resonance imagings (MRIs), computed tomography (CT) scan images for the end-user rural clinics and the specialist at the hub. The digital imaging and communications in medicine (DICOM) can also integrate images from scanners, workstations, printers, and servers and will provide access for consultations to be done through mobile devices.

Credentialing within a state, interstate, between countries is challenging and has been a barrier in the spread of teleneurology. Licensing requirements and consultant privileges vary in different countries. For example, physicians are allowed to practice video telemedicine in Australia if they have a Medicare provider number and the patient is located in an underserved designated telemedicine area irrespective of the state [35]. Similarly, a physician should be able to practice teleneurology in any European country for which they hold licensure. On the other hand, health and the licensing of doctors is a matter that is assigned to the jurisdiction of the provinces in Canada. If a physician in one province decides to provide teleneurology services to a patient in another province, the predominant view is that the physician should be licensed to practice for the province of patient’s location [2]. In most of the countries around the world, there is no separate set of rules for the practice of telemedicine including teleneurology as compared to medical practice in general. Most societies and legal experts recommend same best practice patient management rules and ethics for the practice of telemedicine.

Language barriers may become an important issue to consider especially with teleneurology practice across the borders. It can be overcome by having an interpreter in the vicinity where the patient is being evaluated. This interpreter should preferably be a trained nurse or physician assistant with the neurologist evaluating the patient at distant site through video interface. The other potentially successful way to overcome this difficulty would be the use of online interpretation. For example, the University of Missouri, with the help of funds from Missouri Foundation for Health, is trying to set up telehealth network with online concurrent interpretation of 25 different languages [23]. Swinfen Charitable Trust would also like to respond to increasing requests for services in multiple languages, and has done trials with system operations in English and French languages [34].

While information and communication technology is being used ever increasingly in the Western world, the lack of adequate infrastructure in poor countries creates suboptimal application of telemedicine in these countries. Robertson Global Health Solutions Corporation and Montana Healthcare Solutions Pty Ltd signed a commercial agreement with Telemedicine Africa in 2011 to provide a high-quality telemedicine care to African countries by providing affordable cost-effective technology [32]. Similar cost-effective models can enable better and timely health-care delivery to the poor countries, especially through partnership with respective peers in these countries.

The other factors such as policy, culture, and lack of political Interference are also crucial especially in the case of developing and poor countries. The providers need to work closely with lawmakers for developing policies and promoting a culture of teleneurology for it to be more successful. The Department of Information Technology in India has defined standards for telemedicine systems and the Ministry of Health and Family Welfare in India has constituted a national task force for telemedicine [24]. Similar work at government and providers level around will be helpful in setting up standards and policies, and promoting cultures.

Conclusion

Neurologists should promote and refine teleneurology as a critical branch of healthcare delivery in the years to come as this technology promises to bring quality neurological services to underserved patients both locally and abroad. Services provided should include expert consultation, continuing education, and improving the quality and efficiency of decisions that can impact neurological outcomes. These can be accomplished by more timely provision of service with 24-h remote hospital coverage. In order for teleneurology to gain broader acceptance, it has to resolve a few hurdles such as that of credentialing and reimbursement across all states, reducing language barriers, availability of resources in remote areas, and ensuring protection of patient's privacy. With advances in the development of mobile communications in the future, we can assume that teleneurology will have a greater impact in the delivery of health care around the world.

References

1. Ahmed SN, Mann C, Sinclair DB, Heino A, Iskiw B, Quigley D, Ohinmaa A. Feasibility of epilepsy follow-up care through telemedicine: a pilot study on the patient's perspective. Epilepsia. 2008;49(4):573–85. doi:10.1111/j.1528-1167.2007.01464.x.
2. Ahmed SN, Wiebe S, Mann C, Ohinmaa A. Telemedicine and epilepsy care—a Canada wide survey. Can J Neurol Sci. 2010;37(6):814–8.
3. Bodechtel U, Puetz V. Why telestroke networks? Rationale, implementation and results of the Stroke Eastern Saxony Network. J Neural Transm. 2013;120 Suppl 1:43–7. doi:10.1007/s00702-013-1069-y.
4. Chin JH. Epilepsy treatment in sub-Saharan Africa: closing the gap. Afr Health Sci. 2012;12(2):186–92. doi:10.4314/ahs.v12i2.17.
5. Coates S, Clarke A, Davison G, Patterson V. Tele-EEG in the UK: a report of over 1,000 patients. J Telemed Telecare. 2012;18(5):243–6. doi:10.1258/jtt.2012.111003.
6. DeCapua J. Epilepsy Burdens Developing Countries. http://www.voanews.com/content/epilepsy-deve-world-2oct12/1518932.html.
7. eHealth and the Brain—ICT for Neuropsychiatric Health. http://www.epractice.eu/en/events/brain2013.
8. EHTEL 2012 Symposium. http://www.ehtel.org/references-files/ehtel-symposium-2012-files/EHT12 B2-3 Birgit Beger CPME—Physicians Changing workload and patterns.pdf.
9. Establishment of a Telemedicine system for South Africa. http://www.doh.gov.za. Accessed 12 Feb 2013.
10. Fanale CV, Demaerschalk BM. Telestroke network business model strategies. J Stroke Cerebrovasc Dis. 2012;21(7):530–4. doi:10.1016/j.jstrokecerebrovasdis.2012.06.013.
11. Ganapathy K. Role of telemedicine in neurosciences. Stud Health Technol Inform. 2004;104:116–24.
12. Graham LE, Zimmerman M, Vassallo DJ, Patterson V, Swinfen P, Swinfen R, Wootton R. Telemedicine–the way ahead for medicine in the developing world. Trop Doct. 2003;33(1):36–8.
13. Hargroves D. Will telemedicine facilitate access to hyper acute stroke care across the UK? Br J Hosp Med (Lond). 2012;73(3):155–9.
14. Increasing scope of Telehealth markets in Europe—a concise analysis. http://www.frost.com/prod/servlet/market-insight-print.pag?docid=168892280.
15. Janca A, Aarli JA, Prilipko L, Dua T, Saxena S, Saraceno B. WHO/WFN survey of neurological services: a worldwide perspective. J Neurol Sci. 2006;247(1):29–34. doi:10.1016/j.jns.2006.03.003.
16. Kazley AS, McLeod AC, Wager KA. Telemedicine in an international context: definition, use, and future. Adv Health Care Manage. 2012;12:143–69.
17. Khan K, Shuaib A, Whittaker T, Saqqur M, Jeerakathil T, Butcher K, Crumley P. Telestroke in Northern Alberta: a two year experience with remote hospitals. Can J Neurol Sci. 2010;37(6):808–13.
18. Kutscher B. The long reach of medicine. International telemedicine becoming a growing force for U.S. hospitals. http://www.modernhealthcare.com/article/20121020/MAGAZINE/310209954.
19. Lancashire and Cambria Stroke Network. http://www.csnlc.nhs.uk.
20. Lasierra N, Alesanco A, Campos C, Caudevilla E, Fernandez J, Garcia J. Experience of a real-time tele-EEG service. Conf Proc IEEE Eng Med Biol Soc. 2009;2009:5211–4. doi:10.1109/IEMBS.2009.5334076.
21. Leys D, Ringelstein EB, Kaste M, Hacke W, Executive Committee of the European Stroke Initiative. Facilities available in European hospitals treating stroke patients. Stroke. 2007;38(11):2985–91. doi:10.1161/STROKEAHA.107.487967.
22. McManus J, Salinas J, Morton M, Lappan C, Poropatich R. Teleconsultation program for deployed soldiers and healthcare professionals in remote and austere environments. Prehosp Disaster Med. 2008;23(3):210–6; discussion 217.

23. Medicine@mizzou. http://medicine.missouri.edu/newsletter/2/A9.php.
24. Mishra SK, Kapoor L, Singh IP. Telemedicine in India: current scenario and the future. Telemed J E Health. 2009;15(6):568–75. doi:10.1089/tmj.2009.0059.
25. Misra UK, Kalita J, Mishra SK, Yadav RK. Telemedicine in neurology: underutilized potential. Neurol India. 2005;53(1):27–31.
26. Nagao KJ, Koschel A, Haines HM, Bolitho LE, Yan B. Rural victorian telestroke project. Intern Med J. 2012;42(10):1088–95. doi:10.1111/j.1445-5994.2011.02603.x.
27. Ontario Telestroke Network. http://otn.ca/en/programs/telestroke. Accessed 11 Aug 2013.
28. Patterson V. Teleneurology. J Telemed Telecare. 2005;11(2):55–9. doi:10.1258/1357633053499840.
29. Patterson V, Swinfen P, Swinfen R, Azzo E, Taha H, Wootton R. Supporting hospital doctors in the Middle East by email telemedicine: something the industrialized world can do to help. J Med Internet Res. 2007;9(4):e30. doi:10.2196/jmir.9.4.e30.
30. Powell J, Chiu T, Eysenbach G. A systematic review of networked technologies supporting carers of people with dementia. J Telemed Telecare. 2008;14(3):154–6. doi:10.1258/jtt.2008.003018.
31. Qaddoumi I, Mansour A, Musharbash A, Drake J, Swaidan M, Tihan T, Bouffet E. Impact of telemedicine on pediatric neuro-oncology in a developing country: the Jordanian-Canadian experience. Pediatr Blood Cancer. 2007;48(1):39–43. doi:10.1002/pbc.21085.
32. Robertson Global Health Solutions. http://www.robertsonhealth.com/rghs/investor-relations.aspx. Accessed 12 April 2013.
33. Sairanen T, Soinila S, Nikkanen M, Rantanen K, Mustanoja S, Farkkila M, Pieninkeroinen I, Numminen H, Baumann P, Valpas J, Kuha T, Kaste M, Tatlisumak T, Finnish Telestroke Task Force. Two years of Finnish Telestroke: thrombolysis at spokes equal to that at the hub. Neurology. 2011;76(13):1145–52. doi:10.1212/WNL.0b013e318212a8d4.
34. Swinfen Charitable Trust. http://www.swinfencharitabletrust.org.
35. Telehealth Australia. http://www.medicareaustralia.gov.au/provider/incentives/telehealth/.
36. Telemedindia. http://www.telemedindia.org.
37. Vatankhah B, Schenkel J, Furst A, Haberl RL, Audebert HJ. Telemedically provided stroke expertise beyond normal working hours. The telemedical project for integrative stroke care. Cerebrovasc Dis. 2008;25(4):332–7. doi:10.1159/000118378.
38. Wang YL, Wang YJ, Zhao XQ, Liao XL, Wu D, Yang YQ, Hu CM, Chen QD, Yang Q. [A survey of neurological medical care resources in grade II suburban and urban hospitals in Beijing]. Zhonghua Nei Ke Za Zhi. 2007;46(4):302–5.
39. WHO Draft comprehensive mental health action plan 2013–2020. http://www.who.int/mental_health/web_consultation_02_2013/en/index.html.
40. WHO Epilepsy Report. http://www.who.int/mediacentre/factsheets/fs999/en/. (October 2012).
41. Williams L, O'Riordan S, McGuigan C, Hutchinson M, Tubridy N. A web-based electronic neurology referral system: a solution for an overburdened healthcare system? Ir Med J. 2012;105(9):301–3.
42. Yurkiewicz IR, Lappan CM, Neely ET, Hesselbrock RR, Girard PD, Alphonso AL, Tsao JW. Outcomes from a US military neurology and traumatic brain injury telemedicine program. Neurology. 2012;79(12):1237–43. doi:10.1212/WNL.0b013e31826aac33.

Military Telemedicine

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Introduction

Within the health-care setting, telemedicine is defined as the practice of medicine when geographical distance or isolation separates the physician and patient. Often, this practice is achieved through the use of electronic communications systems, including video teleconferencing (VTC), digital imaging, e-mail, high-speed networks, and other forms of Internet technology [1, 2]. The application of telemedicine can improve patient access to health-care services by increasing the availability of medical specialists and by obviating the need for remotely located patients to travel long distances to receive care. Because it provides efficient health-care delivery without compromising the quality of that care, telemedicine is increasingly used to transmit medical information to specialists, who in turn respond with prompt medical recommendations regarding diagnosis and treatment.

Telemedicine can be applied to a broad range of medical specialties, including, but not limited to, neurology (referred to as teleneurology). The surge of teleneurology cases stems from the timely conjunction of a shortage of neurology specialists with recent advances in technology [3, 4]. In the past decade, teleneurology has been applied most often to emergency stroke care and to neurocritical care [5] but has evolved to include longitudinal care for chronic neurological conditions, such as epilepsy [6], Parkinson's disease [7], multiple sclerosis [8], dementia [9], and migraine headache [10].

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Neurology Telemedicine in the Military

Military health-care providers see a broad spectrum of neurological disorders but there are only a limited number of active duty neurology specialists to consult [11]. In particular, forward-deployed providers, such as those in Afghanistan, are often geographically dispersed in austere environments, have limited resources, and are in critical need of prompt specialist expertise in traumatic brain injury (TBI) and other complex neurological cases. In turn, cases that can be managed locally with the help of specialized knowledge and guidance can avoid costly and unnecessary medical evacuations that reduce unit readiness and are potentially hazardous when overflying enemy territory [12]. Telemedicine is, thus, a viable option to solve access to, to reduce the cost of, and to improve the quality of health-care delivery in the military's battlefield and operational theaters. In general, telemedicine in both the military and civilian spheres can be implemented in two ways: via videoconferencing and via a store-and-forward system.

Videoconferencing

Videoconferencing, or synchronous telemedicine, requires the use of audiovisual equipment that allows the consulting physician, on-site physician, and patient (if applicable) to confer in real time. For example, neurosurgeons at Walter Reed Army Hospital in Washington, DC, used videoconferencing equipment to monitor and advise neurosurgery conducted by general surgeons at a military hospital in Bagram, Afghanistan [13]. The lights above the operating table contained videoconferencing cameras that allowed the remotely located neurosurgeons to have a live view of the operation from the surgeon's perspective. However, videoconferencing operations experience notable time lags between the remotely located surgeon's suggestions and the in-theater surgeon's actual movements. This signal latency makes some emergency neurosurgical videoconferencing inadvisable, and, therefore, overcoming signal transmission latency should be a focus of future telemedicine endeavors.

Store and Forward

Store-and-forward, or asynchronous, telemedicine occurs between consulting and onsite/referring physician exclusively via e-mail. As defined by Poropatich and colleagues, teleconsultation is the specific act of "electronic exchange of patient demongraphics, medical history, and physical examination data between a medical provider (physician, nurse, or medic) and a medical specialist for the purpose of obtaining an expert opinion and/or advice and diagnostic support regarding the treatment of a patient" [14]. The e-mail from the referring physician may also include any relevant clinical pictures or radiological images, and the consulting physician responds with diagnostic and treatment recommendations in a convenient and appropriately timed manner.

Benefits and Limitations of Telemedicine Systems

The military health-care system has taken advantage of both videoconferencing and store-and-forward telemedicine systems. The settings in which these systems are employed depend largely on the availability of required technology and on the schedule of the physicians involved. Live-feed videoconferencing systems allow for the neurologist to take a patient's history personally and to see the neurological exam performed. The real-time communication also means that a diagnosis can be achieved as quickly as a normal face-to-face interaction allows. However, videoconferencing systems are often more costly than store-and-forward systems, and, in a remotely located combat environment, coordinating physicians' and patients' schedules can prove difficult. Store-and-forward systems, on the other hand, are inexpensive and occur in a time frame that is convenient for both the referring and consulting health-care providers. The consulting physician must rely on the clinical skills of the referring provider and is unable to observe nonverbal factors related to the case at hand. These difficulties often result in multiple e-mails between referring and consulting physicians, which may delay the time it takes to achieve a final diagnosis. These hurdles are overcome as the physicians involved become more comfortable with providing sufficient information via store-and-forward telemedicine systems.

The US Army Online teleconsultation program was established using a store-and-forward e-mail-based system. When the program was designed in 2003–2004, it was envisioned as a short-term solution until a robust Internet-based system that linked the deployed physician to the Armed Forces Health Longitudinal Technology Application (AHLTA) and the patient's military health-care records. A prototype application was developed but never implemented due to bandwidth limitations in the 2004–2005 era. Users in 2005 overwhelmingly favored the e-mail-based system. Since then, the US Army Medical Department has utilized the store-and-forward Army Knowledge Online (AKO) teleconsultation program to provide guidance for deployed health-care providers regarding: (1) the treatment and diagnosis for atypical cases, (2) returning service members to full duty as soon as is safely possible, and (3) prevention of unnecessary medical evacuations out of theater [15]. The program provides a standardized electronic platform for managing acute and emergent care requests between forward-based providers and rear-based specialists. The platform can be used by all deployed medical personnel at operational medical facilities, which are at least minimally equipped with low bandwidth technology capable of e-mail. Nondeployed providers, patients, and patient family members are not permitted to use the teleconsultation service currently.

Since its inception with the departments of dermatology and ophthalmology, the AKO teleconsultation program has experienced rapid success. AKO has expanded to include 19 additional subspecialties, including the following (Table 1):

Table 1 List of specialties with consult groups

Specialty
Burn-Trauma
Cardiology
Dermatology
Dental
Infectious Diseases
Infection Control
Internal Medicine
Microbiology/Laboratory
Nephrology
Neurology
Ophthalmology/Optometry
Orthopedics/Podiatry
Pediatrics Intensive Care
Preventive Medicine
Rheumatology
Toxicology
Traumatic Brain Injury
Sleep Medicine
Urology

As of September 2012, more than 10,600 teleconsultations have been requested from more than 2600 providers from all four branches of the military deployed in more than 40 countries [16]. From October 2006 to December 2010, more than 500 of these teleconsultations were addressed to the military teleneurology consultation group and 131 to the TBI consultation group [17]. Most consultation requests were answered in less than 5 h, and approximately 143 known evacuations (3 neurology-specific) were avoided following receipt of the consultants' recommendations [17]. Thus, the AKO telemedicine system has successfully streamlined medical communications between military health-care providers and has led to a better evacuation mechanism (i.e., only evacuation of appropriate cases) in deployed health-care settings.

Current Use in Combat Settings

Technology Required

The austere environment of deployed settings necessitates the use of store-and-forward systems, and so the AKO teleconsultation program predominates as the telemedicine solution to specialty care in theater [15]. No specialized equipment is necessary to support this service. Instead, providers wishing to send a consultation request require only a Department of Defense (DoD) secure computer with Internet and e-mail capability. Most deployed providers also have their own digital camera while deployed, obviating the need to supply cameras to in-theater health-care providers. Because operational medical facilities already own all the equipment necessary to facilitate the AKO teleconsultation program, the program remains both a safe and cost-effective way to obtain medical advice within the existing DoD network.

Telemedicine Team Members

The AKO telemedicine system consists of a range of clinical and administrative members who work together to ensure timely and proficient teleconsultations. These team members include the AKO consult manager (CM), the surgeon generals' medical specialty consultants, the AKO consultants, and the deployed providers.

The AKO CM serves as the "gatekeeper" of the teleconsultation service. The CM supports the daily operations of the service by monitoring consult activity for quality and timeliness. The CM, who has access to all telehealth communications within the AKO network, is familiar with medical terminology and ensures consult compliance with the Health Insurance Portability and Accountability Act (HIPAA; Public Law 104–191) and with the 24-h response time period mandated by the Office of the Surgeon General of the US Army. If necessary, a reminder is sent to the specialty if a teleconsultation is not answered within 12–18 h. Furthermore, the CM has a broad knowledge of digital imaging and information technologies, allowing the CM to troubleshoot technical problems with individual consultations. For example, military treatment facilities often block incoming and outgoing e-mails that exceed certain size limitations. Size limitations can hinder the transmission of medical images, such as radiographs or other supporting documentation, which are larger than the maximum 1–2 MB file size. In these cases, the CM can manually compress the image to the appropriate file size before retransmitting them to the appropriate provider. The CM may also contact the deployed provider directly to instruct him or her on how to adjust the camera resolution to maximize the utility of future consultations.

In addition to ensuring AKO teleconsultation guidelines, the CM also collects, records, and permanently stores all consult data according to specialty. The database is valuable in the support of follow-up consultations and in the generation of the CM's monthly, annual, and ad hoc reports. These reports include data analyses about the epidemiology of disease, number and type of consultation requests, consult response times, patient outcome, number of medical evacuations facilitated or avoided, and levels of provider satisfaction.

Finally, the CM is the central liaison between deployed providers and consultants. The CM trains and educates deploying providers about the AKO teleconsultation program and the rules of engagement. The CM also sends an introductory e-mail to new AKO consultants after they receive their first teleconsultation request. Through these interactions, the CM becomes aware of the geographic locations of all specialty consultants both inside and outside of the combat zone, and is able to route the consult requests to the appropriate locations. The CM can also facilitate collaboration by including multiple specialties—say neurology, ophthalmology, and TBI—in a single consultation request.

The surgeon generals' *medical specialty consultant* supervises his or her respective teleconsultation service. The medical specialty consultants recruit medical staff to answer teleconsultations and develop an on-call roster to ensure the scheduling and availability of consultants from all branches of service (Army, Navy, Air Force, Public Health Service). However, the medical specialty consultant position is optional within a specialty and depends on the availability and willingness of a team member to accept additional responsibility. The specialties of dermatology, pediatrics, and infectious diseases, for example, have designated medical specialty consultants, while the specialty of neurology has not. In the absence of a central supervisor, telemedicine requests may go unanswered until an AKO consultant becomes available. However, the CM ensures that all telemedicine requests are answered within a 24-h time period, regardless of the existence of a medical specialty consultant, by reminding the consultant group or individual providers to answer the consultation request.

The *AKO consultants* review and respond to consult requests every day of the week, including weekends and holidays. The first consultant to respond to the request assumes primary responsibility for the case until diagnosis and treatment recommendations are complete. If necessary, the primary responder may include other medical specialties to complete the request, but in most cases the consultants are board-certified experts in their fields.

Deployed providers generate the consultation requests and send them to the corresponding e-mail utility groups (see below), while adhering to local policies on the transmission and storage of patient information. The deployed provider also assumes primary responsibility for patient outcome and for reviewing the content of the consultant's recommendations. Once the case if closed, the deployed provider is also in charge of documenting the content and outcome of the teleconsultation in the patient's military medical record.

Store-and-Forward System Components

To facilitate the fast and efficient transfer of information between deployed providers and the appropriate AKO consultants, the store-and-forward system is organized into two components. The first component is a utility account with easy to remember e-mail addresses. The second component consists of a contact group which is populated with the e-mail addresses of specialty consultants. Only specialty consultants within a given utility account are able to view the requests and respond with a suggested diagnosis and treatment options.

Model Telemedicine Algorithm

In general, the deployed health-care provider generates one consultation request per patient in the form of a text narrative sent in an e-mail to the appropriate utility account. All e-mail accounts should have a common format: xxx.consult@XXXX.XXX. The consultation request should include nonidentifying information about the patient (age, gender, occupation, branch of service, etc.), history of current injury/illness, previous treatments and outcomes (if applicable), laboratory test results (if any), the referring provider diagnosis, and limitations in managing the patient (e.g., availability of medications, procedures, and equipment). The deployed provider should also indicate his or her unclassified location in the consultation request in the event that the CM knows of any available regional medical assets or consultants. Any supporting digital images attached to the e-mail must obscure the face and any identifiable markings unless required for an accurate diagnosis. In compliance with HIPAA, no protected health information such as name, social security number, date of birth, medical record number, etc. should be included in the request. However, a consulting physician may request patient identifying information (PII) after initial contact is made so they can review the patient's medical history in the military health-care records system. If the consulting physician does not obtain the PII, he/she does not obtain workload credit for answering the teleconsultation.

After the e-mail is sent, the utility account automatically forwards the e-mail to a second server, called "contact groups," which has the names and e-mail addresses of the specialty consultants. The e-mail is automatically forwarded to the contact group, while the primary consultant retrieves the medical information and reviews the teleconsultation. Within 24 h of receipt, the primary responder replies to the entire specialty group and to the referring physician with diagnosis and treatment recommendations. The "reply to all" function ensures central visibility among the entire specialty group, thereby facilitating collaboration within the specialty (Fig. 1).

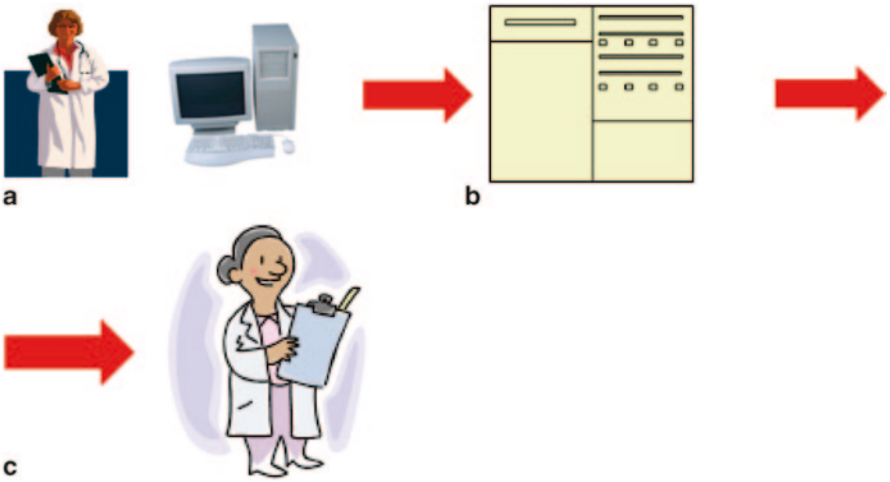


Fig. 1 Process of requesting telemedicine consultation. **a** The deployed health-care provider sends an e-mail to the utility account. All e-mail accounts have a common format: xxx.consult@XXXX.XXX. **b** The utility account automatically forwards the e-mail to a second server, called "contact groups," which has names and e-mail addresses of the consultants. **c** The e-mail is automatically forwarded to the consultants who answer the consultation. The consultant replies to the entire group and the referring physician. This facilitates collaboration within the specialty

The deployed provider may then respond to the group as a whole with follow-up questions or with new information that may change the consultant diagnosis. The CM may also send the consultation request with primary responder diagnosis to other specialties for further confirmation and collaboration. In 2011, approximately 15 % of military neurology telemedicine cases involved such back-and-forth communication between the referring physician and consultants to achieve a final diagnosis and treatment regimen. In 2012, this number decreased to 9 % of cases requiring such dialogue, indicating that referring physicians became more efficient at providing sufficient medical information for diagnosis and that the consultations were routed initially to the appropriate consultant groups.

Figures 2 and 3 provide case studies highlighting typical AKO teleconsultation e-mail exchanges. While one case involves occipital neuralgia and the other neurofibromatosis type 1, each of these cases follows the ideal algorithm with both deployed provider and consulting specialist utilizing the telemedicine program as intended.

Civilian Counterparts

There are a number of e-mail and web-based teleconsultation programs available in both the civilian and government systems. A health-care facility that is interested in a system can either purchase a commercial off-the shelf (COTS) system, task their information management directorate, or hire an outside agency to develop a system that meets their needs.

Take Home Points

The setup and operation of the AKO teleconsultation program allows for one or more specialists to provide medical opinions and also allows for rapid back-and-forth communication with the provider to obtain additional clinical details as needed. The overall goal of telemedicine use in theater is to deliver a timely assessment, to make an accurate diagnosis, and to deliver the appropriate medical treatment, all within strict confines of reliability and effectiveness so that the best patient outcome may be achieved.

Referring Physician's Narrative:
A 40-year-old white female who for the last 7 days has been complaining of (c/o) sharp "knife like" seldom pain onsets to the right occipital area, ~2 in posterior to the right ear. There were no MOI, no bug bites, no dizziness, no lightheadness, no vertigo, no weakness in either side of her body, and no noticeable facial/extremity palsy. Two years ago, she was "diagnosed with occipital neuralgia"; no record exists in her health record (H/R).

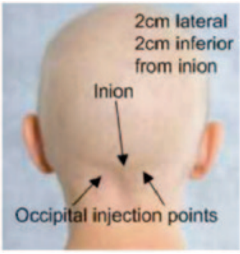
Now, she is experiencing these "quick and sudden" pain onsets that last less than 2 s. I put her on Indocine 25 mg (she is off it now and on Motrin 800 mg) and Robaxin 500 mg thinking that it may be some type of spasm in the temporalis or SCM muscles. She states that the medicines seemed to have taken the edge off the pain but, it still remains albeit, the pauses are longer now.

I was going to have her consulted by the officer-in-charge (OIC) at the XX Clinic (we were underway). We got there on the second and she was going to see him on the sixth but we got word to drop everything and get underway on the night of the fourth.

For what I have read, it would seem to be that [occipital neuralgia] again. There is no neuro deficit; CN I–XII are intact. No photophobia; strength and DTR are 3+ bilaterally. Neg Romberg.

Ophthalmologist's Reply:
This is out of the ophthal area. We shall monitor the message string though and provide input PRN.

First Neurologist's Recommendation/Diagnosis: I would agree that this history sounds very consistent with occipital neuralgia. The treatment of choice is an occipital nerve block. I use a mixture of lidocaine or bupivicaine and kenalog, and inject around the greater and lesser occipital nerves. Not sure if you have the capabilities to do such an injection there. It is a fairly simple procedure. I have attached some information about occipital nerve blocks but there are many resources on the Internet. An alternative would be to start a neuropathic pain agent such as neurontin 300 mg TID. This case sounds fairly straightforward and, based upon this history, would not require much more in the way of diagnostics.



Second Neurologists's Recommendation/Diagnosis: You are describing occipital neuralgia (ON). It is caused by entrapment of the C2—greater occipital nerve (sometimes the lesser). The usual treatment of choice is conservative therapy with heat packs and NSAIDS. If this does not work, you may consider greater occipital nerve block (GONB). I have attached a typical template note with the mixture I use. The procedure is very simple but would best be performed by someone familiar with it. I would have her seen at your next MTF to consider having the block tried. Also, muscle relaxants can sometimes help. I would use something like baclofen (probably not AMAL). It is less sedating and more effective than Flexeril. BOTOX has not been shown to be effective in the treatment of ON.

Diagnosis: Occipital Neuralgia

Outcome: Patient was injected at the region of maximal point tenderness (depth < 1 cm) with 2 ml of 0.5% Ropivicaine and 5 mg of Triamcinolone (Kenalog-10mg/ml) solution. The patient was released with a scheduled follow-up.

Fig. 2 Teleconsultation example #1 (*c/o* complaining of, *dx* diagnosis, *DTR* deep tendon reflexes, *hx* history, *H/R* health record, *MOI* mechanism of injury, *MTF* military treatment facility, *NSAID* nonsteriodal anti-inflammatory drug, *OIC* officer in charge, *PRN pro re nata* [as needed], *SCM* sternocleidomastoid, *TID* three times a day)

Referring Physician's Narrative:
A 44-year-old white male has had soft nodules under his skin for the most part of his life. The nodules increased in numbers recently, and he was advised to be evaluated for neurofibromatosis. He is healthy with no past medical issues, no history of hypertension or back pain or other pain or numbness that may be explained by a neurofibroma. He has no surgical history. No medicines or allergies. He has no family members who have these nodules, but he does not know his father's side.
HEENT: Normal, with specifically no spots or nodules on his iris on slit lamp exam.
Skin: He has multiple soft nodules with a few on his chest and several on his back with only a few along his arms. They are compressible lesions and are softer than a lipoma. He has two larger areas of hyperpigmentation on his right side and otherwise no lesions that appear larger than 15 mm. He has axillary freckling and no groin freckling.
Additionally, he has no neurologic symptoms on my examination and appears well. In reviewing the diagnostic criteria for NF1, he does not have more than six café-au-lait spots. He does have more than two neurofibromas. He has axillary freckling, does not have Lisch nodules. He has no history of long bone problems and no family history. We are currently still off the coast, near a large naval medical center….

1. Is there enough of an increased risk for intracranial lesions to warrant sending him back for a full set of scans?
2. Does his later presentation mean he will likely have a milder course?
3. If sent ashore, is this neurology consult with dermatology evaluation or dermatology with neuro more appropriate?
4. Are there other conditions that would explain these findings and do these findings need to be evaluated now or can they wait until after deployment ~ 7 months?
Thank you again for this service and I look forward to whatever information you can provide.

First Neurologist's Recommendation/Diagnosis:
It is possible your patient has NF but without additional confirmation (histologic, radiographic) I am not completely convinced as the lesions are smaller than what I have seen in the several NF cases I have been involved with over the years. Also the absence of Lisch nodules (maybe sending a photo of the iris would be useful for us to review?), limited cutaneous signs other than nodules and lack of family history do not fit with classic NF. If he does indeed turn out to have NF, I would venture that because he is 44 and asymptomatic, this would predict a more benign course, but then again NFs are slow-growing lesions and could still cause major concerns depending on location/etc. Regarding evaluation, from the neurologic standpoint I feel he can safely hold on workup until you all return to home port, as you report he has no neurologic symptoms and has a normal neurologic examination. Regarding differential dx and other diagnostic recommendations for the skin nodules, I defer to my dermatology colleagues. Certainly if any change in examination is noted, especially if any objective neurologic signs develop during the rest of your deployment, he should be sent on for evaluation, but you and he should be OK for the remainder of your voyage.

Dermatologist's Follow-Up: Agree with Neurology that ultimately the diagnosis rests on histology (one or more biopsies) and imaging.
Could he have NF1? Yes
Does he have NF1? Maybe
Could he have segmental NF (this is a limited form)? Maybe

What else could he have? Collagenomas, leiomyomas, granular cell tumors, or any host of other benign soft tissue multiple neoplasms that occur in multiples.
Can he stay on the ship? Yes, but do realize that neurofibromatosis places you at an increased risk of meningioma, astrocytoma, glioma, and neurofibrosarcoma no matter what type he may have and about 5–10 % of lifetime risk malignancy.

Do you have the capability of snagging a punch biopsy or similar small biopsy of two representative lesions? If they were to confirm NF, I really would get him fully evaluated and he would need close lifetime specialty follow-up. Even if they come back as leiomyomas (although these are usually tender) that could mean he has Reed Syndrome (familial leiomyomatosis and renal cell carcinoma) and he would need kidneys checked for cancer. So much really rides on the actual pathology of the papular lesions.

These agminated (grouped) papules should be regarded as a cutaneous marker for something and I do favor it being NF and with a host of possible sequelae I would look at the big picture on this guy. If you think all of his papules fit into one dermatome, i.e., left-sided T10–12 (left chest, left back, left arm) then I would worry about him less because the segmental variety of NF does not have a whole lot of problems lifetime. If they are truly scattered all the heck over the place full phenotypic expression of NF is likely and he is at risk for malignancies as well as neurofibromas that can cause space occupying soft tissue problems.
So bottom line if you can get a biopsy cranked out that would settle the issue for me.

Referring Physician's First Follow-up: I will work on finding out the pathology of this patient. It was not in his chart when I looked previously, but I will use a few contacts to see if there are path results in AHLTA. Due to the size of the photos I was only able to send one or two because our ship is limiting the size of emails leaving the boat. He has lesions all over his body. Most are on his back, with some on his arms, chest and legs. So if he has it, then I am more concerned he has full NF. Thanks for the info. We have the capability of doing a punch biopsy and getting it ashore, but the command is currently planning on having him go ashore for further workup and if the workup is negative, he will meet us when we port.

Second Neurologist's Recommendation/Diagnosis:
Agree with all. Would add that only 50% of Nf1 is inherited, and the other 50% is spontaneous mutation (large gene, 17). Although generally diagnosed early, also are NF1 modifier genes/factors (unidentified) that cause a variable presentation (spectrum/mosaics). See this periodically in recruits and young service members. 44 y/o is a new one for me, but certainly not unheard of in NF1 circles.

Fig. 3 Teleconsultation example #2 (*AHLTA* Armed Forces Health Longitudinal Technology Application, *dx* diagnosis, *NF1* neurofibromatosis type 1, *y/o* years old)

Referring Physician's Second Follow-up: Thanks for the info. I was able to contact a friend ashore and get biopsy and pathology results which were not in the patients chart. He did have 3 biopsies in June which were positive for neurofibromas. The patient had three lesions which were benign neural tissue, later stated to be neurofibromas. The patient does have larger lesions in a different area on his chest and on his arms.

I appreciate the help and discussion that this service has provided and I have to say that I have learned a lot through this whole experience.

Diagnosis: NF1

Outcome: Patient sent to Naval Medical Center San Diego to see neurology and to direct his care and follow up.

Fig. 3 (continued)

References

1. Grigsby J, Brega AG, Devore PA. The evaluation of telemedicine and health services research. Telemed J E Health. 2005;11(3):317–28 (Epub 2005/07/23).
2. Grigsby J, Sanders JH. Telemedicine: where it is and where it's going. Ann Intern Med. 1998;129(2):123–7 (Epub 1998/07/21).
3. Patterson V. Time for teleneurology. Pract Neurol. 2004;4:129–30.
4. Organization WH. Neurology atlas. 2004.
5. Ganapathy K. Telemedicine and neurosciences. J Clin Neurosci. 2005;12(8):851–62 (Epub 2005/12/06).
6. Ahmed SN, Mann C, Sinclair DB, Heino A, Iskiw B, Quigley D, et al. Feasibility of epilepsy follow-up care through telemedicine: a pilot study on the patient's perspective. Epilepsia. 2008;49(4):573–85 (Epub 2007/12/14).
7. Samii A, Ryan-Dykes P, Tsukuda RA, Zink C, Franks R, Nichol WP. Telemedicine for delivery of health care in Parkinson's disease. J Telemed Telecare. 2006;12(1):16–8 (Epub 2006/01/28).
8. Kane RL, Bever CT, Ehrmantraut M, Forte A, Culpepper WJ, Wallin MT. Teleneurology in patients with multiple sclerosis: EDSS ratings derived remotely and from hands-on examination. J Telemed Telecare. 2008;14(4):190–4 (Epub 2008/06/07).
9. Loh PK, Donaldson M, Flicker L, Maher S, Goldswain P. Development of a telemedicine protocol for the diagnosis of Alzheimer's disease. J Telemed Telecare. 2007;13(2):90–4 (Epub 2007/03/16).
10. Cottrell C, Drew J, Gibson J, Holroyd K, O'Donnell F. Feasibility assessment of telephone-administered behavioral treatment for adolescent migraine. Headache. 2007;47(9):1293–302 (Epub 2007/10/12).
11. Miller TC, Zwerdling D. Brain injuries remain undiagnosed in thousands of soldiers. 2010. http://www.propublica.org/article/brain-injuries-remain-undiagnosed-in-thousands-of-soldiers. Accessed 14 Jan 2013
12. Lilie C. Moving images not patients. Signal [Internet]. 2005. Accessed 14 Jan 2013 (63 p.).
13. Ackerman RK. Telemedicine reaches far and wide. Signal [Internet]. 2005. http://www.afcea.org/content/?q=node/693. Accessed 14 Jan 2013 (55–9 pp.).
14. Poropatich RK, DeTreville R, Lappan C, Barrigan CR. The U.S. Army telemedicine program: general overview and current status in Southwest Asia. Telemed J E Health. 2006;12(4):396–408 (Epub 2006/09/01).
15. General OotS. Policy memo 09–034: use of Army Knowledge Online (AKO) email to conduct electronic medical consultation. In: Command USAM, editor. 2009. pp. 1–6.
16. Lappan C. Office of the Surgeon General Teleconsultation Program for Deployed Healthcare Professionals. 2012.
17. Yurkiewicz IR, Lappan CM, Neely ET, Hesselbrock RR, Girard PD, Alphonso AL, et al. Outcomes from a US military neurology and traumatic brain injury telemedicine program. Neurology. 2012;79(12):1237–43 (Epub 2012/09/08).

Telemedicine Technology

Dwight Channer

Abbreviations

AES	Advanced Encryption Standard
DICOM	Digital Imaging and Communications in Medicine
ePHI	Electronic protected health information
FIPS	Federal Information Process Standard
Gbps	Gigabits per second
HIPAA	Health Insurance Portability and Accountability Act
HL7	Health Level Seven
KB	Kilobytes
Kbps	Kilobits per second
Mbps	Megabits per second
PACS	Picture archiving and communications systems
SIP	Session initiation protocol

Telecommunications

The transmission of data across any communication modality in telemedicine is impacted by the amount of data the communication modality can carry reliably. Bandwidth can be described as the rate at which data (measured in bits or bytes) is sent and received in an information technology network. As a rule of thumb, asynchronous telemedicine technology applications (e.g., store-and-forward imaging) require less bandwidth than synchronous or real-time applications (e.g., videoconferencing) with the caveat that smaller bandwidth results in longer transfer times. Furthermore, high-definition videoconferencing tends to require the largest bandwidth to achieve higher real-time video resolution.

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Table 1 Performance quality at 1 Mbps bandwidth for various telemedicine applications

Application	Size	Estimated transfer time or minimum requirements
Computed tomography (CT) file transfer	510 KB (kilobyte)/image	
	×80 images/study (chest CT)	40.8 s
	×120 images/study (head CT)	61.2 s
	×140 images/study (body CT)	71.4 s
	×300 images/study (multi-slice CT)	153 s
Magnetic resonance imaging (MRI) file transfer	300 KB/image	
	×350 images/study	105 s
Ultrasound	250 KB/image	
	×30 images/study	7.5 s
Standard definition video-conferencing using H.323 standard	640×480 resolution at 30 frames/s	Minimum requirement of 384 kbps (kilobits per second)
High-definition videoconferencing using H.323 standard	1280×720 resolution at 60 frames/s	Minimum requirement of 1.1 Mbps

Mbps megabits per second

Estimated bandwidth requirements for typical telemedicine applications vary. Table 1 shows the estimated time to transfer data or minimum transmission requirements for several telemedicine applications.

Data transmission rates have grown steadily over time across the spectrum of wired and wireless communication. Wired local area network speeds have evolved from 3 Mbps (megabits per second) in the 1970s to100 Gbps (gigabits per second) in the 2010s. Broadband wireless speeds can now reach over 100 Mbps, while 4G cellular rates vary by network. 4G download speeds range upwards from 10 Mbps with nonsymmetrical upload speeds ranging upwards from 4 Mbps [1].

Security

Security measures to safeguard patient medical data are integral to implementing any telemedicine network within regulated environments. More than 80 countries and territories have enacted data protection laws covering multiple sectors of commerce and health care [2]. In the USA, the Health Insurance Portability and Accountability Act (HIPAA) Security Rule establishes a national standard for electronic health-care data transmissions [3].

The HIPAA Security Rule provides technical safeguards in the areas of access control, audit control, integrity, person or entity authentication, and transmission security. Access control covers “the ability or the means necessary to read, write, modify, or communicate data/information or otherwise use any system resource.” Access control focuses mainly on establishing policies for person or software access to electronic protected health information (ePHI). Audit control details the need to “implement hardware, software, and/or procedural mechanisms that record and examine activity in information systems that contain or use electronic protected health information.” Integrity relates to “the property that data or information have not been altered or destroyed in an unauthorized manner.” Person or entity authentication instructs that procedures should be implemented “to verify that a person or entity seeking access to electronic protected health information is the one claimed.” Finally, transmission security aims to “implement technical security measures to guard against unauthorized access to electronic protected health information that is being transmitted over an electronic communications network.”

The US Department of Health and Human Services has recommended the Federal Information Process Standard (FIPS) 140-2 encryption standard to ensure transmission security [4]. FIPS 140-2 uses cryptographic module specification to meet compliance standards. FIPS 140-2 falls under the Advanced Encryption Standard (AES) specification established by the US National Institute of Standards and Technology.

Image Sharing and Medical Information Transfer

Two main standards, Digital Imaging and Communications in Medicine (DICOM) and Health Level Seven (HL7), are predominantly associated with image and information sharing in telemedicine. Picture archiving and communications systems (PACS) leverage the DICOM standard to create software and hardware networks capable of sharing imaging from a variety of modalities such as computed tomography (CT), magnetic resonance imaging (MRI), and ultrasound to name a few. HL7 is an organization promoting the development of health-care information standards integral in electronic health record sharing.

DICOM hardware- and software-based systems typically fall into two categories of communication between devices: push or pull mode [5]. In the push scenario, a device can be configured to automatically send images to another device within a distributed network (Fig. 1).

Conversely, the pull scenario can be described as allowing a user to fetch selected images from a remote device by initiating a query of the remote PACS within the network autonomously (Fig. 2). After the query is matched, the user can request that the record is retrieved resulting in the PACS sending the image to the user workstation.

Presently, a wide range of devices are capable of displaying DICOM images ranging from traditional desktop workstations to tablets and smartphones. The

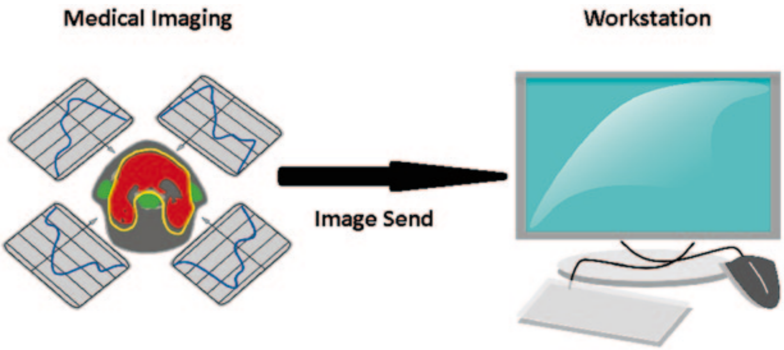

Fig. 1 DICOM push mode. DICOM Digital Imaging and Communications in Medicine

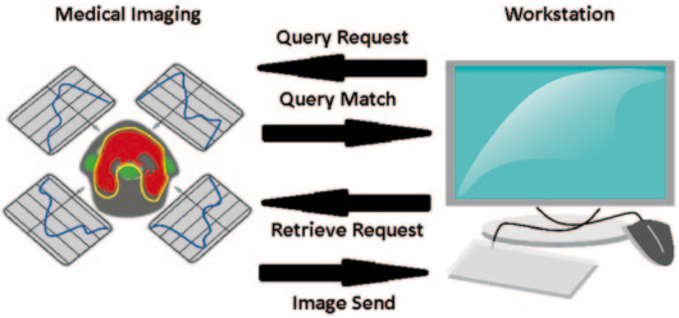

Fig. 2 DICOM pull mode. DICOM Digital Imaging and Communications in Medicine

variability in display characteristics in these devices necessitates DICOM calibration techniques, implemented through software design, to ensure quality control in diagnostic medical imaging review. Many smartphones and tablets implement ambient light sensors to adjust display brightness according to lighting conditions; however, without proper intervention from software-based DICOM calibration, image quality may be adversely affected. As a result, diagnostic integrity may be compromised in mobile devices unless calibration options are explicitly stated.

HL7 has been identified as the correct health-care industry standard for establishing software solutions utilized for sharing clinical data across disparate systems [6]. Specifically, vendors of electronic medical record software should adhere to the HL7 standard as it pertains to the development of applications for exchanging patient data. The HL7 organization has international roots and is formally accredited by the American National Standards Institute. At a basic level, the HL7 standard offers important interoperability solutions necessary for patient medical record sharing across organizations. Leveraging the HL7 standard offers a wide range of collaboration opportunities within teleneurology, thus broadening growth potentials for network building.

Videoconferencing

The growth of videoconferencing as a communications tool within telemedicine has been steady since the 1960s [7]. Advancements in the development of compression/decompression technology have permitted the transmission of large quantities of audio and video data over varying bandwidth conditions. Codecs (*cod*er-*dec*oder) are hardware- or software-based implementations that compress video and audio data pre-transmission and then subsequently decompress this same data post transmission. Using the strategy of data compression and decompression allows for lower bandwidth use with regard to videoconferencing [8]. Leveraging the strength of codecs has allowed developers to produce videoconferencing applications that can be utilized on desktop or laptop computers, tablets, and smartphones.

Videoconferencing protocols and standards have been developed to define the field for interoperability and multimedia communication. Two main standards that have emerged through time are the International Telecommunications Union (ITU) H.323 and the Internet Engineering Task Force (IETF) session initiation protocol (SIP) [9]. The standards differ in their approach to defining the guidelines for multimedia communication.

The H.323 standard has a historically well-defined architecture with guidelines detailing call setup and control along with the media used in the call. These guidelines permit updates; however, all updates must be backwards compatible with the existing standard. As a result, interoperability between H.323 compliant videoconferencing systems is strong. H.323 supports peer-to-peer communications without the need for a brokering agent to control the call.

SIP's strength and weakness is in the definition of its standard. SIP focuses on the definition of the initiation of a call session. Other parts of the call session (control, media transmission) can be defined by a variety of different protocols. SIP is designed to work in tandem with many core Internet protocols (IP). SIP architecture does require a proxy server for call management. The openness in the SIP standard definition can allow more opportunities for interoperability; however, in practice the openness has led to multiple interpretations. As a result, there are more than 80 SIP implementations with varying levels of interoperability.

Each standard allows for the inclusion of similar functionality although using different mechanisms to achieve the end goal of two-way audio/visual communication. Key features like multipoint conferencing (the connection of more than two endpoints on a given call), transmission encryption, remote pan, tilt and zoom control of the distant end camera, and dynamic responsiveness to varying bandwidth conditions can be incorporated within videoconferencing solutions in both standards.

Robots

The advent of robotic technology has provided more choices for telemedicine providers seeking innovative remote connectivity solutions. The main advantage telemedicine robots offer clinicians is autonomy in navigating the remote environment. Historically, two-way audio/visual communications systems were either room-based or incorporated into "computers on wheels"-based telemedicine carts. Robotic technology has afforded the industry with independently mobile platforms that do not require intervention from local clinical staff for setup.

Telemedicine robots leverage wireless Internet communication to allow remote users to send navigation commands to the robot and autonomously drive the robot in the remote environment. Users are provided with audio and visual feedback. Drive systems can navigate at speeds that surpass 5 ft/s. Additionally, battery life ranges from 4 to 12 h [10]. Key features may include:

- Automatic navigation—ability to travel with minimal user input to pre-programmed destinations within a remote environment
- Obstacle avoidance—onboard sensors detect impending collisions and prevent robot contact with objects in close proximity
- Zoom cameras—providing high-resolution diagnostic capabilities
- Docking Station—manual or automatic drive to a battery charging station connected to an electrical outlet

Peripherals

There is an expansive variety of peripherals that can be used to extend the medical examination capabilities of telemedicine systems. Peripherals typically connect to telemedicine systems and capture external data for transmission to remote users. The list includes (but is not restricted to):

- Electronic stethoscope
- Dermascope
- Video otoscope
- Endoscopes
- Ultrasound
- Electroencephalography (EEG), electrocardiography (ECG), electromyography (EMG) capture systems
- Glucometers
- Vital sign monitors

In the USA, the Food and Drug Administration (FDA) provides oversight and classification for any device that transmits, stores, converts, or displays medical device data used by health-care professionals for immediate decision making in clinical environments [11]. Operating and maintaining telemedicine technology may require adherence to compliance standards based on local regulatory agencies.

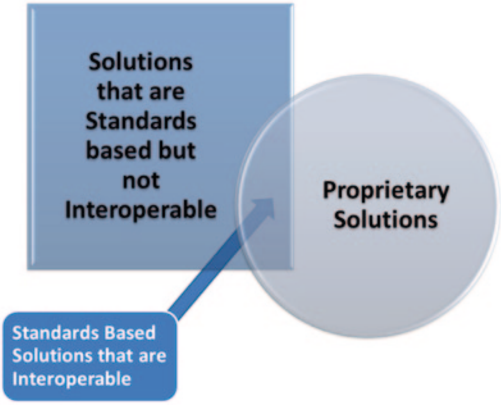

Fig. 3 Interoperability at the intersection of standards-based and proprietary telemedicine solutions

Interoperability

An essential key to the growth of teleneurology networks is the adherence to approved standards that encourage interoperability between disparate vendor solutions for image sharing, videoconferencing, and electronic health record access [12]. Current offerings across the spectrum of technology for telemedicine can be grouped into three categories: (1) solutions that are standards based but not interoperable, (2) proprietary solutions, and (3) standards-based solutions that are interoperable (Fig. 3). Although noninteroperable solutions may meet the minimum telemedicine communication requirements, the inherent closed design nature of these solutions can prove costly and time consuming as telemedicine networks work to integrate practices across an increasing number of organizations [13]. Telemedicine technology consumers can drive the telemedicine technology marketplace towards incorporating interoperability design components simply by pursuing a focused goal of unified standards and guidelines for remote patient care clinical activities.

References

1. Bashford C. General devices. 2011. http://www.general-devices.com/thinking-about-ems-telemedicine. Accessed: 28 Sept 2011.
2. Greenleaf G. Global Data Privacy Laws: 89 Countries, and Accelerating. Privacy Laws & Business International Report. 2012 February.
3. Code of Federal Regulations. US Department of Health & Human Services. 2003. http://www.hhs.gov/ocr/privacy/hipaa/administrative/securityrule/. Accessed: 12 Aug 2010.
4. FIPS Publication. US Department of Health & Human Services. 2001. http://www.hhs.gov/ocr/privacy/hipaa/administrative/securityrule/fips1402.pdf. Accessed: 9 Sept 2013.
5. Bidgood WD. Understanding and using DICOM, the data interchange standard for biomedical imaging. J Am Med Inf Assoc. 1997;4(3):199–212.
6. Hinchley A. In: Whittaker M, editor Understanding version 3—a primer on the HL7 version 3 healthcare interoperability standard—normative edition (Chapter 2, Background). Mönch: Alexander Moench Publishing; 2007.

7. Jarvis-Selinger S, et al. Clinical telehealth across the disciplines: lessons learned. Telemed e-Health. 2008;14(7):720–5.
8. Polycom Global Services. 2007. http://docs.polycom.com/global/documents/services/professional_services/high_definition_readiness_services/whitepaper_preparing_your_ip_network_for_hd_video_conferencing.pdf. Accessed: 3 Dec 2009.
9. Firestone S, Ramalingam T, Fry S. Voice and video conferencing fundamentals. Indianapolis, Indiana, USA: Cisco Press; 2007.
10. Lichtman H. Telepresence options. 2011. http://www.telepresenceoptions.com/2011/05/robotic_telepresence_tale_of_t/. Accessed: 30 Jan 2012.
11. U.S. Food and Drug Administration. Medical Device Data Systems. 2011. http://www.fda.gov/MedicalDevices/ProductsandMedicalProcedures/GeneralHospitalDevicesandSupplies/MedicalDeviceDataSystems/ucm251897.htm. Accessed: 10 March 2011.
12. Puskin D, et al. American Telemedicine Assosciation. 2006. http://www.americantelemed.org/docs/default-source/policy/telemedicine-telehealth-and-health-information-technology.pdf?sfvrsn=8. Accessed: 18 April 2012.
13. Ackerman M, et al. Chapter 6: telemedicine technology. Telemed J E-Health. 2002;8(1):71–8.

Telestroke

Mark N. Rubin, Bart M. Demaerschalk, Lee H. Schwamm and Lawrence R. Wechsler

Introduction

Cerebrovascular disease, including acute ischemic stroke, remains a major public health problem in the USA [1] and throughout the world [2]. There has been a concerted effort to apply evidence-based practices to stroke care in order to improve primary and secondary prevention as well as poststroke outcomes. One facet of this effort includes the development and accreditation of primary and comprehensive stroke centers, which have been demonstrated to improve stroke care [3]. The prompt and guideline-based administration of an acute stroke evaluation and management are among the more heavily scrutinized aspects of a stroke center [4]. The rationale for the particular attention to expedient administration of acute stroke evaluation and therapy is sound, given the limited time window and highly time-dependent benefits of rapid administration of the only Food and Drug Administration-approved therapy for acute stroke, recombinant tissue plasminogen activator (rt-PA) [5, 6, 7].

Geography contributes to a disparity in stroke care, however, as most stroke centers are based in large, urban academic medical centers. It is estimated that upwards of 40 % of the US population resides outside the reasonable clinical reach

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of a Joint Commission-certified primary stroke center. This previously presented a considerable barrier to the timely administration of acute stroke therapy. Furthermore, there remains a shortage of vascular neurologists, who are best equipped to provide acute stroke care and achieve the desired health outcomes [8–10].

In an attempt to combat the rural- and suburban-to-urban disparity and expand the availability of best stroke practices, Levine and Gorman proposed the development of telemedical outreach for acute stroke evaluation and management, which they called “telestroke” [11]. Since then, scientific evidence supporting telestroke has accumulated, with excellent interrater agreement between telemedicine-enabled versus bedside assessment of the National Institutes of Health Stroke Scale (NIHSS) score [12–14], and increased correct rt-PA decision making [15–17] by telestroke as compared to telephone-only consultation, and the telestroke model has been calculated to be cost-effective for both hubs and spokes as well as from a societal perspective [18–20]. In light of these findings and the perception of benefit by acute stroke providers and patients, there has been a rapid expansion of telestroke networks both in the USA [21, 22] and internationally [23]. The use of telestroke infrastructure for the complex, multifaceted, and similarly important prehospital and subacute phases of stroke evaluation and management is less known [24].

Evidence for Telestroke

Acute Stroke

Most telestroke publications to date focus on the acute phase of stroke care ($n=155$ for acute stroke, $n=28$ for poststroke) [16, 17, 24, 25]. The state of telestroke practice has matured to the point that there are specific American Heart Association/American Stroke Association statements detailing the evidence for its use [26] and guidelines for implementation [27, 28]. This came to be on the strength of studies that suggest excellent interrater reliability of NIHSS examination between remote and bedside examiners [13, 14, 29], randomized controlled trials of telestroke versus telephone consultation for acute stroke demonstrating superiority of telestroke for thrombolysis decision making [15, 17], and favorable health economic analyses [18-20].Telestroke is now considered in the mainstream of clinical practice in the academic and community environments [21, 22]. Furthermore, it has been demonstrated that high-quality telestroke consultations may soon be routinely able to be performed with mobile computers [30] and smartphones [11, 31, 32], enhancing the portability of the service.

Only two published randomized controlled trials compared telestroke to telephone methods of consultation for consideration of thrombolysis of acute ischemic stroke as of late 2013. The first trial, published in 2008, randomized 222 patients ($n=111$ for each study arm) with acute ischemic stroke to either telephone-only or telestroke-guided evaluation. The primary outcome was adjudication of “correct treatment” with rt-PA by the National Institute of Neurological Disorders and Stroke (NINDS) criteria. Typical stroke metrics were also tracked. In brief, the rt-

PA decision was adjudicated to be correct significantly more often with telestroke (98.2 %) than telephone (82 %) consultations. In spite of the telephone group having a significantly lower NIHSS on presentation (7.7) as compared to the telestroke group (11.4), there were no differences in 90-day mortality or outcome, nor any differences in the rate of hemorrhage [17]. A second group emulated this methodology with the intent of demonstrating feasibility of a telestroke versus telephone for acute ischemic stroke trial in another region (e.g., underpowered to demonstrate superiority of one mode over another). Fifty-four patients participated ($n=27$ for each arm) and no consultations were aborted but technical issues were frequent in the telestroke arm. Adjudicated rt-PA decision making was similar and good between the telephone (89 %) and telestroke (85 %) groups. There were no differences in 90-day mortality or outcome, nor any differences in the rate of hemorrhage [15]. A pooled analysis of these identically designed trials support the conclusions of the original trial, with a correct rt-PA decision significantly more likely with telestroke (96 %) versus telephone (83 %) with excellent frequency of rt-PA use (26 %) and no difference in mortality, outcomes, or hemorrhage.

There are a substantial number of pilot and feasibility studies that make the foundation of the field, detailing how to effectively incorporate telestroke into practice. The field appears to be advancing, but primarily via creative post-implementation studies, particularly in the prehospital setting. A group of investigators at the University of Maryland, otherwise known by the moniker TeleBAT, published the early data on prehospital telestroke [33, 34], and although they demonstrated reasonable interrater agreement of NIHSS between on-site and telestroke providers, their reported technology is antiquated and frame rates were unacceptably slow. The German Telemedical Project for Integrative Stroke Care (TEMPiS) group reported on their pilot [35], called PHANTOM-S, using enhanced stroke-dedicated ambulances equipped with computed tomographic (CT) scanners, point-of-care laboratory, teleradiology, and telestroke capabilities. However, their initial experience yielded an unacceptably high rate of technical failures [36]. Subsequent studies, however, utilizing a modern fourth-generation (4G) mobile network for data transmission, demonstrated feasibility and excellent call-to-needle times for treated patients [37]. Further study is planned, and the potential benefit to individual patients as well as society is substantial.

Poststroke

To date, 18 studies contribute primary data on the use of telestroke technology for poststroke evaluation and care, all small pilots and exploratory in nature. There were no randomized controlled trials, economic analyses, or post-implementation studies. Of note, nearly one third of the manuscripts ($n=10$) were narrative reviews and opinion pieces [24].

Many of the published manuscripts for poststroke telestroke come from the physiatry and rehabilitative medicine literature and detail pilots of home telerehabilitation systems for patients who have experienced a stroke. The studies that evaluated videoconferencing infrastructure for other, nonphysiatric elements of poststroke care are limited but promising. For example, an interesting pilot study conducted by Mikulik et al. compared logistics of performing a telementored transcranial Doppler (TCD) and carotid duplex (CD) examination by remote video-enabled guidance of a novice versus an in-person examination by an experienced sonographer [38]. They performed telemedical and in-person studies in each of the eight patients. There was reasonable agreement in the findings, particularly in the seven patients with sonographically normal carotid and intracranial vasculature. Their conclusion was that telemedical guidance of TCD and CD studies by an experienced sonographer was feasible for nonurgent studies and had good agreement with in-person studies in patients with normal vasculature.

Another aspect of poststroke care for patients with aphasia is a consultation with a speech pathologist. A pilot study by Brennan et al. sought to determine if telemedicine is an effective means of providing this service [39]. They studied 40 patients who each underwent in-person and telemedical observation while performing the Story Retelling Procedure. The goal was to identify any difference in performance between the experimental (e.g., telemedical) or control (e.g., in-person) settings and, if any were found, associate them with any demographics such as age, gender, or experience with technology. No significant differences were found in performance between the two settings, and no demographic features predicted particularly good or poor performances in any setting. The telemedical method was also highly satisfactory to participants. The authors concluded that videoconferencing has potential in poststroke aphasia evaluation but requires more investigation.

Health Economic Analysis

Telestroke practice is at a stage where health economic analyses have been performed and reported societal cost-effectiveness [18, 20] or long-term cost savings from the hospital and societal perspective [19].

The first telestroke economic analysis was designed to estimate the societal cost of telestroke for delivery of acute stroke therapy at 90-day and lifetime horizons versus usual care. A decision-analytic model was employed and data inputs came from the clinical experience of the investigators assuming a network of a single receiving ("hub") and eight referring ("spoke") centers. Costs and outcome estimations were based on studies current as of 2008. Briefly, it was shown that telestroke for delivery of thrombolysis is more cost-effective in the lifetime horizon as compared to usual care, with an incremental cost-effectiveness ratio (ICER) of US $ 2449 per quality-adjusted life-year (QALY), more so than in the 90-day horizon (ICER of US $ 108,363/QALY). The authors suggested that the divergence of results by time horizon is most likely due to the large up-front fixed costs of telestroke equipment compared to the lifelong benefit of better neurologic outcomes and avoidance of disability [18].

Following that study, others sought to model the cost-related aspects of stroke care for spoke and hub institutions more specifically with and without a telestroke network in place. They employed a decision analytic model and shaped the "with telestroke network" and "no telestroke network" on their considerable clinical experience with referring centers. Costs and outcome estimations were based on studies current as of 2011. The analysis assumed one hub and a seven-spoke network. In brief, with the telestroke network in place, the model predicted that about 114 fewer stroke patients would be admitted to the hub hospital each year, whereas approximately 16 more patients would be admitted to each spoke hospital compared with a no network setting. The model predicted that about 45 more patients would be expected to be treated with intravenous thrombolysis and 20 more with endovascular stroke therapy in a telestroke network per year. From the entire network perspective, an estimated average cost saving of US $ 358,435 per year could be achieved with a telestroke network versus a network without telestroke during the first 5 years. The hub would bear positive costs of US $ 405,121 per year, but each spoke would save US $ 109,080 per year. With cost-sharing arrangements between the hub and spoke hospitals, this analysis suggests that each hospital could achieve equal cost savings of US $ 44,804 per year during a 5-year time horizon. Overall, the results of this study suggest that a telestroke network may be an effective and financially tenable way to extend the reach of stroke specialists to remote areas and thus to improve the overall quality of care for stroke patients [19].

Building on the methodologic strengths and encouraging findings of previous health economic analyses for telestroke, Demaerschalk, et al. [20] conducted a cost analysis akin to their study of hub-and-spoke telestroke networks [19] but utilized novel and expansive data inputs from two different clinical telestroke networks to derive information from a societal perspective. As was the case with their previous model, the assumed network size was one hub and seven spokes. A unique feature of this study is the breadth of model inputs, including different health states and costs of everything from acute endovascular therapy to telestroke infrastructure maintenance to long-term care. The major finding of this analysis was that having a telestroke network was an overall dominant strategy to no network in the medium-to-long term, because telestroke was cost-saving and effectively increased QALYs over the lifetime horizon (e.g., beyond 1 year). Having a telestroke network versus no network was more costly per patient after 1 year (incremental US $ 444 per patient), but was cost-saving over the lifetime horizon (savings of US $ 1436), mostly due to savings in long-term skilled nursing care. Overall, incremental effectiveness was minimal in the first year of implementation (additional QALY 0.002) but increased by an order of magnitude (QALY 0.02) over the lifetime horizon. Overall, the investigators conclude from these data that telestroke is a cost-saving and effective program from a societal perspective, although these findings may be sensitive to specific network features.

Telestroke Technology

The term "telestroke" has been defined as "live, audio–video telecommunication applied to care of acute stroke" [23]. Historically, remote stroke consultation was practiced by a number of technological means less sophisticated than videoconferencing including telephone [40], multimedia messaging service (MMS) [41], e-mail, or some combination thereof. Although no evidence-based technological standards exist for telestroke, most modern telestroke systems are based on high-quality videoconferencing, which an American Heart Association/American Stroke Association guideline defines as a system that "…includ[es] transmission rates and algorithms of sufficient quality to support > 20 frames per second of bi-directional synchronized audio and video at a resolution capable of being accurately displayed on monitors of ≥ 13 in" [26]. These represent minimum standards, however, and reflect expert consensus opinion. Furthermore, telestroke networks vary significantly in the technology platforms and documentation platforms utilized. The technological aspects of a telestroke network are of interest as there has been growth in the telestroke-related telecommunications market within the last decade and the cost thereof remains one of the most consistently identified barriers to implementation of a telestroke network [22, 42]. Furthermore, in addition to hardware specifications, the desire for mobile telestroke capability (e.g., mobility of the hardware for prehospital application and/or mobility of the stroke expert) requires evolution of technical and privacy standards, as well as guaranteed quality of service frameworks for wireless data transmission.

Legal and Legislative Issues

In spite of a robust and growing evidence base supporting the use of telemedicine in general and telestroke in particular, there are a host of legal considerations that constitute a barrier to more widespread implementation.

Licensure

The essence of telemedicine is to disseminate medical expertise to patients and local providers irrespective of geographical boundaries. Currently, medical licensure and hospital credentialing processes run counter to that principle, as they are predicated almost entirely on geography. In the USA, medical licensure is under the purview of an individual state. Furthermore, in most states, a physician must be licensed in the state where a patient seeks care. Thus, a telemedicine physician must undergo the rigorous licensure process in nearly each and every state and territory. The exceptions, who have a mechanism to grant a telemedical license for practitioners licensed in another state, include Alabama (ALA.CODE § 34-24-502), Louisiana (LA.REV. STAT.ANN. § 1276.1), Minnesota (MINN. STAT. § 147.032(1)), Montana (MONT. ADMIN.R. 24.156.802(5)), Nevada (NRS § 630.261(e)), New Mexico (NM STAT. ANN. 1978 § 61-6-6), Ohio (OH. REV.CODE ANN. § 4731.296(C)), Oregon (OR. REV. STAT.ANN. § 677.139), Tennessee (TCA § 63-6-209(b)), Texas (22 TEX. ADMIN.CODE § 174.12), and Guam (10 G.C.A. § 12202). The Federation of State

Medical Boards proposed the Model Act in 1995 which would afford a licensed physician in any state the privilege to practice telemedicine across state lines, limiting in-person medical care to the primary state of licensure. This act has not been formally accepted by any state to date, although the aforementioned states that grant telemedicine licensure based on a medical license in good standing elsewhere in the USA have enacted its basic tenet. A recent piece of federal legislation (42 CFR §§ 482.12 and 482.22) helped to streamline the process of being credentialed for a telemedicine site by allowing the credentialing process of the hub site to effectively "transfer" so as to avoid duplicative administrative barriers.

Privacy

The right to privacy of medical records is considered fundamental and is protected by federal law (45 CFR § 160) in the form of the Health Insurance Portability and Accountability Act (HIPAA). Compliance with HIPAA is necessary whether medical information is transmitted by hand or over the Internet. Privacy and security of the telemedicine systems can be maintained by Secure Site License (SSL) conditional access, data encryption, intruder alerts, and access logging and reporting. The integration of security features into modern telemedical hardware and software ensures HIPAA compliance for telestroke consultations. Given the new ubiquity of smartphones and their high-quality videoconferencing capability, the desire to employ these inexpensive handheld devices for telemedicine must be matched by a HIPAA-compliant means of doing so, including the use of virtual private networks (VPN) or closed wireless networks.

Fraudulence and Abuse

The practice of telestroke introduces new opportunities for clinical outreach and dissemination of best practices, but quality cannot be sacrificed for the sake of access. A cynic might conceptualize a situation where the ubiquity of videoconferencing devices is leveraged to establish a for-profit, direct-to-consumer telemedicine model. As a means of maximizing profit, there would be a natural drive to find low-cost providers to meet what one would anticipate to be heavy demand for the service, and the practice responsibilities desired and assigned might fall outside of the scope of the training of said providers. There are numerous federal laws in place that help to ensure medicine is practiced by licensed individuals, the most notable being the Criminal Health Care Fraud Statute (18 U.S.C. §§ 1347, 1349) and the False Claims Act (31 U.S.C. §§ 3729–3733).

Patients are also protected from the potential conflict of interest of self-referral by a physician for expensive medical services by the Physician Self-Referral Law (or "Stark Law" for the California congressman who sponsored the initial legislation (42 U.S.C. § 1395 nn, 42 C.F.R. §§ 411.350–.389) and the Anti-Kickback

Statute (42 U.S.C. § 1320a–7b[b], 42 C.F.R. § 1001.952). These laws broadly discourage the circumstance of self-referral by a physician and regulate the "legitimate business" of referral within a group practice. The regulations are entirely relevant to telestroke practice as arrangements with telestroke hubs—financial or otherwise—must comply with these laws. For example, contractual "subscriptions" as financial compensation for telestroke services can be undertaken based on exceptions to the broad aim of the law, but under careful regulation. Health-care-specialized legal oversight is advised when drafting such contracts.

Many of the legal and legislative issues exist for the use of telemedicine in general, but there are some that are particularly relevant to telestroke. Some who are wary of developing a telestroke network cite the lack of legal clarity at a federal level (or even in most states) as regards shared liability between hub and spoke sites in the case of a bad outcome. For the case of acute stroke, since it seems that the majority of stroke-related lawsuits come from rt-PA *not* being administered, the institution of a process that affords emergency medicine providers access to stroke specialists and has been shown to increase rt-PA use should mitigate this concern. That said, there is still a role for establishing clear contractual agreements between hub and spoke sites, be they supported by federal law or on an interindividual basis.

Future Direction

It is worth noting that the appearance of advancement in the field comes from the contribution of post-implementation telestroke studies rather than on the strength of randomized trials or cost analyses. Moreover, the telestroke literature is rife with reviews. This is to be expected from a relatively mature field and as the practice grows in utilization and popularity. A possible alternative explanation for nearly half of all manuscripts in the field being in the form of a review might be the perceived importance of disseminating the data and opinions of leaders in the field. In light of the substantial up-front costs of a telestroke system [42, 43], it is only reasonable that payers and administrators would require equally substantial evidence that might encourage them to make such an expenditure. Along those lines, the use of high technology to expand the reach of specialty services to patients in a time of great need can be said to make for compelling reading, possibly enhancing "buy-in" from readership, be they patients, providers, administrators, or payers.

More than a decade since its published conceptualization, there is now a robust and growing literature base that supports the use of telestroke in mainstream clinical stroke practice. It is noteworthy that telemedicine publications in acute stroke represent approximately 40% of all published articles on telemedicine applied to the broad field of clinical neurological sciences and all of its subspecialties [44, 45]. The trajectory of telestroke research is mostly encouraging given the recent flurry of post-implementation studies, particularly in the prehospital setting, which aim to further reduce time to stroke recognition and treatment. Further study is recommended to establish minimum technical standards for in- and prehospital telestroke use as well as to establish quality process and outcome metrics. The use of telestroke videoconferencing infrastructure for subacute stroke management and education of trainees and the community at large about acute stroke evaluation and management also remains largely unstudied. Perhaps most importantly, there is a paucity of randomized trials and cost analyses, which might otherwise serve to buttress the practice. These data as well as fair, sustainable reimbursement for services should help to dissolve barriers to the implementation of telestroke. Overall, telestroke practice and its evidence base continue to grow, to the benefit of stroke patients.

References

1. Roger VL, Go AS, Lloyd-Jones DM, Benjamin EJ, Berry JD, Borden WB, et al. Heart disease and stroke statistics–2012 update: a report from the American Heart Association. Circulation. 2012;125(1):e2–e220.
2. Brundtland GH. From the World Health Organization. Reducing risks to health, promoting healthy life. JAMA. 2002;288(16):1974.
3. Lichtman JH, Allen NB, Wang Y, Watanabe E, Jones SB, Goldstein LB. Stroke patient outcomes in US hospitals before the start of the Joint Commission Primary Stroke Center certification program. Stroke. 2009;40(11):3574–9.
4. Fonarow GC, Gregory T, Driskill M, Stewart MD, et al. Hospital certification for optimizing cardiovascular disease and stroke quality of care and outcomes. Circulation. 2010;122(23):2459–69.
5. The National Institute of Neurological Disorders and stroke rt-PA stroke study group. Tissue plasminogen activator for acute ischemic stroke. N Engl J Med. 1995;333(24):1581–7.
6. Hacke W, Kaste M, Bluhmki E, Brozman M, Davalos A, Guidetti D, et al. Thrombolysis with alteplase 3 to 4.5 h after acute ischemic stroke. N Engl J Med. 2008;359(13):1317–29.
7. Saver JL, Fonarow GC, Smith EE, et al. Time to treatment with intravenous tissue plasminogen activator and outcome from acute ischemic stroke. JAMA. 2013;309(23):2480–8.
8. Donnan GA, Davis SM. Neurologist, internist, or strokologist? Stroke. 2003;34(11):2765.
9. Goldstein LB, Matchar DB, Hoff-Lindquist J, Samsa GP, Horner RD. VA Stroke Study: neurologist care is associated with increased testing but improved outcomes. Neurology. 2003;61(6):792–6.
10. Smith MA, Liou JI, Frytak JR, Finch MD. 30-day survival and rehospitalization for stroke patients according to physician specialty. Cerebrovasc Dis. 2006;22(1):21–6.
11. Levine SR, Gorman M. “Telestroke”: the application of telemedicine for stroke. Stroke. 1999;30(2):464–9.
12. Demaerschalk BM, Vegunta S, Vargas BB, Wu Q, Channer DD, Hentz JG. Reliability of real-time video smartphone for assessing National Institutes of Health Stroke Scale scores in acute stroke patients. Stroke. 2012;43(12):3271–7.
13. Shafqat S, Kvedar JC, Guanci MM, Chang Y, Schwamm LH. Role for telemedicine in acute stroke. Feasibility and reliability of remote administration of the NIH stroke scale. Stroke. 1999;30(10):2141–5.
14. Wang S, Lee SB, Pardue C, Ramsingh D, Waller J, Gross H, et al. Remote evaluation of acute ischemic stroke: reliability of National Institutes of Health Stroke Scale via telestroke. Stroke. 2003;34(10):e188–91.
15. Demaerschalk BM, Bobrow BJ, Raman R, Kiernan TE, Aguilar MI, Ingall TJ, et al. Stroke team remote evaluation using a digital observation camera in Arizona: the initial mayo clinic experience trial. Stroke. 2010;41(6):1251–8.

16. Demaerschalk BM, Raman R, Ernstrom K, Meyer BC. Efficacy of telemedicine for stroke: pooled analysis of the stroke team remote evaluation using a digital observation camera (STRokE DOC) and STRokE DOC Arizona telestroke trials. Telemed J E Health. 2012;18(3):230–7.
17. Meyer BC, Raman R, Hemmen T, Obler R, Zivin JA, Rao R, et al. Efficacy of site-independent telemedicine in the STRokE DOC trial: a randomised, blinded, prospective study. Lancet Neurol. 2008;7(9):787–95.
18. Nelson RE, Saltzman GM, Skalabrin EJ, Demaerschalk BM, Majersik JJ. The cost-effectiveness of telestroke in the treatment of acute ischemic stroke. Neurology. 2011;77(17):1590–8.
19. Switzer JA, Demaerschalk BM, Xie J, Fan L, Villa KF, Wu EQ. Cost-effectiveness of hub-and-spoke telestroke networks for the management of acute ischemic stroke from the hospitals' perspectives. Circ Cardiovasc Qual Outcomes. 2013;6(1):18–26.
20. Demaerschalk BM, Switzer JA, Xie J, Fan L, Villa KF, Wu EQ. Cost utility of hub-and-spoke telestroke network from societal perspective. Am J Manag Care. 2013;19(12):976–85.
21. George BP, Scoglio NJ, Reminick JI, et al. Telemedicine in Leading US neurology departments. Neurohospitalist. 2012; 2(3):123–128
22. Silva GS, Farrell S, Shandra E, Viswanathan A, Schwamm LH. The status of telestroke in the United States: a survey of currently active stroke telemedicine programs. Stroke. 2012;43(8):2078–85.
23. Demaerschalk BM, Miley ML, Kiernan TE, et al. Stroke telemedicine. Mayo Clin Proc. 2009;84(1):53–64.
24. Rubin MN, Wellik KE, Channer DD, Demaerschalk BM. Systematic review of telestroke for post-stroke care and rehabilitation. Curr Atheroscler Rep. 2013;15(8):343.
25. Rubin MN, Wellik KE, Channer DD, Demaerschalk BM. A systematic review of telestroke. Postgrad Med. 2013;125(1):45–50.
26. Schwamm LH, Holloway RG, Amarenco P, Audebert HJ, Bakas T, Chumbler NR, et al. 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. Stroke. 2009;40(7):2616–34.
27. Schwamm LH, Audebert HJ, Amarenco P, et al. Recommendations for the implementation of telemedicine within stroke systems of care: a policy statement from the American Heart Association. Stroke. 2009;40(7):2635–60.
28. Jauch EC, Saver JL, Adams HP, et al. Guidelines for the early management of patients with acute ischemic stroke: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. Stroke. 2013;44(3):870–947.
29. Handschu R, Littmann R, Reulbach U, et al. Telemedicine in emergency evaluation of acute stroke: interrater agreement in remote video examination with a novel multimedia system. Stroke. 2003;34(12):2842–6.
30. Audebert HJ, Boy S, Jankovits R, Pilz P, Klucken J, Fehm NP, et al. Is mobile teleconsulting equivalent to hospital-based telestroke services? Stroke. 2008;39(12):3427–30.
31. Anderson ER, Smith B, Ido M, Frankel M. Remote assessment of stroke using the iPhone 4. J Stroke Cerebrovasc Dis. 2013;22(4):340–4.
32. Gonzalez MA, Hanna N, Rodrigo ME, Satler LF, Waksman R. Reliability of prehospital real-time cellular video phone in assessing the simplified National Institutes Of Health Stroke Scale in patients with acute stroke: a novel telemedicine technology. Stroke. 2011;42(6):1522–7.
33. LaMonte MP, Cullen J, Gagliano DM, Gunawardane R, Hu P, Mackenzie C, et al. TeleBAT: mobile telemedicine for the Brain Attack Team. J Stroke Cerebrovasc Dis. 2000;9(3):128–35.
34. LaMonte MP, Xiao Y, Hu PF, et al. Shortening time to stroke treatment using ambulance telemedicine: TeleBAT. J Stroke Cerebrovasc Dis. 2004;13(4):148–54.
35. Ebinger M, Rozanski M, Waldschmidt C, et al. PHANTOM-S: the prehospital acute neurological therapy and optimization of medical care in stroke patients—study. Int J Stroke. 2012;7(4):348–53.
36. Liman TG, Winter B, Waldschmidt C, et al. Telestroke ambulances in prehospital stroke management: concept and pilot feasibility study. Stroke. 2012;43(8):2086–90.

37. Weber JE, Ebinger M, Rozanski M, et al. Prehospital thrombolysis in acute stroke: results of the PHANTOM-S pilot study. Neurology. 2013;80(2):163–8.
38. Mikulik R, Alexandrov AV, Ribo M, et al. Telemedicine-guided carotid and transcranial ultrasound: a pilot feasibility study. Stroke. 2006;37(1):229–30.
39. Brennan DM, Georgeadis AC, Baron CR, Barker LM. The effect of videoconference-based telerehabilitation on story retelling performance by brain-injured subjects and its implications for remote speech-language therapy. Telemed J E Health. 2004;10(2):147–54.
40. Frey JL, Jahnke HK, Goslar PW, Partovi S, Flaster MS. tPA by telephone: extending the benefits of a comprehensive stroke center. Neurology. 2005;64(1):154–6.
41. Singh R, Ng WH, Lee KE, Wang E, Ng I, Lee WL. Telemedicine in emergency neurological service provision in Singapore: using technology to overcome limitations. Telemed J E Health. 2009;15(6):560–5.
42. Switzer JA, Demaerschalk BM. Overcoming Challenges to Sustain a Telestroke Network. J Stroke Cerebrovasc Dis. 2012;21(7):535–40.
43. Fanale CV, Demaerschalk BM. Telestroke Network Business Model Strategies. J Stroke Cerebrovasc Dis. 2012;21(7):530–4.
44. Rubin MN, Wellik KE, Channer DD, Demaerschalk BM. Role of Telemedicine in Providing Tertiary Neurological Care. Curr Treat Options Neurol. 2013;15(5):567–82.
45. Bladin CF, Cadilhac DA. Effect of Telestroke on Emergent Stroke Care and Stroke Outcomes. Stroke. 2014;45(6):1876–80.

Teleneurointensive Care Unit (TeleneuroICU): Expanding the Reach of Subspecialty NeuroICU Care

William D. Freeman, Fred Rincon and Kenneth A. Vatz

Introduction

Teleneurology is defined as the remote audiovisual (AV) neurological evaluation of patients with neurological signs or symptoms, whereas telestroke is considered a subset of teleneurology and only evaluates stroke patients remotely. Telestroke, for example, is commonly employed to evaluate patients for tissue plasminogen activator (tPA) administration [1–4] consideration within 3–4 h of symptom onset. Telestroke and teleneurology applications, however, are increasingly being utilized in the intensive care unit (ICU) setting, especially in remote and underserved areas [5–10]. TeleneuroICU (or teleneurointensive care unit) evaluations are therefore defined as the remote neurological evaluation of neurointensive care unit (NeuroICU) patients within dedicated neuroscience or neurosurgical ICUs, or for neurological evaluation of patients that reside with general ICUs (Fig. 1). While the value of neurointensivists in terms of outcomes in critical care situations has been well demonstrated [5, 11–13], a similar utilization of neurointensivists via remote TeleneuroICU applications is beginning, as shown by Vespa and others [6, 8, 14, 15].

Neurocritical care requires clinical neurologic acumen on the part of the physician in addition to the physiologic and laboratory data that guide general critical

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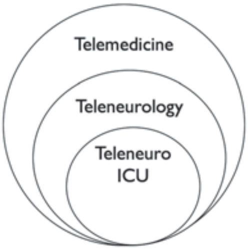


Fig. 1 Venn diagram illustrating telemedicine as a whole, and subdisciplines of teleneurology and TeleneuroICU (when it involves ICU evaluation of neurological patients or ICU patients being evaluated for neurological issues). *ICU* intensive care unit, *TeleneuroICU* teleneurointensive care unit

care. Wijman et al. summarized the essential role of the neurointensivist as "… [focusing] on the recognition of subtle changes in the neurological examination, interactions between the brain and systemic derangements, and brain physiology" [16]. This defines the basic challenge to teleneurocritical care, that is, to be able to perform at a distance the neurologic examination, and to observe and interpret the findings correctly.

There are approximately 554 board-certified neurointensivists in 2012 per the United Council of Neurological Subspecialties, which is a number too low to provide adequate care to all the hospitals requiring advanced NeuroICU evaluations. While neurointensivists are limited in number, they may use robotic telepresence (RTP) or a similar AV interface to cover their own patients. Conversely, TeleneuroICU can be used to evaluate other ICU patients in need of neurological evaluation. In this role, it serves as a general neurological consultation (teleneurology) for ICU patients admitted with nonneurologic diagnoses such as sepsis, cardiac arrest, and respiratory failure, but who develop secondary neurological problems including weakness, coma, or abnormal movements found by the local team. For this type of ICU neurological intervention, a neurologist or teleneurohospitalist, who may or may not be a neurointensivist, can utilize an RTP or a similar AV telemedicine system to perform the evaluation. When the physician performing the TeleneuroICU evaluation is a neurointensivist, the term teleneurointensivist is applicable. When the physician is a neurologist performing a neurological consultation in the ICU, the terms teleneurohospitalist and teleneurology are applicable [17].

For both types of evaluations, however, the AV and robotic equipment in use in 2013 have certain limitations in terms of the neurologic examination, and these are shown in Tables 1 and 2, which are adapted and expanded from Freeman et al. [18] The credentials, communication skills, and clinical abilities of the personnel at the spoke end all affect the capacity of the hub neurointensivist or teleneurohospitalist to function as if he or she were present at the bedside. The TeleneuroICU evaluation requires a coordinated effort and teamwork, and ideally a protocol indicating when to alert or consult the TeleneuroICU physician appropriately, depending upon the neurologic experience and skills of the spoke nurses, technicians, and local physician, and the nature of the setup at the spoke end.

Table 1 TeleneuroICU examination assessments and tools, feasibility, and limitations

Examination or assessments	Robotic telepresence or AV feasibility	Limitations
Level of consciousness scales GCS[36, 45] FOUR score[45, 46]	Yes, feasible if trained and at bedside	Bedside nurse needed to administer Lack of familiarity with GCS or FOUR
Cranial nerves (Table 2)	Yes, feasible, but with several limitations even with trained personnel at the bedside	Pupil and tongue assessments difficult without high-quality optics/zoom. Fundus examination may be impossible without adaptive equipment. Endotracheal tube and tube holder apparatus may prevent visualization of full facial movements
Language NIHSS aphasia screen section, reading	Yes, if bedside staff are trained in NIHSS or have reading cards available, or if robotic/AV system can display words or sentences to read	Disturbances in audiovisual connection ICU patients may be intubated Encephalopathic patients may not pay attention to video screen to read words
Motor examination NIHSS MRC	Yes, NIHSS and MRC use strength grading relative to antigravity status or examiner resistance	Observational, strength relative to examiner strength
Reflexes	Nurse/MD to administer	Observational
Chest auscultation	Yes on some RTP platforms, others not. Bedside nurse or MD may be surrogates	Not available on all RTP or AV systems
Other physical exam features in critically ill patients	Inconsistent exam features including airway assessment via direct laryngoscopy (DL), jugular venous distention, stridor, cyanosis and/or acrocyanosis, pallor, subtle skin abnormalities	RTP/AV systems cannot perform cardiopulmonary resuscitation, but can activate the local "code team," thereby intervening as a first responder
Laboratory and vital sign data	Nurse or bedside MD can read data out loud, some RTP/AV systems can review ICU on screen of the vital signs and other monitors (end-tidal CO_2, ventilators, ICP)	Electronic health record data does not integrate into RTP/AV interfaces for near-real-time co-assessment (exception being Phillips eICU system)
EEG	Yes, but optics need to be adequate and robotic system in optimal position to review EEG near real time in terms of proper reading aspect ratio	Visualization may not be adequate via RTP or AV system for subtle EEG changes, and EEG workstation access may not be separately available. "EEG neurotelemetry" services are starting to emerge that offer EEG technicians, machines, and monitoring [47]

Table 1 (continued)

Examination or assessments	Robotic telepresence or AV feasibility	Limitations
MMM	Yes, if optics are sufficient to review the bedside MMM computer, or if one has access to the data concomitantly	MMM not available except at some advanced NeuroICU centers due to resources and expenses. Moberg system is an all-in-one monitor that collects the MMM data into one display
Imaging review	Yes, ideal if one has PACS or similar electronic imaging access	Without PACS or similar access, review of imaging within the patient's room is limited by several visual factors such as quality of the optics, the aspect ratio, and light/contrast effects in the room, and is not ideal to see subtle changes such as dense artery sign, gray–white differentiation of anoxic brain injury, etc.

AV audiovisual, *EEG* electroencephalography, *eICU* electronic intensive care unit, *GCS* Glasgow Coma Scale, *MMM* multimodal monitoring, *MRC* Medical Research Council, *NIHSS* National Institutes of Health Stroke Scale, *PACS* picture archiving and communication system, *RTP* robotic telepresence, *TeleneuroICU* teleneurointensive care unit

Craig et al. in 2000 found the interactive video consultation to be feasible for neurologic inpatient assessment.[19] Rubin et al. reviewed the literature in 2012, looking at 375 unique studies which met eligibility criteria and concluded, "Use of telemedicine for general and most subspecialty neurologic consultation, beyond stroke, appears very promising but the clinical science is nascent" [20]. Vespa demonstrated that ICU RTP facilitated rapid physician response to unstable patients as well as decreased cost in the neuroICU [6].

Methodology and Technological Aspects of TeleneuroICU Evaluations

The basic requirement for TeleneuroICU evaluations is to have a reliable, high-quality AV conference call camera and interface. In the USA, regulations associated with the Health Insurance Portability and Accountability Act (HIPAA) require any communication that might disclose the patient's identity to be secured (e.g., secure socket layer or SSL) with encrypted information to protect the patient's confidential information. While the number of RTP and AV telemedicine vendors is growing, one is referred to the following resource references [21–24]

Table 2 TeleneuroICU cranial nerve examination, limitations, and adaptations

Cranial nerve (CN)	Robotic/AV examination	Limitation (robotic or AV) and or adaptations
II (optic)	Pupillary light reflex Visual fields Visual acuity Fundoscopy/papilledema	Subjective view from RTP/AV optics, or use of pupil gauge [48] or pupillometer [49, 50] Bedside nurse performance ICU patient cooperation, nurse grading each eye Fundic exam may be impossible without specialized equipment (Pan-optic/iExaminer™[51], and even then may be impossible for RTP/AV
III, IV, VI (ocular motor function, motility)	Bedside nurse instructs patient to follow finger or object or look in a particular direction to assess for gaze paresis and or CN palsy Cold-water calorics (CWC) performed by nursing	Bedside nurse instruction, limitations in field of view, but some systems have the ability to record video for re-review for ocular motor paresis, nystagmus Nursing must check ear canal, proper instruction on CWC, and adequate observation period.
V (trigeminal)	Facial sensation, corneal reflex	Technically limited to the method used by bedside nurse (e.g., safety pin or gross light touch). For example, corneal reflex testing in comatose patients has the nurse use a cotton swab while observing.
VII (facial)	Facial strength and asymmetry	ICU patients may be intubated, limiting the reliability due to endotracheal tube to gauge neurological deficits
VIII (auditory)	Hearing	Gross side to side auditory stimuli by nurse such as calling patient's name, or fingernail clicking in cooperative patients (grading as present/absent or diminished)
IX, X (glossopharyngeal, vagus)	Bedside nurse instructs patient to elevate palate Apnea test	Limited visualization unless nurse points light into pharynx and optics allow zoom visualization. With intubated patients, this exam feature may not be possible Apnea test done by local intensivist
XI (accessory)	Nurse instructs patient to shoulder shrug, turn head against examiner's hand	Subjective, observational, relies on nurse training and feedback about degree of strength
XII (hypoglossal)	Nurse instructs patient to stick out tongue	ICU patients may be intubated, limiting the reliability due to endotracheal tube to gauge neurological deficits

AV-audiovisual, *ICU* intensive care unit, *RTP* robotic telepresence system, *TeleneuroICU* teleneurointensive care unit for a review of specific systems, costs, and technical specifications. Recently, the use of an iPhone 4 or later (Apple Inc., Cupertino, CA, USA) has been described [25, 26] for TeleneuroICU evaluations. While more expensive (full service) commercially available robotic platforms exist such as the InTouch Health (InTouch Health Inc., Santa Barbara, CA, USA) [3, 22, 27], and REACH platforms (REACH Health Inc., Alpharetta, GA, USA) [23, 27, 28], a broad array of other vendor platforms is beginning to emerge including the "V-Go" platform (V-Go Communications Inc., Nashua, NH, USA) [24] and Phillips "eICU" platform (Phillips Healthcare, Andover, MA, USA) [29]. Some third-party firms such as Specialists on Call (SOC) also provide complete teleneurology services, that is, a neurologist and not just the technology, to interface with another hospital or emergency department (ED) [17, 30].

Two major issues to consider for the technological aspects of TeleneuroICU evaluations are network reliability and security. First, the network in performing an emergent TeleneuroICU consult must be extremely reliable. It is also suggested that the network or providing service be rapidly responsive, with 24/7 on-call tech support to regain access immediately in case the connection is dropped or lost. Commercially available platforms rely on fast broadband connections for adequate telemedicine evaluations. Though broadband connections provide undisputed reliability, wireless-based (third generation (3G), fourth generation (4G), long-term evolution (LTE), and Wi-Fi) communications have been implemented to extend the range and access of telemedicine platforms. The use of telestroke and TeleneuroICU services over Wi-Fi has already been tested and found feasible [6, 9, 15, 19]. Manufacturers of telemedicine platforms such as InTouch Health (InTouch Health Inc., Santa Barbara, CA, USA) and V-Go (V-Go Communications Inc., Nashua, NH, USA) allow providers to extend the practical use of desktop-based software onto mobile devices such as the iPad (Apple Inc., Cupertino, CA, USA), thus improving mobility and accessibility. Using the RP-Express (InTouch Health Inc., Santa Barbara, CA, USA) over 4G and LTE networks, simulated evaluations of stroke patients at the prehospital level were performed in the "Pre-hospital Utility of Rapid Stroke evaluation Using In-ambulance Telemedicine (PURSUIT)" study. The applicability of this approach and impact of the rapid evaluation of stroke and neurocritical care patients at the prehospital level will require further study.

Second, as alluded to above, security issues for physicians in terms of HIPAA compliance over such a network, using SSL or https-encrypted methods, are suggested [23, 31], as well as adherence to applicable state and local regulations.

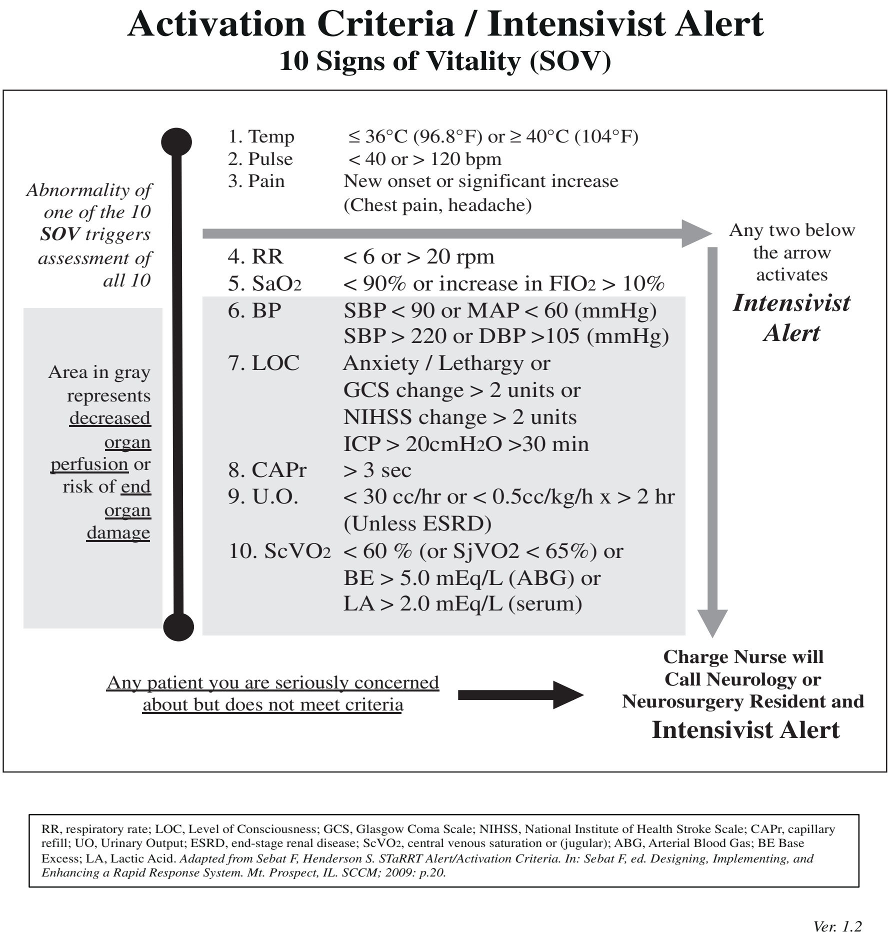
Additional data can enhance the TeleneuroICU evaluation. This includes "paraclinical" information such as neuroimaging via a picture archiving and communication system (PACS), laboratory and electronic record data review of vital signs, laboratory values, and electroencephalography (EEG) data. Various robotic vendors offer an integrated PACS system to the teleneurointensivist, albeit with an incremental fee [31]. Some hospitals themselves are able to grant similar remote electronic medical record with imaging, or PACS, access, similar to that provided to their local physicians [32]. Such information, though, generally must be accessed separately from the robotic or AV telestroke or teleneurology encounter, a process that requires additional time, raises third-party information technology (IT) concerns such as connectivity and 24/7 support issues, and, if TeleneuroICU services are to be provided to more than one site, adds the burden of distinct login information, passwords, etc., for each site.

At advanced academic NeuroICUs, multimodal monitoring (MMM) of sophisticated cerebral physiologic data of intracranial pressure monitoring variables, cerebral autoregulation, and cerebral microdialysis data may be available, and can be utilized if a patient has unexplained neurological deterioration. The Phillips electronic intensive care unit (eICU) system (Phillips Healthcare, Andover, MA, USA) also has software to detect different organs at risk based on the electronic inputs. The amount of paraclinical data review needed will vary depending on the complexity of the ICU being served and the clinical question to be answered. For example, Vespa reported [6, 33, 34] using an RTP system to monitor NeuroICU patients remotely when off-site, to rapidly assess unstable patients faster than would be possible physically due to travel logistics, and, as an advanced use of an RTP system, to monitor cerebral microdialysis, other MMM data, and EEG findings.

General Clinical Aspects of TeleneuroICU Evaluations

TeleneuroICU examinations ideally should be done by a bedside nurse. There are several reasons for this. First, the bedside nurse will be able to stimulate the ICU patient, and perform various actions that are not currently feasible with existing technology. Further, properly trained nurses can perform certain scales such as the Glasgow Coma Scale (GCS) or c (NIHSS) that have fairly good inter-rater reliability [35, 36]. It is generally advised that ICU bedside nurses be trained in the NeuroICU exam techniques or scales to be used at the spoke site, for example, GCS and NIHSS for optimal assessments (Table 1). This can be achieved through educational in-service lectures to the nursing staff given either locally or remotely by physician staff, or by having the nursing staff trained via national online resources such as American Heart Association or National Stroke Association [37, 38]. Building a pool of ICU nursing staff trained in these specific neurological assessments and other important clinical assessments (Table 2) is crucial to optimizing the clinical efficiency for the teleneurointensivist. Further, training ICU nurses in methods of interacting and setting up the robot or AV interface is equally important. For example, some centers move the robot to the ICU patient's bedside before the teleneurointensivist or teleneurohospitalist "beams in," i.e., before the AV connection is on and streaming live.

Moreover, it is critical to create or establish a local protocol as to "when" to activate a TeleneuroICU evaluation for proper utilization, efficiency [9], and overall satisfaction. One such protocol described by Rincon et al. at Jefferson NeuroICU triggers the remote teleneurointensivist whenever there is a GCS score drop of two



Activation Criteria / Intensivist Alert

10 Signs of Vitality (SOV)

Abnormality of one of the 10 ***SOV*** *triggers assessment of all 10*

1. Temp	≤ 36°C (96.8°F) or ≥ 40°C (104°F)
2. Pulse	< 40 or > 120 bpm
3. Pain	New onset or significant increase (Chest pain, headache)
4. RR	< 6 or > 20 rpm
5. SaO_2	< 90% or increase in FIO_2 > 10%
6. BP	SBP < 90 or MAP < 60 (mmHg) SBP > 220 or DBP >105 (mmHg)
7. LOC	Anxiety / Lethargy or GCS change > 2 units or NIHSS change > 2 units ICP > 20cmH_2O >30 min
8. CAPr	> 3 sec
9. U.O.	< 30 cc/hr or < 0.5cc/kg/h x > 2 hr (Unless ESRD)
10. $ScVO_2$	< 60 % (or SjVO2 < 65%) or BE > 5.0 mEq/L (ABG) or LA > 2.0 mEq/L (serum)

Any two below the arrow activates ***Intensivist Alert***

Area in gray represents decreased organ perfusion or risk of end organ damage

Any patient you are seriously concerned about but does not meet criteria

Charge Nurse will Call Neurology or Neurosurgery Resident and Intensivist Alert

RR, respiratory rate; LOC, Level of Consciousness; GCS, Glasgow Coma Scale; NIHSS, National Institute of Health Stroke Scale; CAPr, capillary refill; UO, Urinary Output; ESRD, end-stage renal disease; $ScVO_2$, central venous saturation or (jugular); ABG, Arterial Blood Gas; BE Base Excess; LA, Lactic Acid. *Adapted from Sebat F, Henderson S. STaRRT Alert/Activation Criteria. In: Sebat F, ed. Designing, Implementing, and Enhancing a Rapid Response System. Mt. Prospect, IL. SCCM; 2009: p.20.*

Ver. 1.2

Fig. 2 Jefferson NeuroICU protocol for neurointensivist remote telepresence activation from Rincon et al. [9, 40]

points, NIHSS worsening of two points, or other designated markers of vital sign deterioration (Fig. 2). This protocol was found to improve overnight nursing satisfaction and enhance communication. Beyond the technical aspects and which particular robotic system or AV system to utilize, it is likewise important to consider the protocol for activation of TeleneuroICU evaluation prior to embarking on or offering such TeleneuroICU services. Regardless of what protocol is adopted and proposed, the team of ICU nurses and physicians should review it before implementing and activating such a service. Longitudinally, a quality review of such a TeleneuroICU service can help improve the quality and systems-based practice in terms of proper and improper activations, lines of communication, and protocol modifications or improvements.

The type of TeleneuroICU model is also an important consideration. Some centers employ an RTP to cover their own NeuroICU overnight for airway, cardiac

Fig. 3 TeleneuroICU examples demonstrating the optic resolution of the RTP robotic system used to monitor an intubated comatose NeuroICU patient's continuous EEG (*left image*). The image on the right demonstrates the vital signs displayed on the ICU monitor of a comatose surgical ICU cardiac patient who suffered a seizure, and who has a pulmonary artery catheter (*yellow line*), along with other standard vital signs, and the ventilator settings (*bottom white numbers*). *EEG* electroencephalography, *ICU* intensive care unit, *NeuroICU* neurointensive care unit, *RTP* robotic telepresence, *TeleneuroICU* teleneurointensive care unit

arrest, and sepsis response on top of in-house general intensivists, because there are not enough neurointensivists to stay in-house 24/7 and 365 days a year. Other hospitals that are underserved and without intensivists or neurointensivists may employ a general "eICU" model to cover their ICU patients for a variety of conditions, regardless of the nominal subspecialty categories of the patients [29, 39].

Other clinical aspects of the TeleneuroICU evaluation include availability of additional paraclinical data to the teleneurointensivist performing the evaluation, such as access to the electronic health record, laboratory data, and imaging. Particularly relevant to TeleneuroICU are neuroimaging information and imaging review of computed tomographic (CT) scans of the brain, magnetic resonance imagings (MRIs), and other vascular imaging studies, and these are required in near real time with the AV connection. This is especially so in the case of ICU patients with acute stroke with regard to decision making regarding intravenous tPA, or referral to a neuroendovascular specialist if the ICU patient is not a candidate for intravenous (IV) tPA. The availability and ability to review EEG data or reports are also important factors in evaluating ICU patients due to the growing recognition of nonconvulsive seizures (NCSz) in general ICU patients and NeuroICU patient populations. The incidence of NCSz ranges from 10 to 30 % depending on the type of primary or secondary brain injury [34, 41]. EEG data can be sent remotely to the neurologist to review [42], or the EEG, along with vital signs, can be directly reviewed in near real time while they are being recorded at the bedside with an RTP system [34] (Fig. 3) or a similar high-quality AV system. EEG availability at a remote hospital with the required resources is described by Kull et al., and these resources include EEG machines, a reliable network, and technicians or nursing personnel qualified to apply and maintain EEG electrodes 24/7 [43]. The Montreal Neurological Institute describes a nurse-driven monitoring protocol that may be less labor intense than EEG technician monitoring [43, 44]. Because of these logistical complexities and resource requirements, EEG may not be available at all centers for TeleneuroICU purposes. However, given the incidence of seizures, both overt clinical and silent NCSz, EEG should be considered in implementing a TeleneuroICU model. Finally, advanced NeuroICU MMM physiological monitoring of these variables may be utilized effectively if the RTP system or a similar AV system can obtain the data at the bedside. If a network server is set up on these patients, then the data may be reviewed remotely, as well [9, 34].

A systematic, TeleneuroICU examination approach is suggested. This should incorporate the timing of the “beam in” for the teleneurointensivist relative to the presence of the bedside nurse or examiner, the setup of the RTP system (unless the AV system is fixed, as are some eICU systems) at the foot of the bed or some other protocolized location, and the type of examination tools typically used, e.g., NIHSS reading cards and pictures, pinprick tools, pupil gauge or devices, etc., as outlined in Tables 1 and 2.

Clinical and Technical Limitations to TeleneuroICU Evaluations and Consultations

TeleneuroICU examinations have a growing literature base, but may not be available in all hospitals and underserved regions due to costs of implementation, maintenance fees, and/or lack of available TeleneuroICU service provider. Further, there are many clinical limitations outlined in Tables 1 and 2 compared to the true bedside neurological examination. Figure 4 demonstrates two TeleneuroICU patient examples with different uses of the RTP system. The patient on the left is an aneurysmal subarachnoid hemorrhage patient who develops weakness as detected by the ICU nursing assessment. The nurse pages the neurointensivist to verify the examination, who in turn agrees and liberalizes her blood pressure parameter from 140 mmHg systolic to 160 mmHg and boluses 500 cc normal saline, which in turn resolves the deficit. The patient on the right in Fig. 4 demonstrates the optical resolution of zooming in on a patient’s eyes to see pupil reactivity, which was present in this case. Not all RTP/AV systems have adequate zoom functions to see this degree of resolution, but these are important considerations in performing TeleneuroICU evaluations.

Another example of clinical limitations is shown in Fig. 5, which depicts a comatose 80-year-old patient with small almost unreactive pupils as seen by the RTP system. An infrared pupillometer device is obtained and utilized, and which shows trace reactivity. The patient had received narcotics before being sent emergently to the NeuroICU. Without such a device, the pupils might have been deemed small but unreactive. However, the patient had other brain-stem reflexes such as cough,

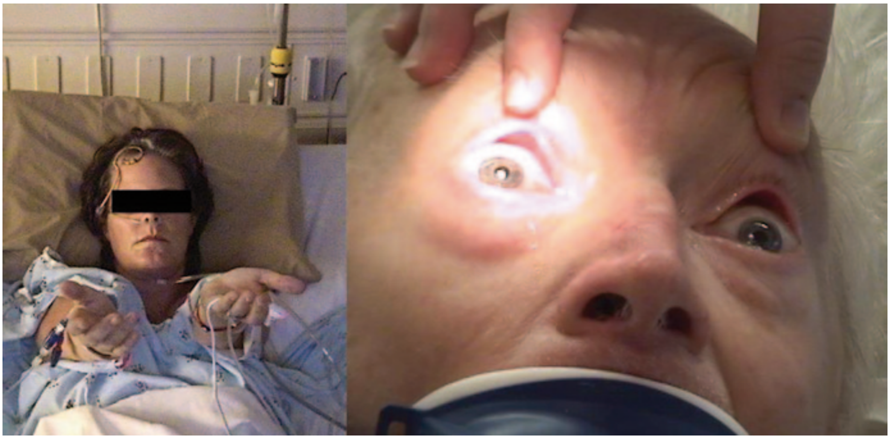


Fig. 4 TeleneuroICU patient examples. Patient A, *left image,* is a 47-year-old female who had a aneurysmal subarachnoid hemorrhage and external ventricular drain (EVD) placement (right side of head, *orange*) for symptomatic hydrocephalus, and who developed left middle cerebral artery vasospasm and right pronator drift. Patient B, *right image,* demonstrates an intubated, comatose patient with intracranial hemorrhage on warfarin. The examination is a "zoomed-in" view from the InTouch [22] RTP robot (InTouch Health Inc., Santa Barbara, CA, USA) of the patient's eyes, while the nurse shines a flashlight on the right eye, showing the optical resolution, and in this example adequate evaluation due to approximately 4–5-mm pupils

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NPi:	4.2 [Right]	4.1 [Left]	
MAX:	1.16	1.02	0.14 R>L
MIN:	1.00	0.88	0.12 R>L
%CH:	14%	14%	
LAT:	0.15	0.31	
CV:	0.22	0.25	
MCV:	0.58	0.63	
DV:	0.06	0.09	

Fig. 5 TeleneuroICU comatose 80-year-old patient who had small almost unreactive pupils on clinical RTP robotic examination, but the use of a "pupillometer" device [50] (NeuroOptics Inc., Irvine, CA, USA) demonstrated that although pupils were small, they remained reactive. This patient received narcotics before the current pupil exam. The left image shows approximately 1-mm maximum pupils, which constrict about 0.12–0.14 mm. The *right image* illustrates the appearance of the pupils at baseline side by side (*right* = *green, left* = *yellow*), as well as in the lower screen the reactivity in size (mm) on the *y*-axis over time (*x*-axis)

doll's head response, and corneal reflexes. Many of these examination limitations are constraints of the current technology in A/V equipment and/or robotics which require further refinements and advancements.

Financial and administrative aspects of employing RPT or AV telemedicine systems are important considerations, and are provided within the following references [6, 17, 52]. Different robotic systems vary in price; some are available for purchase whereas others are only available to lease. The startup and maintenance costs will also vary, and may require a workstation use and other resources such as PACS integration. One is encouraged to explore local vendors for pricing options. Careful consideration of the different and evolving robotic and AV telemedicine systems available should be made before embarking on an offer of TeleneuroICU services to other hospitals. Furthermore, review of the internal resources is necessary, and one should assess beforehand the 24/7/365 availability of the hub center and staff providing the proposed TeleneuroICU services.

Medicolegal risks of the hub-and-spoke personnel should be considered, similar to telestroke/teleneurology providers [18, 53, 54]. The satisfaction of ICU patients and families, as well as the complexity of decision making in critically ill, unstable, and end-of-life decision making situations, should be appreciated and understood for this patient population. For patients with poor neurological prognosis, the use of the bedside nurse as a witness for family discussions, ideally with the local intensivist or hospitalist present, may be employed to enhance the communication process for these difficult cases. Alternatively, providing the local spoke physician the neurologic diagnostic impression and prognosis may be another way to streamline communication, with that local physician hosting the family discussion.

Further, it is necessary to anticipate the ability of the local hospital team to respond to acute neurological diagnoses (such as acute stroke) in the ICU with appropriate contingency planning, including acute treatment strategies. Similarly, the possibility of NCSz discovery and need for EEG monitoring (intermittent or prolonged) should be considered. EEG services might be offered by the hub but may not always be possible due to lack of technical and/or 24-h support. ICU-acquired weakness is another example of a potential condition requiring TeleneuroICU consultation in medical and surgical ICUs. While the diagnosis of ICU-acquired weakness or critical illness myopathy/neuropathy is largely made on the history and clinical examination, which has limitations as described above, in some contexts the diagnosis may require neurophysiological testing such as electromyography (EMG) for diagnosis of Guillain–Barre syndrome or myasthenia gravis. Currently, some hospitals physically transport stable ICU patients in need of neurological expertise to tertiary referrals centers to get such neurological or neurosurgical input. TeleneuroICU consultations may serve to prevent unnecessary transportation and save the referring hospital costs of transportation and the associated risks of transfer. Creation of a spoke-and-hub model for TeleneuroICU services can, in effect, create an interinstitutional relationship for underserved hospitals, thereby allowing more streamlined access when specialized testing or services are available at the hub hospital.

Future Horizons in TeleneuroICU Care

TeleneuroICU evaluations have a growing body of literature supporting its use [6, 33, 34, 55, 56], or outlining areas for future research, but there remain considerable technological limitations compared to the bedside neurological examination. However, given the shortages of intensivists [57], neurologists, and neurointensivists now and in the foreseeable future [58], TeleneuroICU evaluations (outside or within the scope of teleneurology) are predicted to increase. Further refinements are needed to the TeleneuroICU examination, and will likely include the use of a bedside nurse or physician to help "extend" the examination techniques of the hub TeleneuroICU examiner. To improve efficacy, future challenges to manufacturers of telemedicine platforms and third-party applications will be to integrate or funnel different critical data components to allow providers to view and manipulate data using a single interface. The use of TeleneuroICU services in the future will undoubtedly help bridge geographic disparities and address underserved regions without access to neurological subspecialists. More rigorous studies examining the TeleneuroICU personnel, process (education, protocols, optimal delivery, or technology to be used), and outcomes (patient, users, cost-effectiveness) are needed.

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References

1. Levine SR, Gorman M. "Telestroke": the application of telemedicine for stroke. Stroke. 1999 Feb;30(2):464–9. PubMed PMID: 9933289. (Epub 1999/02/05. eng).
2. Wang S, Lee SB, Pardue C, Ramsingh D, Waller J, Gross H, et al. Remote evaluation of acute ischemic stroke: reliability of National Institutes of Health Stroke Scale via telestroke. Stroke. 2003;34(10):e188–91. PubMed PMID: 14500929. (Epub 2003/09/23. eng).
3. Demaerschalk BM, Miley ML, Kiernan T-EJ, Bobrow BJ, Corday DA, Wellik KE, et al. Stroke telemedicine. Mayo Clin Proc. 2009;84(1):53–64.
4. Switzer JA, Hall CE, Close B, Nichols FT, Gross H, Bruno A, et al. A telestroke network enhances recruitment into acute stroke clinical trials. Stroke. 2010;41(3):566–9.
5. Suarez JI, Zaidat OO, Suri MF, Feen ES, Lynch G, Hickman J, et al. Length of stay and mortality in neurocritically ill patients: impact of a specialized neurocritical care team. Crit Care Med. 2004;32(15640647):2311–7.
6. Vespa PM, Miller C, Hu X, Nenov V, Buxey F, Martin NA. Intensive care unit robotic telepresence facilitates rapid physician response to unstable patients and decreased cost in neurointensive care. Surg Neurol. 2007;67(4):331–7. PubMed PMID: 17350395. (Epub 2007/03/14. eng).
7. Josephson SA, Douglas VC, Lawton MT, English JD, Smith WS, Ko NU. Improvement in intensive care unit outcomes in patients with subarachnoid hemorrhage after initiation of neurointensivist co-management. J Neurosurg. 2010;112:626–30 (19731990).
8. Mateen FJ. Neurocritical care in developing countries. Neurocrit Care. 2011;15(3):593–8. PubMed PMID: 21863357.

9. Rincon F, Vibbert M, Childs V, Fry R, Caliguri D, Urtecho J, et al. Implementation of a model of robotic tele-presence (RTP) in the neuro-ICU: effect on critical care nursing team satisfaction. Neurocrit Care. 2012;17(1):97–101. PubMed PMID: 22547040.
10. Wesenberg Kjaer T, Sabers A. Landsdaekkende telemedicinsk hjernemonitorering. [Nationwide telemedicine brain monitoring]. Ugeskrift for laeger. 2013;175(12):792. PubMed PMID: 23582798.
11. Mirski MA, Chang CW, Cowan R. Impact of a neuroscience intensive care unit on neurosurgical patient outcomes and cost of care: evidence-based support for an intensivist-directed specialty ICU model of care. J Neurosurg Anesthesiol. 2001;13(2):83–92.
12. Varelas PN, Conti MM, Spanaki MV, Potts E, Bradford D, Sunstrom C, et al. The impact of a neurointensivist-led team on a semiclosed neurosciences intensive care unit. Crit Care Med. 2004;32(11):2191–8.
13. Thomas EJ, Lucke JF, Wueste L, Weavind L, Patel B. Association of telemedicine for remote monitoring of intensive care patients with mortality, complications, and length of stay. JAMA. 2009;302(24):2671–8.
14. Lazaridis C, Desantis SM, Jauch EC, Adams RJ. Telestroke in South Carolina. J Stroke Cerebrovasc Dis. 2011 Dec 22. PubMed PMID: 22196873.
15. Khan K, Shuaib A, Whittaker T, Saqqur M, Jeerakathil T, Butcher K, et al. Telestroke in northern alberta: a two year experience with remote hospitals. Can J Neurol Sci. 2010;37(6):808–13. PubMed PMID: 21059543. (Epub 2010/11/10. eng).
16. Wijman CA, Smirnakis SM, Vespa P, Szigeti K, Ziai WC, Ning MM, et al. Research and technology in neurocritical care. Neurocrit Care. 2012;16(1):42–54. PubMed PMID: 21796494. Pubmed Central PMCID: 3790471.
17. Freeman W. David BK, Vatz K, Demaerschalk B. Future neurohospitalist: teleneurohospitalist. Neurohospitalist. 2012;2:132–43.
18. Freeman WD, Barrett KM, Vatz KA, Demaerschalk BM. Future neurohospitalist: teleneurohospitalist. Neurohospitalist. 2012;2(4):132–43. PubMed PMID: 23983878. Pubmed Central PMCID: 3726112.
19. Craig J, Patterson V, Russell C, Wootton R. Interactive videoconsultation is a feasible method for neurological in-patient assessment. Eur J Neurol. 2000;7(6):699–702. PubMed PMID: 11136358. (Epub 2001/01/03. eng).
20. Rubin MN, Wellik KE, Channer DD, Demaerschalk BM. Systematic review of teleneurology: methodology. Front Neurol. 2012;3:156. PubMed PMID: 23162527. Pubmed Central PMCID: 3497715.
21. American Telemedicine Association link to Products and Vendors. Available from: http://atatelemedicinedirectory.com/. Accessed 27 Jan 2015.
22. Intouch Health Website. http://www.intouchhealth.com. Accessed 27 Jan 2015.
23. Reach on Call Website. http://reachcall.com. Accessed 27 Jan 2015.
24. V Go. http://www.vgocom.com: V Go; 2013. Accessed 28 Nov 2013.
25. Demaerschalk BM. Telemedicine or telephone consultation in patients with acute stroke. Current neurology and neuroscience reports. 2011;11(1):42–51. PubMed PMID: 20922505. (Epub 2010/10/06. eng).
26. Anderson ER, Smith B, Ido M, Frankel M. Remote assessment of stroke using the iPhone 4. J Stroke Cerebrovasc Dis. 2013;22(4):340–4.
27. Lai F. Stroke networks based on robotic telepresence. J Telemed Telecare. 2009;15(3):135–6. PubMed PMID: 19364896. (Epub 2009/04/15. eng).
28. Meyer BC, Lyden PD, Al-Khoury L, Cheng Y, Raman R, Fellman R, et al. Prospective reliability of the STRokE DOC wireless/site independent telemedicine system. Neurology. 2005;64(6):1058–60. PubMed PMID: 15781827. (Epub 2005/03/23. eng).
29. Phillips. Phillips eICU Infortmation Webpage. http://www.healthcare.philips.com/main/products/patient_monitoring/products/eicu/2013. Accessed 28 Nov 2013 (updated 2013).
30. Call SO. 2013. http://www.specialistsoncall.com/en/. Accessed 28 Nov 2013.
31. Yousem DM, Beauchamp NJ, Jr. Clinical input into designing a PACS. J Digit Imaging. 2000;13(1):19–24. PubMed PMID: 10696597. (Epub 2000/03/04. eng).

32. Vassallo DJ, Hoque F, Roberts MF, Patterson V, Swinfen P, Swinfen R. An evaluation of the first year's experience with a low-cost telemedicine link in Bangladesh. J Telemed Telecare. 2001;7(3):125–38. PubMed PMID: 11346472. (Epub 2001/05/11. eng).
33. Vespa P. Robotic telepresence in the intensive care unit. Critical care. 2005;9(4):319–20. PubMed PMID: 16137369. Pubmed Central PMCID: 1269464.
34. Vespa PM. Multimodality monitoring and telemonitoring in neurocritical care: from microdialysis to robotic telepresence. Curr Opin Crit Care. 2005;11(2):133–8. PubMed PMID: 15758593.
35. Goldstein LB, Bertels C, Davis JN. Interrater reliability of the NIH stroke scale. Archives of neurology. 1989;46(6):660–2. PubMed PMID: 2730378. (Epub 1989/06/01. eng).
36. Heron R, Davie A, Gillies R, Courtney M. Interrater reliability of the Glasgow Coma Scale scoring among nurses in sub-specialties of critical care. Australian critical care: official journal of the Confederation of Australian Critical Care Nurses. 2001;14(3):100–5. PubMed PMID: 11899634. (Epub 2002/03/20. eng).
37. AHA. Education and Training. http://learn.heart.org/ihtml/application/student/interface.heart2/nihss.html: American Heart Association; 2013. Accessed 28 Nov 2013 (updated 2013).
38. NSA. http://nihss-english.trainingcampus.net/uas/modules/trees/windex.aspx: National Stroke Association; 2013. Accessed 28 Nov 2013.
39. Celi LA, Hassan E, Marquardt C, Breslow M, Rosenfeld B. The eICU: it's not just telemedicine. Crit Care Med. 2001;29(Suppl 8):183–9.
40. Funk D, Sebat F, Kumar A. A systems approach to the early recognition and rapid administration of best practice therapy in sepsis and septic shock. Curr Opin Crit Care. 2009;15(4):301–7.
41. Sutter R, Stevens RD, Kaplan PW. Continuous electroencephalographic monitoring in critically ill patients: indications, limitations, and strategies. Crit Care Med. 2013;41(4):1124–32. PubMed PMID: 23399936. (Epub 2013/02/13. eng).
42. Rozza L, Tonella P, Bertamini C, Orrico D, Antoniol G, Castellaro L. Telephone transmission of 20-channel digital electroencephalogram using lossless data compression. Telemed J. 1996;2(4):267–71. PubMed PMID: 10165363. (Epub 1996/01/01. eng).
43. Kull LL, Emerson RG. Continuous EEG monitoring in the intensive care unit: technical and staffing considerations. J Clin Neurophysiol (official publication of the American Electroencephalographic Society). 2005;22(2):107–18. PubMed PMID: 15805810. (Epub 2005/04/05. eng).
44. Gotman J, Ives JR, Gloor P, Quesney LF, Bergsma P. Monitoring at the Montreal Neurological Institute. Electroencephalogr Clin Neurophysiol Suppl. 1985;37:327–40. PubMed PMID: 3924566. (Epub 1985/01/01. eng).
45. Fischer M, Ruegg S, Czaplinski A, Strohmeier M, Lehmann A, Tschan F, et al. Inter-rater reliability of the Full Outline of UnResponsiveness score and the Glasgow Coma Scale in critically ill patients: a prospective observational study. Crit Care. 2010;14(2):R64. PubMed PMID: 20398274. Pubmed Central PMCID: Pmc2887186. (Epub 2010/04/20. eng).
46. Wijdicks EF, Bamlet WR, Maramattom BV, Manno EM, McClelland RL. Validation of a new coma scale: the FOUR score. Ann Neurol. 2005;58(4):585–93. PubMed PMID: 16178024. (Epub 2005/09/24. eng).
47. Corticare. Corticare-An EEG Neurotelemetry Company. http://www.corticare.com2013. Accessed 28 Nov 2013.
48. Pascoe DA. A pupil gauge. Anaesthesia. 1980;35(10):1021. PubMed PMID: 7446900. (Epub 1980/10/01. eng).
49. Taylor WR, Chen JW, Meltzer H, Gennarelli TA, Kelbch C, Knowlton S, et al. Quantitative pupillometry, a new technology: normative data and preliminary observations in patients with acute head injury. Technical note. J Neurosurg. 2003;98(1):205–13. PubMed PMID: 12546375. (Epub 2003/01/28. eng).
50. Fountas KN, Kapsalaki EZ, Machinis TG, Boev AN, Robinson JS, Troup EC. Clinical implications of quantitative infrared pupillometry in neurosurgical patients. Neurocrit Care. 2006;5(1):55–60. PubMed PMID: 16960298. (Epub 2006/09/09. eng).

51. Welch-Allyn. iExaminer http://www.welchallyn.com/promotions/iExaminer/index.html: Welch-Allyn; 2013. Accessed 28 Nov 2013.
52. Breslow MJ, Rosenfeld BA, Doerfler M, Burke G, Yates G, Stone DJ, et al. Effect of a multiple-site intensive care unit telemedicine program on clinical and economic outcomes: an alternative paradigm for intensivist staffing. Crit Care Med. 2004;32(1):31–8.
53. de Bustos EM Moulin T Audebert HJ. Barriers, legal issues, limitations and ongoing questions in telemedicine applied to stroke. Cerebrovasc Dis. 2009;27(Suppl 4):36–9. PubMed PMID: 19546540. (Epub 2009/06/27. eng).
54. Schwamm LH, Audebert HJ, Amarenco P, Chumbler NR, Frankel MR, George MG, et al. Recommendations for the implementation of telemedicine within stroke systems of care: a policy statement from the American Heart Association. Stroke. 2009;40(7):2635–60. PubMed PMID: 19423851. (Epub 2009/05/09. eng).
55. Breslow MJ. Remote ICU care programs: current status. J Crit Care. 2007;22(1):66–76.
56. Kahn JM, Hill NS, Lilly CM, Angus DC, Jacobi J, Rubenfeld GD, et al. The research agenda in ICU telemedicine: a statement from the Critical Care Societies Collaborative. Chest. 2011;140(1):230–8.
57. Angus DC, Kelley MA, Schmitz RJ, White A, Popovich J. Caring for the critically ill patient. Current and projected workforce requirements for care of the critically ill and patients with pulmonary disease: can we meet the requirements of an aging population? JAMA. 2000;284(21):2762–70.
58. Dall TM, Storm MV, Chakrabarti R, Drogan O, Keran CM, Donofrio PD, et al. Supply and demand analysis of the current and future US neurology workforce. Neurology. 2013;81(5):470–8. PubMed PMID: 23596071.

Teleneurology and Neurointerventional Therapy for Acute Stroke

Nobl Barazangi, Joey English and David Tong

The Use of Teleneurology for Neurointerventional Therapy

Telestroke has evolved dramatically over the last two decades. Advances such as faster Internet connections, inexpensive new video platforms, and an explosion of new devices have greatly improved its technological aspects [1, 2]. Culturally, telemedicine has become an accepted and, at times, a preferred method of patient care. It has been endorsed by numerous professional and regulatory medical organizations, including the American Heart Association/American Stroke Association, American Academy of Neurology, and the Center for Medicare and Medicaid Services [3, 4]. Similarly, neurointerventional radiology (NIR) has grown as a field in the last 20 years, especially acute stroke therapy. The advent of new devices for mechanical thrombectomy and coiling of aneurysms has significantly advanced the field and has been associated with reduced morbidity and mortality, and in some cases, improved outcome [5]. The use of telemedicine for acute stroke care has increased the number of patients eligible to receive NIR therapy by the "hub-and-spoke" model, where smaller hospitals "drip-and-ship" patients to larger stroke centers for NIR therapy and comprehensive stroke/neurocritical care. The benefits of direct, real-time communication between transferring facilities and comprehensive stroke centers are twofold: Local hospitals have access to stroke neurologists and other specialists who would be difficult to access at their facility alone, and stroke neurologists have the additional clinical and imaging information via telemedicine to review whether a patient is a good candidate for NIR therapy, allowing for appropriate and efficient use of resources. A further benefit is increasing access of

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patients in remote locales to clinical trials and concurrently helping to increase enrollment in stroke research trials [6].

Telestroke has been shown in several studies to be effective and safe; it can also expand the use of thrombolysis to remote and underserved regions [7–9]. It can also reduce delays to treatment [10], and is cost-effective [11, 12] (for further details, see the chapter "Telemedicine and Parkinson Disease"). Telestroke can improve stroke care at the referring facility by implementing quality measures and protocols and enhancing stroke education [13]. It has also been shown to expand the availability of NIR therapies to patients who would have otherwise not been able to receive such therapy at the referring hospital [14]. Telestroke has also been shown to reduce the number of unnecessary transfers by improving efficiency in patient selection for NIR therapy [15]. In addition, telestroke helps improve transfer time [16]. Conversely, improving the transfer processes and patient volume to a comprehensive stroke center offering NIR therapy may improve the comprehensive stroke center program's safety, efficiency, and outcomes by providing the volume of patients needed to develop staff and facility expertise [6, 5].

There are more than 50 facilities in the USA, Canada, and Europe that have telestroke programs, and in general, most of these facilities have at least one hub facility that can perform NIR therapy [13, 17]. Overall, having a network of community/smaller hospitals, some with primary stroke center designation, connected via telemedicine to a comprehensive stroke center with NIR capability, is becoming the standard in the field of stroke therapy, but little data are available on the effectiveness of this model in the USA [6].

The California Pacific Medical Center Experience

CPMC Comprehensive Stroke Care Center Telestroke Network and NIR Program

The California Pacific Medical Center (CPMC) Comprehensive Stroke Care Center (CCSCC) is one of the largest stroke centers in California, evaluating patients from across the northern two thirds of the state, covering ~120,000 square miles with a population of more than 12 million. CPMC is a group of four academic, not-for-profit teaching hospitals in San Francisco offering primary through quaternary services in multiple specialties and has a dedicated neuroscience campus and neurocritical care intensive care unit. It is part of the Sutter Health Network (SHN), a private not-for-profit system of 29 hospitals primarily located in Northern and Central California. The CCSCC houses the CCSCC Telestroke Network (CPMCTEL). The network consists of ~20 hospitals spanning from South Central California (Visalia) to the California–Oregon border (Crescent City), a distance of ~600 miles. The participating hospitals include many facilities within underserved and rural areas of California (Fig. 1). CPMCTEL is the largest stroke telemedicine network in the region. This network encompasses ~3100 beds and >134,000 admissions annually.

Fig. 1 CPMC telestroke sites including CPMCTEL sites (with video teleconferencing capability) [red stars], referring hospitals within Sutter Health Network [green stars], and other referring hospitals [yellow stars]. *CPMC* the California Pacific Medical Center, *CPMCTEL* CPMC Comprehensive Stroke Care Center Telestroke Network

All sites possess 24/7 live video teleconference capability and full online radiology access. Furthermore, more than 40 sites utilize phone consultation and transfer patients to CPMC.

The CCSCC team of neurological experts includes five board-certified neurocritical care/stroke physicians. These are unusually well-trained specialists in the field who can handle nearly every conceivable vascular neurological condition. The program also includes the neurointerventional surgery service consisting of two full-time neurointerventional radiologists. The CCSCC is a teaching facility and has active academic and research programs as well as a high volume of vascular patients permitting expert evaluation and management of a diverse range of cerebrovascular and critically ill neurology patients.

Triage and Transfer Protocol

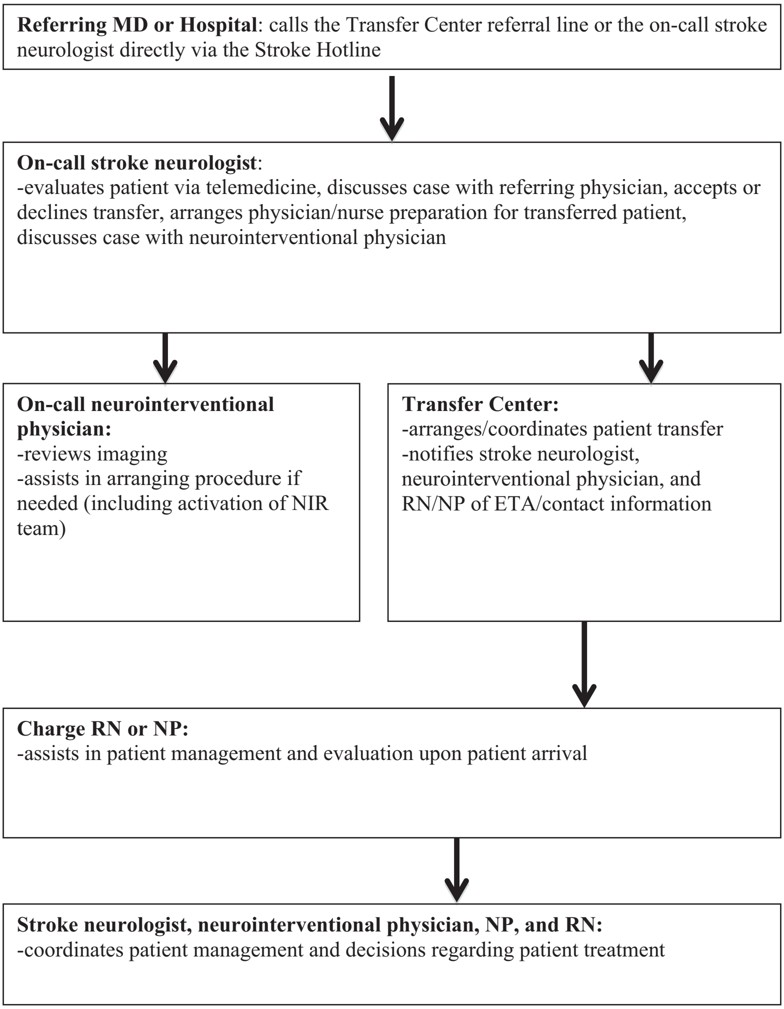
In 2013, more than 400 patients were transferred from these outside facilities. More than 800 patients/year (~70 % ischemic stroke) are treated at our CCSCC, with a high percentage receiving IV recombinant tissue plasminogen activator (rt-PA; $n = \sim 125$ per year, ~25 % of all ischemic stroke patients) and mechanical thrombectomy ($n > 75$ per year). Similar to our local population, the transferred patient group includes a high percentage of individuals from underserved populations, minority groups, and low socioeconomic status regions.

The average patient transfer time is <2 h from most referring facilities. Our most distant telemedicine hospital (Crescent City, CA, USA; 353 miles) can transfer patients to our facility within 3 h and often within 2.5 h. The high number of mechanical thrombectomy (>75 per year) and thrombolysis (~125 per year) cases reflects this ability to rapidly evaluate and treat patients. Approximately, 70 % of all thrombectomy patients from CPMCTEL facilities arrive at CPMC within 6 h of symptom onset, also demonstrating the effectiveness of the transfer mechanism.

The triage and transfer system (Fig. 2) begins with the outside hospital (OSH) emergency department calling a dedicated stroke hotline, where an operator connects that OSH directly to the on-call CPMC stroke neurologist within 5–10 min. The neurologist reviews the case, performs a video consult if needed, reviews the imaging (all sites provide neuroimaging data for remote review), and then decides if the patient is appropriate for transfer. While treatment is initiated, the CPMC transfer center coordinates patient movement to the CCSCC. There are standard times established for each OSH for transport time and also a standard order set for stroke management. The stroke neurologist then reviews the case with the NIR physician as appropriate. Other nurses, physicians, and personnel are also notified via a phone tree that is established in a formal protocol. The neurologist and NIR physician are notified of the patient's admission and proceed to the NIR suite within minutes of arrival if the patient is a candidate for NIR therapy.

Support and Sustainability of CPMCTEL and NIR at CPMC

Quality and efficiency are ensured by reviewing the transfer process during monthly Stroke Task Force meetings. Times such as door-to-needle, door-to-computed



Referring MD or Hospital: calls the Transfer Center referral line or the on-call stroke neurologist directly via the Stroke Hotline

On-call stroke neurologist:
-evaluates patient via telemedicine, discusses case with referring physician, accepts or declines transfer, arranges physician/nurse preparation for transferred patient, discusses case with neurointerventional physician

On-call neurointerventional physician:
-reviews imaging
-assists in arranging procedure if needed (including activation of NIR team)

Transfer Center:
-arranges/coordinates patient transfer
-notifies stroke neurologist, neurointerventional physician, and RN/NP of ETA/contact information

Charge RN or NP:
-assists in patient management and evaluation upon patient arrival

Stroke neurologist, neurointerventional physician, NP, and RN:
-coordinates patient management and decisions regarding patient treatment

Fig. 2 CPMCTEL triage and transfer flowchart. *CPMCTEL* the California Pacific Medical Center Comprehensive Stroke Care Center Telestroke Network, *ETA* estimated time of arrival, *NP* nurse practitioner, *NIR* neurointerventional radiology, *RN* registered nurse

tomography (CT), transfer from OSHs, and door-to-groin puncture times are reviewed. Constant communication with the telemedicine facilities is vital to maintain efficiency and patient safety, and the directors of the telemedicine and NIR programs make frequent visits to OSHs to understand their specific needs and to provide education and training. Maintaining this high level of quality and service to the transferring facilities is the key to making telestroke and NIR services successful. A significant level of administrative commitment and support from the participating institutions is also necessary to make such a program a success [18, 19]. At this facility, neurosciences is an important and valued service line. Administration is tasked with providing the necessary infrastructure and resources to enable state-of-the-art neurological care and to provide excellent neurological services. Furthermore, it is important in maintaining relationships with other regions and hospitals within the SHN and beyond. A dedicated team of physicians, nurses, and coordinators with a unified goal and strong leadership is essential. Once a successful telestroke network with comprehensive NIR capabilities is established based on a sound business model [20], it can be self-sustaining as in this case, allowing for further growth of the program.

Conclusions and Future Directions

Telestroke and NIR therapy have been become “mainstays” for acute stroke therapy, and there is mounting evidence that telestroke is safe and effective, as is NIR therapy. There are several models utilizing telestroke that can achieve the same goal: identifying and triaging patients safely and efficiently. One such example is presented in this chapter. Critical features include strong leadership, institutional support, and high-quality personnel as well as attention to detail and constant surveillance of quality.

In addition to the clinical advantages telemedicine affords in treating acute stroke patients, it has helped to expand the field of neurointerventional therapy and research in acute stroke therapy by increasing patient access, and potentially improving participation in investigational studies, including NIR studies. Traditionally, poor enrollment is one of the largest impediments to clinical stroke trials [6, 15]. In sum, telestroke and NIR therapy will continue to evolve hand in hand as acute stroke therapy advances.

References

1. Switzer JA, Demaerschalk BM. Overcoming challenges to sustain a telestroke network. J Stroke Cerebrovasc Dis (Research Support, Non-U.S. Gov’t Review Video-Audio Media). 2012;21(7):535–40.
2. Meyer BC, Demaerschalk BM. Telestroke network fundamentals. J Stroke Cerebrovasc Dis (Research Support, Non-U.S. Gov’t Review Video-Audio Media). 2012;21(7):521–9.
3. Schwamm LH, Holloway RG, Amarenco P, Audebert HJ, Bakas T, Chumbler NR, et al. 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. Stroke (Practice Guideline Review). 2009;40(7):2616–34.
4. Schwamm LH, Audebert HJ, Amarenco P, Chumbler NR, Frankel MR, George MG, et al. Recommendations for the implementation of telemedicine within stroke systems of care: a policy statement from the American Heart Association. Stroke (Practice Guideline). 2009;40(7):2635–60.
5. Meyers PM, Schumacher HC, Connolly ES Jr, Heyer EJ, Gray WA, Higashida RT. Current status of endovascular stroke treatment. Circulation (Review). 2011;123(22):2591–601.
6. El Khoury R, Jung R, Nanda A, Sila C, Abraham MG, Castonguay AC, et al. Overview of key factors in improving access to acute stroke care. Neurology (Review). 2012;79(13 Suppl 1):S26–34.

7. Henninger N, Chowdhury N, Fisher M, Moonis M. Use of telemedicine to increase thrombolysis and advance care in acute ischemic stroke. Cerebrovasc Dis (Review). 2009;27 Suppl 4:9–14.
8. Demaerschalk BM, Raman R, Ernstrom K, Meyer BC. Efficacy of telemedicine for stroke: pooled analysis of the Stroke Team Remote Evaluation Using a Digital Observation Camera (STRokE DOC) and STRokE DOC Arizona telestroke trials. Telemed J E Health (Comparative Study Randomized Controlled Trial Research Support, N.I.H., Extramural Research Support, Non-U.S. Gov't). 2012;18(3):230–7.
9. Meyer BC, Raman R, Hemmen T, Obler R, Zivin JA, Rao R, et al. Efficacy of site-independent telemedicine in the STRokE DOC trial: a randomised, blinded, prospective study. Lancet Neurol (Randomized Controlled Trial Research Support, N.I.H., Extramural Research Support, Non-U.S. Gov't Research Support, U.S. Gov't, Non-P.H.S.). 2008;7(9):787–95.
10. Mazighi M, Derex L, Amarenco P. Prehospital stroke care: potential, pitfalls, and future. Curr Opin Neurol (Review). 2010;23(1):31–5.
11. Demaerschalk BM, Switzer JA, Xie J, Fan L, Villa KF, Wu EQ. Cost utility of hub-and-spoke telestroke networks from societal perspective. Am J Manage Care (Research Support, Non-U.S. Gov't). 2013;19(12):976–85.
12. Switzer JA, Demaerschalk BM, Xie J, Fan L, Villa KF, Wu EQ. Cost-effectiveness of hub-and-spoke telestroke networks for the management of acute ischemic stroke from the hospitals' perspectives. Circ Cardiovasc Qual Outcomes (Comparative Study Research Support, Non-U.S. Gov't). 2013;6(1):18–26.
13. Muller-Barna P, Schwamm LH, Haberl RL. Telestroke increases use of acute stroke therapy. Curr Opin Neurol (Review). 2012;25(1):5–10.
14. Audebert HJ, Schwamm L. Telestroke: scientific results. Cerebrovasc Dis (Review). 2009;27 Suppl 4:15–20.
15. Tatlisumak T, Soinila S, Kaste M. Telestroke networking offers multiple benefits beyond thrombolysis. Cerebrovasc Dis (Review). 2009;27 Suppl 4:21–7.
16. Pedragosa A, Alvarez-Sabin J, Rubiera M, Rodriguez-Luna D, Maisterra O, Molina C, et al. Impact of telemedicine on acute management of stroke patients undergoing endovascular procedures. Cerebrovasc Dis (Research Support, Non-U.S. Gov't). 2012;34(5–6):436–42.
17. Silva GS, Farrell S, Shandra E, Viswanathan A, Schwamm LH. The status of telestroke in the United States: a survey of currently active stroke telemedicine programs. Stroke (Research Support, U.S. Gov't, P.H.S.). 2012;43(8):2078–85.
18. Switzer JA, Levine SR, Hess DC. Telestroke 10 years later—'telestroke 2.0'. Cerebrovasc Dis (Review). 2009;28(4):323–30.
19. de Bustos EM, Vuillier F, Chavot D, Moulin T. Telemedicine in stroke: organizing a network–rationale and baseline principles. Cerebrovasc Dis (Review). 2009;27 Suppl 4:1–8.
20. Fanale CV, Demaerschalk BM. Telestroke network business model strategies. J Stroke Cerebrovasc Dis (Research Support, Non-U.S. Gov't Review Video-Audio Media). 2012;21(7):530–4.

Teleneurosurgery

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Introduction

Ideally, all patients should have equal and immediate access to appropriate medical care, especially in emergency cases, irrespective of where the individual is located around the world.

Clinics and hospitals have constantly been built through private and public initiatives, and the number of facilities has grown significantly over the past few decades. More attention has also been paid to rural areas, which have been largely ignored in the past. Still, the situation remains far from ideal.

Unfortunately, the challenge is even bigger when looking at medical specialists. Many hospitals are missing experience in various specialist fields because the absolute number of available doctors is inadequate. Even in countries with sufficient numbers of specialists, many doctors prefer to reside in big cities, leaving rural areas with reduced access to specialists.

Telemedicine is a method that allows the expertise of neurological and stroke specialists to be brought to a hospital despite geographical barriers. Although many hospitals do not have the on-site resources to have a stroke team available all day every day, allocation of resources can be guided via telemedicine. One example is the drug alteplase, which has been shown to be administered safely using telestroke systems [1].

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There is no question of the importance of telemedicine for neurosurgical emergencies, especially in countries with inadequate health-care systems. Telemedicine offers real benefits in countries as vast as India, where the majority of the population lives in remote areas with access to nothing but the most rudimentary health care (nearly 70 % of the population of India is rural, with limited or no access to specialty neurosurgery care) [2].

Even in the USA, only 55 % of Americans have access to primary stroke centers within a 60-min drive [3].

Telemedicine was born to fill such gaps. The use of telecommunications in medical care has been attempted since the 1900s, when people living in remote areas of Australia used two-way radios (powered by dynamos and bicycle pedals) to communicate with the Australian Royal Flying Doctor Service. Telemedicine by video communication was first implemented by the University of Nebraska in the 1960s to allow clinicians to service remote populations [3].

Telemedicine or Telestroke

The use of thrombolytic tissue-type plasminogen activator (tPA) was approved in 1996 by the Food and Drug Administration (FDA) of the USA for the treatment of acute ischemic stroke [4], and its efficacy is greater the earlier it is administered [5]. The efficacy of tPA is very time dependent and is maximal when given early after stroke onset, with efficacy diminishing beyond about 4.5 h [3].

Despite the growing body of evidence supporting the use of tPA, even countries with advanced health-care systems show geographical disparities in the delivery of stroke thrombolysis [3]. Such disparities are much higher in countries with inadequate health-care systems, which demands even more use of telestroke in the system.

Telemedicine or telestroke is a method for delivering stroke care in regions without local stroke expertise [6]. Doctors who have advanced training in the nervous system (neurologists) remotely evaluate individuals presenting with suspected acute stroke, make a diagnosis, and provide treatment recommendations to emergency medicine doctors at other sites. Doctors communicate using digital video cameras, Internet telecommunications, robotic telepresence, smartphones, and other technologies.

Various reasons underlie the growing popularity of telestroke, which is being used to facilitate the evaluation and tPA treatment of patients with acute stroke in emergency departments (EDs) lacking on-site specialists [5].

The technology in telestroke has grown quickly over the past few decades. Prior telestroke work focused first on developing feasible and reliable telemedicine systems, then maximizing their use with administrations of recombinant tPA. The field of telestroke has continued to grow and our focus has evolved from maximization to optimization [7].

One of the great consequences of diagnosis through telestroke is the contribution to markedly reducing the number of interhospital transfers by offering the possibility of rapidly providing high-level clinical expertise to large numbers of patients [8]. This translates to a reduction in unnecessary transfers of patients and subsequently to cost benefits for both patients and medical providers [9].

Telestroke also has a great impact on the treatment of patients with intracerebral hemorrhage (ICH), which shows even worse mortality rates than ischemic stroke, approaching 50 % by 30 days after hemorrhage. Even among patients who survive, independent status by 6 months after ICH is achieved in less than 20 % of cases [10]. For this reason, ICH is one of the most frequent clinical conditions requiring emergency neurosurgical consultation. Telestroke allowed rapid visualization of neuroradiological and clinical data, providing neurosurgical expertise to community hospitals on demand and within minutes. This resulted in the treatment of patients at the community hospitals and optimized resource utilization. A small percentage of patients had secondary deterioration; telemedicine also enabled faster patient transfer when necessary and provided improved accuracy in patient care. Given the controversies remaining for many aspects in the treatment of ICH and the lack of universally accepted guidelines, prompt provision of a neurosurgical second opinion through a telestroke system may facilitate the treatment of patients with ICH [10].

Many tentative steps have been taken toward building effective networks for managing telestroke. Collaborations between stroke facilities can be divided into vertical and horizontal networking [11]:

- Vertical networking involves the centralization of expertise in specialized medical centers for the purposes of cooperation and collaboration with other institutions in the health-care system [11].
  Most current academic medical center-based telestroke programs are based on variations of the "hub-and-spoke" model, where one or more regional centers provide expertise via telecommunication links to outlying centers. These models may be challenging to implement in largely rural communities, where transportation links to the regional centers may be difficult [12].
- Horizontal networking consists of the implementation of widely independent infrastructures in geographically distant locations. The challenge is the need for neurological and neurosurgical expertise in each unit, which may not be available in many general hospitals [11].
  Research conducted in Bavaria, Germany, used five community hospitals without preexisting specialized stroke care along with telemedicine support from two academic hospitals; the study concluded that acute stroke care was able to be substantially improved in the networked community hospitals [13].
  The novelty of this structure is that local stroke physicians participate in the regional service, so delivery is not dependent on regional centers. This has clear advantages for local specialists, in that they retain and build upon competencies through the treatment of sufficient numbers of thrombolysis cases, even though their own services are relatively small. Keeping services local offers particular advantages in relatively large rural regions by minimizing dependence on regional transportation services and developing rehabilitation and follow-up care for patients closer to their homes [12].

In contrast with the fixed-site model described above, where the consultant is either at or travels to the hub hospital when called upon to provide a consultation, a site-independent or web-based model allows the consultant to access a web application on the public Internet via any computer using wireless or wired broadband [14]. This model is becoming more interesting and attractive with the rapid advance of new technologies such as smartphones.

The Increasing Use of Smartphones

The story of the growth of smartphones is remarkable. In 2006, only 1 % of the global population had a smartphone [15], while 14% of the global population used a smartphone in 2012; and by 2016, those numbers will be 30%. [16]. By 2017, 2.5 billion people around the world are expected to be using smartphones [17]. Not surprisingly, medical professionals are no exception to this growth in smartphone use.

Mobile technology has the potential to revolutionize how physicians practice medicine. From providing access to the latest medical research at the point of care to being able to communicate at a moment's notice with physicians and other colleagues around the world, we are practicing medicine in an increasingly technological age [18].

A survey conducted by *InformationWeek* in 2013 indicated that 47 % of doctors use a smartphone and/or tablet. The percentage of digital consumers was highest in oncology (59 %), cardiology (54 %), and primary care (48 %), followed by psychiatrists (44 %), nurse practitioners (40 %), and physician assistants (30 %) [19].

Clearly, smartphones are a new tool that will allow health-care providers to become more efficient in their daily activities, while providing clinically up-to-date care to their patients [18].

Massive use of social networking and short message service (SMS) applications such as WhatsApp and Line has been observed among medical groups for sharing information, discussing, and obtaining second opinions.

The Use of Smartphones in Telestroke

With the advances in mobile phone technology, soon we will be able to be reached at anytime and anywhere in the world. Many people from medical fields have already identified practical uses for these amazing devices and have adopted them to seek for solutions to problems encountered in day-to-day practice. We have observed doctors using smartphone apps such as WhatsApp or Line to share images or videos of computerized tomography (CT) scans or magnetic resonance imaging (MRI) results among groups.

Questions that must be considered include:

- Are there any issues regarding image quality as still images or videos are taken from computer screens and resent through the smartphone?
- Are there any security risks for patient information?
- Should we maximize and standardize the use of smartphones and apps to allow health-care providers around world to connect even better and make the sharing and networking seamless and easy to benefit patients?

For each of these questions above, the answer appears to be a loud and clear *yes*.

Maximizing the use of these communication devices in telestroke practice may be a wonderful and obvious step to networking the entire world and providing the best diagnostic and support assistance in neurosurgery [20].

With just such goals in mind, an app was born at Jikei University School of Medicine in Japan: JOIN. JOIN is a very simple app, allowing medical professionals to connect with each other through a now standard social communication app format interface, similar to ones existing on the market (Fig. 1a and b). This app allows doctors to compose intra- and interhospital groups of professionals (Fig. 1c),

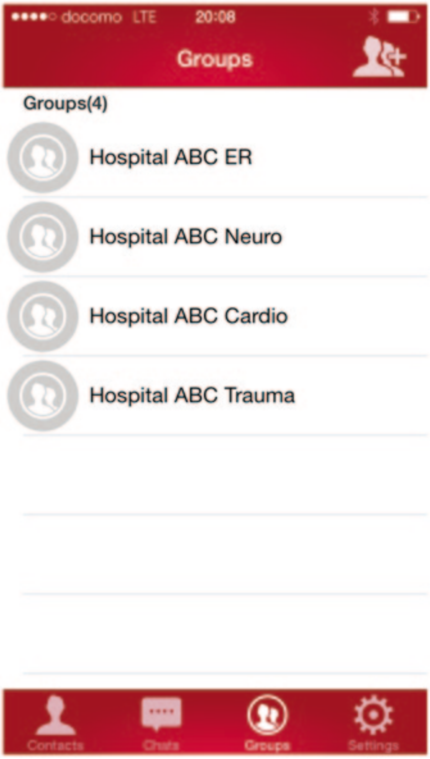

Fig. 1 **a** Adding a new contact in the JOIN app. **b** Chat page for group members. Use of a "current standard" interface minimizes the learning curve for health-care providers. **c** Creating new groups within and between hospitals is free, allowing the provider to connect with their team members

Dr. A
A SAH patient has arrived.
What is your suggestion
For management?

Dr. B
Do first CTA, and let us
Decide later.

Dr. B
It is an A-com aneurysm.
Prepare patient for Coiling.

Dr. A
OK.

Fig. 2 **a** View of the "timeline" format in the smartphone. **b** The "timeline" format offers a great snapshot of events in the clinical course

access a unique timeline viewer for time-sensitive treatments, such as stroke and/or emergencies (Fig. 2a and b), and gain a huge advantage in that users can access the picture archiving and communication system (PACS) to obtain images directly, obviating the need to take still images or films from the computer screen (Fig. 3).

JOIN has debuted simultaneously in 15 hospitals and is expected to rapidly spread around Japan and the world, setting a new standard for the practice of remote diagnostics and medicine. Medical professionals will be able to access information anywhere, anytime, to assist in diagnostics. Patients will, thus, have access to the best diagnostic and treatment plans wherever they might be.

Telerobotics

Going beyond telestroke, the very next step will be advancing neurosurgery with image-guided robotics.

The history of robot-assisted surgical interventions started in 1985, when Kwoh et al. used a modified Puma 560 industrial robot (Advance Research & Robotics, Oxford, CT, USA) to define the trajectory of a frame-based brain biopsy [21].

In early 1991, Davies was the first to use an active motion robot for interactions with soft tissue. This system was the forerunner to the Probot, which is currently in use for transurethral resection of the prostate [21].

In late 1991, Robodoc (Integrated Surgical Systems, Davis, CA, USA) underwent clinical evaluation in humans. The Robodoc system prepares the proximal femur to accept a noncemented total hip prosthesis, creating a cavity ten times more accurately than that achieved via manual reaming [21].

In 1994, the FDA approved the first robot for clinical use in the abdomen. Modified from a robotic arm used by the National Aeronautics and Space Administration (NASA) in the American space program, the Automated Endoscopic System for Optimal Positioning (AESOP; Intuitive Surgical, Sunnyvale, CA, USA) was developed to hold a laparoscopic camera [21].

Fig. 3 DICOM viewer in JOIN. Data are kept secure, as the data are in a streaming format and does not remain on the mobile device. *DICOM* Digital Imaging and Communications in Medicine

In 1994, the first telesurgical robot was developed by SRI International, Inc. (Menlo Park, CA, USA) and initially used for abdominal surgery. A laparoscopic version was subsequently designed [21].

The first human telesurgery consultation was reported in 1996, and completely remote telesurgical animal trials were conducted in 2000 [22].

In 2004, the FDA cleared yet another robotic system for use in neurosurgery, the Pathfinder (Prosurgics, Cupertino, CA, USA). Based on preoperative medical imaging, the surgeon makes use of the system to accurately specify the target and trajectory [23].

The Zeus (Intuitive Surgical) and da Vinci (Intuitive Surgical) Incrobotic systems have been successfully used in cardiac surgery [21].

The development of a new robot was initiated in 2003 by researchers at the University of Calgary, in collaboration with MacDonald, Dettwiler and Associates, Ltd. [24], taking advantage of the MR environment and incorporating technological advances in haptic feedback, three-dimensional image reconstruction, and hand-controller design. The design was guided by health-care and regulatory requirements. As a result, the first image-guided, MR-compatible robot capable of both microsurgery and stereotaxy was born: the NeuroArm [25].

NeuroArm performed as well and as accurately as conventional methods in the initial surgical application. The technology has seen successful use for increasingly difficult planned tumor resection surgeries in a series of clinical cases, and the safety mechanisms included have successfully mitigated hardware failures [25]. Surgeons tend to leave the surgical site to view imaging data in conventional methods and cannot interact with images without breaking sterility. NeuroArm provides the operating surgeon with access to sophisticated imaging data without interrupting the surgical procedure. NeuroArm represents a major step toward a future in which a variety of machines are merged with medicine [24].

Furthermore, new technologies and systems are continuing to be developed. Renaissance (Mazor Robotics, Caesarea, Israel), an image-guided system that incorporates a robot, was built for minimally invasive cranial neurosurgery. An accuracy study indicated that the Renaissance system may present a possible alternative for procedures, such as keyhole surgery [26].

Surgical robots have the potential to improve surgical precision and accuracy through motion scaling and tremor filters, although human surgeons currently possess superior speed and dexterity [24]. Robotic surgery systems offer enormous advantages, such as [21]:

- Accurate, predictable, predefined and reprogrammable complex three-dimensional paths
- Accuracy and repeatability in positioning and orientation at a reprogrammable point
- Ability for repetitive motions for long periods
- Movement to a location and then the ability to hold tools for long periods accurately, rigidly, and without tremor
- Active constraint of tools within a particular path or location, even against externally imposed forces, thus preventing vital organ damage
- Quick and automatic response and adaption to sensor signals or changes in commands
- Ability for precise micromotions with pre-specified microforces

Equipment such as telecontrolled micromanipulator systems for minimally invasive microneurosurgery have been developed. Preliminary results suggest that use of such systems in neurosurgery is promising, with procedures being safer, more accurate, and less invasive. Telesurgery can also be envisioned using such systems in the near future [27].

Practices that require great precision, such as brain tumor removal, seem likely to benefit greatly from the application of neurosurgical robotic systems. The design framework was developed under the concept of "integration of diagnosis and treatment." In the proposed system, real-time diagnosis can be achieved by pre- or intraoperative MRI and tumor-detecting sensors. Sensor-integrated surgical instruments can then precisely remove the lesion. A robotic arm can be introduced to precisely position the surgical instrument at the lesion (i.e., NeuroArm, which is equipped with two MRI-compatible robotic arms) [28].

As a result, the proposed system has these features [28]:

- Enhancing the surgeon's ability by introducing a precisely controlled surgical robot
- Introducing a new surgical instrument that can perform precise tumor removal
- Allowing collaboration with tumor-detecting sensors and navigation systems to optimize identification of lesion location

In conclusion, telesurgical usage of the telecontrolled manipulation systems represents an ideal to strive for. A patient could undergo surgery at a nearby hospital without traveling long distances to a specialized hospital. Even in clinics situated in remote corners of the world, such as isolated islands or mountain villages, complex surgical procedures should be possible [29].

Limitations of Telerobotics

Telerobotics definitely represents a future solution to providing accessible medical care, no matter where the patient is. In the future, specialists will be able to lead surgical procedures remotely, staying in the hospital where they work, while reaching out to patients in hospitals in rural areas. However, despite the advances in technology that have been made and the great milestones that have been passed, particularly for preliminary studies, we may consider that this field is still in its infancy.

For instance, robots have very limited abilities in decision making and qualitative judgment. Conversely, humans remain superior at integrating diverse sources of information, considering and applying qualitative data, and exercising judgment. Humans also have superior dexterity and robust hand–eye coordination, although at a limited scale, and most importantly have access to the exquisitely precise sensation of touch. These crucial differences in capabilities imply that current surgical robotic systems are restricted to basic tasks, with surgeons providing detailed preoperative commands or exact move-for-move instructions to complete a preprogrammed task [21].

Robotic systems still have great difficulty identifying objects on the basis of visual appearance or feel and handle objects clumsily, so are far from ready to autonomously perform complex tasks such as surgery on the brain [21].

One other potential pitfall of using a surgical robot is the lack of human dexterity. Although surgical robots have great precision, they cannot yet replicate human speed [24].

There is also an issue of transmission speed. Whenever a telecontrolled manipulator system is used in telesurgery, two types of data need to be transmitted: patient images to the surgeon and control data from the surgeon's system to a manipulator in the patient's hospital. Even if the transmitted data in the telesurgery system are not severely deteriorated compared to those in directly connected systems, transmission speed must inevitably have a direct effect on the feasibility of the manipulation, and, thus, could affect the results of surgery [29].

The primary difficulty with teleoperations over large distances or over a low-quality network infrastructure is the lag time in communication. Accurate and synchronized sensory feedback is essential to ensure reliable and effective telesurgical treatments [22]. Such lag time results in a temporary delay between controlling the system and confirming the movement of the system according to the transmitted data, representing a critical issue in telesurgery. Although a time delay of less than 300 ms in telerobotic surgery is generally accepted, the range of time delays permissible differs between robotic systems [29].

For example, using commercial Internet services, the delay might be approximately 85 ms across the USA and anywhere from 20–400 ms worldwide. Satellite-based Internet connections can use a fleet of low or medium Earth orbit satellites, where typical roundtrip delays are 40 ms, but bandwidth remains very limited. In addition, geosynchronous satellites provide higher latency due to their 36,000 km altitude; round trip latency is typically 540–700 ms [22].

Most humans are capable of adapting to a sensory feedback latency of up to 500 ms, and some experiments have suggested that individuals might be able to perform tasks even with a consistent 1000 ms delay [22].

Instability during transmission of the packet is also a problem in telesurgery. This is known as "jitter" and increases when "traffic" in the network system is crowded. This "jitter" results in occasional packet loss and wavering of packet sending time and is frequently observed in public network systems. Occasional packet loss may cause interference in telesurgery [29].

Due to such limitations and the potential risks to the patient's life, the current function of surgical robots is to assist the surgeon under supervision and to extend or enhance human skill, rather than to replace the surgeon. These robotic systems enhance the practice of surgery by allowing the surgeon to operate at a very small scale (microsurgery) or through very limited opening (minimally invasive surgery), to perform highly accurate and repeatable manipulations (stereotactic surgery) and to perform surgery with the use of large amounts of quantitative information (image-guided surgery) [21, 22].

Convincing neurosurgeons and patients of robot safety may prove to be the biggest challenge to their widespread implementation [21] With all these potential limitations, telesurgery remains a very expensive solution to implement. The economic and ethical aspects must be considered before routine clinical application is adopted [29] Finally, the issues of responsibility to and liability for the patient are vague in telemedicine and need to be better codified [29].

Conclusions and the Future

Despite half a century of advances in robotic technology, the capabilities of current systems remain limited [21]. However, marked gains in the prominence of such techniques in neurosurgery appear likely to occur soon.

New technologies are always fancy and fascinating, and the world naturally pays more attention and shows excitement for these unconquered frontiers. However, while we are waiting for such days to come, we should focus our attention on maximizing currently available resources. This may be less trendy, but is just as, if not more, important in overcoming current limitations in the technology.

For instance, along with the advances in robotic technology, we still need to establish and standardize telestroke on a worldwide basis. The patient should have access to the knowledge and experience of the very best medical team, wherever they are located. There is still a long way to go for such scenarios to be reached.

With the major and continuing advances in mobile phone technology, we will soon be able to reach out to anyone at anytime, anywhere in the world. Maximizing the use of these communication devices in telestroke practice may represent an obvious step to networking the entire planet for the best diagnostic and support assistance in the field of neurosurgery.

Furthermore, all data transmitted during telestroke should be able to be stored in a single location, serving as a big data collection point to build statistics based on the path of diagnosis and the related treatment.

Such information will prove invaluable in the near future. It will feed the development of future robots, which will in turn provide suggestions on treatment and/or surgery based on the past paths, for better decision making by humans.

Robots seem likely to initially be more acceptable to the surgeon if the physician remains in control of the entire surgical procedure, with the robot acting primarily as a dexterity enhancer (in robot-assisted procedures), but future robots will suggest procedures based on major data sets collected from telestroke and, with the approval of the surgeon, will take action in most surgical procedures. The surgeon, in such scenarios, will keep monitoring the robot and will intervene only in emergency cases or where situations cannot be predicted based on past data. This situation would be analogous to modern pilots flying an airplane using the autopilot function.

References

1. Hess DC, Wang S, Hamilton W, Lee S, Pardue C, Waller JL, et al. REACH: clinical Feasibility of a rural telestroke network. Stroke. 2005;36:2018–20.
2. Sinha VD, Tiwari RN, Kataria R. Telemedicine in neurosurgical emergency: Indian perspective. Asian J Neurosurg. 2012;7(2):75–7.
3. Bladin CF, Cadilhac DA. Effect of telestroke on emergent stroke care and stroke outcomes. Stroke. 2014;45:1876–80.
4. Wang S, Lee SB, Pardue C, Ramsingh D, Waller J, Gross H, et al. Remote evaluation of acute ischemic stroke: reliability of National Institutes of Health Stroke Scale via Telestroke. Stroke. 2003;34:e188–91.
5. Bruno A, Lanning KM, Gross H, Hess DC, Nichols FT, Switzer JA. Timeliness of intravenous thrombolysis via telestroke in Georgia. Stroke. 2013;44:2620–2.
6. Jauch EC, Saver JL, Adams HP Jr, Bruno A, Connors JJ, Demaerschalk BM, American Heart Association Stroke Council, Council on Cardiovascular Nursing, Council on Peripheral Vascular Disease, Council on Clinical Cardiology, et al. Guidelines for the early management of patients with acute ischemic stroke. A guideline for healthcare professionals from the American Heart Association/American Stroke Association. Stroke. 2013;44:870–947.
7. Meyer BC. Telestroke evolution: from maximization to optimization. Stroke. 2012;43:2029–30.

8. Handschu R, Littmann R, Reulbach U, Gaul C, Heckmann JG, Neundörfer B, et al. Telemedicine in emergency evaluation of acute stroke: interrater agreement in remote video examination with a novel multimedia system. Stroke. 2003;34:2842–6.
9. Hassan R, Siregar JA, Rahman NAA. The implementation of teleneurosurgery in the management of referrals to a neurosurgical department in Hospital Sultanah Amninah Johor Bahru. Malays J Med Sci. 2014;21(2):54–62.
10. Angileri FF, Cardali S, Conti A, Raffa G, Tomasello F. Telemedicine-assisted treatment of patients with intracerebral hemorrhage. Neurosurg Focus. 2012;32(4):E6.
11. Audebert H. Telestroke: effective networking. Lancet Neurol. 2006;5:279–82.
12. Agarwal S, Day DJ, Sibson L, Barry PJ, Collas D, Metcalf K, et al. Warburton thrombolysis delivery by a regional telestroke network—experience from the UK National Health Service. J Am Heart Assoc. 2014;3:e000408.
13. Audebert HJ, Schenkel J, Heuschmann PU, Bogdahn U, Haberl RL, Telemedic Pilot Project for Integrative Stroke Care (TEMPiS) Group. Effects of the implementation of a telemedical stroke network: the Telemedic Pilot Project for Integrative Stroke Care (TEMPiS) in Bavaria, Germany. Lancet Neurol. 2006;5:742–8.
14. Hess DC, Wang S, Gross H, Nichols FT, Hall CE, Adams RJ. Telestroke: extending stroke expertise into underserved areas. Lancet Neurol. 2006;5:275–8.
15. Heggestuen J. One in every 5 people in the world own a smartphone, one in every 17 own a tablet. Business Insider. 2013. http://www.businessinsider.com/smartphone-and-tablet-penetration-2013-10. Accessed 28 April 2015.
16. CMO Council https://www.cmocouncil.org/facts-stats-categories.php?view=all&category=mobile-marketing. Accessed Aug 2012.
17. eMarketer Research. http://www.emarketer.com/Article/Smartphone-Users-Worldwide-Will-Total-175-Billion-2014/1010536. Accessed 16 Jan 2014.
18. Burdette SD, Herchline TE, Oehler R. Practicing medicine in a technological age: using smartphones in clinical practice. Clin Infect Dis. 2008:47(1):17–22.
19. Terry K. 47% of Doctors use Smartphone, Tablet and PC. InformationWeek. http://www.informationweek.com/mobile/47-of-doctors-use-smartphone-tablet-and-pc/d/d-id/1111170?cid=rssfeed_iwk_all. Accessed 14 Aug 2013.
20. Takao H, Murayama Y, Ishibashi T, Karagiozov KL, Abe T. A new support system using a mobile device (smartphone) for diagnostic image display and treatment of stroke. Stroke. 2012;43(1):236–9.
21. Nathoo N, Çavuşoğlu MC, Vogelbaum MA, Barnett GH. In touch with robotics: neurosurgery for the future. Neurosurgery. 2005;56(3):421–33.
22. Haidegger T, Sándor J, Benyó Z. Surgery in space: the future of robotic telesurgery. Surg Endosc. 2011;25:681–90.
23. Zhang Y1, Zhao D, Li H, Li Y, Zhu X, Zhang X. Emerging new trends in neurosurgical technologies. Cell Biochem Biophys. 2014 Sep;70(1):259-67. doi: 10.1007/s12013-014-9891-x.
24. Sutherland GR, Lama S, Gan LS, Wolfsberger S, Zareinia K. Merging machines with microsurgery: clinical experience with neuroArm. J Neurosurg. 2013;118:521–9.
25. Pandya S, Motkoski JW, Serrano-Almeida C, Greer AD, Latour I, Sutherland GR. Advancing neurosurgery with image-guided robotics: technical note. J Neurosurg. 2009;111:1141–9.
26. Joskowicz L, Shamir RR, Israel Z, Shoshan Y, Shoham M. Renaissance robotic system for keyhole cranial neurosurgery: in-vitro accuracy study. Proceedings of the Simposio Mexicano en Cirugía Asistida por Computadora y Procesamiento de Imgenes Medicas (MexCAS '11); 2011 Sep 30; Iztapalapa, Mexico.
27. Hongo K, Kobayashi S, Kakizawa Y, Koyama J, Kan K, Fujie MG, et al. Neurorobot: telecontrolled micromanipulator system for minimally invasive microneurosurgery—preliminary results. Neurosurgery. 2002;51(4):985–8.
28. Arata J, Tada Y, Kozuka H, Wada T, Saito Y, Ikedo N, et al. Neurosurgical robotic system for brain tumor removal. Int J CARS. 2011;6:375–85.
29. Goto T, Miyahara T, Toyoda K, Okamoto J, Kakizawa Y, Koyama J, et al. Telesurgery of microscopic micromanipulator system "neuRobot" in neurosurgery: interhospital preliminary study. J Brain Dis. 2009;1:45–53.

Hospital Teleneurology

Mark N. Rubin and Kevin M. Barrett

Introduction

Neurohospitalists are the site-specific subspecialty neurologists who care for patients in the emergency department, general ward, and intensive care unit setting [1–5]. The increasing demand for timely neurologic consultation and management in the hospital setting has led to rapid growth in the practice. With an aging population and various unfavorable financial and regulatory pressures in the hospital setting, it is unlikely that the neurohospitalist workforce, even at the current growth rate, will be able to satisfy the needs of hospitalized patients with neurologic illness. Telemedicine is one means by which a neurohospitalist may be able to extend expertise to centers without neurohospitalists on staff.

Telemedicine for acute neurological indications in the hospital setting is utilized clinically, albeit primarily for acute stroke (see the chapter entitled "Telestroke" for an in-depth review of that specific indication). The focus of this chapter is on the use of telemedicine for other, nonstroke inpatient neurologic indications, to be referred to broadly as hospital teleneurology. In this chapter, current evidence for the use of hospital teleneurology and future directions thereof are discussed.

Practice of Hospital Teleneurology

Hospital teleneurology is practiced across a broad range of inpatient care settings. In contrast to telestroke which is predominantly performed in the emergency department setting and less frequently on hospital wards, teleneurology evaluations may occur in the emergency department, hospital ward, progressive care unit, and recovery areas with greater frequency (see Table 1). Diverse inpatient utilization of remote telepresence devices for teleneurology has technological implications as

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Table 1 Differentiating features between telestroke and hospital teleneurology practice

	Telestroke	Hospital teleneurology
Location	Primarily ED, some ward	ED, ward, PCU, ICU
Examination	Validated NIHSS	Unvalidated, limitations (tone, reflexes, ocular motor), can use peripherals (ophthalmoscope, &c)
Ancillary Studies	NCHCT, point-of-care laboratories, vital signs	Neuroimaging of any modality of any element of the neuraxis, CSF analysis, myriad labs, EEG, EMG/NCS, vitals, medication lists
Number of published manuscripts as of 7/2012	155	28

ED emergency department, *PCU* progressive care unit, *ICU* intensive care unit, *NIHSS* National Institutes of Health Stroke Scale, *NCHCT* noncontrast head computed tomography, *CSF* cerebrospinal fluid, *EEG* electroencephalogram, *EMG/NCS* electromyography/nerve conduction studies

robust wireless Internet connectivity should be ensured across all anticipated usage areas prior to implementation.

In addition to a comprehensive history, the neurological examination remains the cornerstone of neuroanatomic localization and diagnosis. Remote telepresence allows a real-time communication with the patient, family, and witnesses to collect relevant elements of the present and past neurologic history. Teleneurological evaluation is well suited for patients with episodic neurological dysfunction (seizures, transient ischemic attack, and spells) or headache disorders with a normal neurological examination where the history forms the basis for diagnosis. The National Institutes of Health Stroke Scale (NIHSS) has been validated as an effective tool to remotely examine patients with suspected stroke syndromes [6–8]. Although there are reports of certain elements of a general neurologic examination that may be reliably assessed by teleneurology[9], standardized and validated scales for remote evaluation of patients with nonstroke diagnoses have yet to be developed.

Detailed evaluation of cranial nerve function, muscle tone, reflexes, sensation, and gait with telemedicine poses challenges to the remote examiner. Practically, a provider (registered nurse, mid-level practitioner, or physician) at the bedside is necessary to facilitate teleneurological examination. An experienced bedside examiner can likely collaborate with the teleneurohospitalist to accurately elicit abnormal findings. Those less experienced with neurological examination techniques may limit the ability to accurately assess and report findings to the teleneurohospitalist, particularly for elements of the examination that require “feel” (i.e., rigidity, spasticity, meningismus, or reflexes) rather than simple observation. Additionally, the variability and distractibility that often accompany functional neurological syndromes may be difficult to elicit by the remote examiner and appreciate by the teleneurohospitalist.

Limitations associated with teleneurological examination can be potentially overcome with the utilization of peripherals to objectively measure neurological function. Pupil size and reactivity can be measured with a bedside pupil gauge [10] or infrared pupillometers which offer the ability to quantify the pupillary light reflex and measure pupillary reactivity that may not be detected by the naked eye or through remote telepresence [11]. Abnormalities of pupillary size and the pupillary light reflex are important components of the assessment in patients with decreased level of consciousness or coma as they may indicate increased intracranial pressure when measured with peripherals. Technology has been developed to display funduscopic findings identified with direct ophthalmoscopy on a handheld device which could then be viewed by the teleneurohospitalist (panoptic device used with personal digital assistant (PDA), iPhone and iExamine software to examine the retina by local examiner. iExamine, Intuitive Medtech http://www.youtube.com/user/IntuitiveMedTech). This approach has yet to be validated, but offers the potential to remotely evaluate papilledema or abnormalities of the retinal vasculature in patients with suspected elevated intracranial pressure or visual symptoms. Dyanometery has been established as a useful objective measure of grip strength and has been used for teleneurologic indications, although not in the hospital setting [12]. Peripherals such as the “cookie theft picture” and reading cards used as part of the NIHSS evaluation could be utilized for standardized evaluation of language and motor elements of speech. Future developments may include application of a constant force to a tendon and surface measurement of muscular response as a means to objectively measure the monosynaptic reflex arc. Recent technological advances offer an opportunity to develop teleneurological peripherals to aid in the neurological examination performed by a bedside examiner at a remote site and assessed by a teleneurohospitalist.

The teleneurohospitalist also faces challenges in the interpretation of ancillary diagnostic studies. Third-party servers that receive neuroradiology studies from the remote site allow timely review of neuroimaging for the teleneurohospitalist. An alternative, but less efficient, mechanism to view neuroimaging is the use of a direct login through a secure portal to review neuroimaging within the remote site’s radiology environment. This is a cumbersome approach as the teleneurohospitalist is required to manage identification/password combinations for each of the remote sites at which care is provided. Third-party radiology servers allow the advantage of a single login identification and a single software-viewing platform that the teleneurohospitalist can become familiar with through repeated use.

In order to determine the eligibility for intravenous recombinant tissue plasminogen activator (rtPA) in a patient with suspected stroke, review of the initial noncontrast head computed tomography (CT) and selected laboratory values drawn at the time of patient arrival is sufficient. For nonstroke diagnoses, one or more ancillary studies such as cerebrospinal fluid (CSF) examination, magnetic resonance imaging (MRI) of the brain or spinal cord, electroencephalogram (EEG), electromyography (EMG), or nerve conduction studies may be necessary. As the studies are performed, the results will need to be reviewed by the teleneurohospitalist in order to make diagnostic or therapeutic recommendations. Therefore, the teleneurohospitalist will need to review the results as they become available and often will need to perform serial neurological evaluations to establish the temporal profile of the patient’s symptoms. Best practices regarding how studies are reviewed (verbal communication by the local team vs. personal review by the teleneurohospitalist), notification of the teleneurohospitalist when results are available, and frequency of clinical reevaluation will need to be reported before consensus recommendations can be developed.

Evidence for Hospital Teleneurology

Much of what has been studied to date involving telemedicine for acute neurology concerns acute stroke. The literature base for teleneurology beyond vascular neurology accounts for a plurality of extant manuscripts but is not at the level of sophistication with incorporation into international guidelines that is noted for stroke indications [13–16]. This is particularly true for hospital teleneurology, with very little evidence for its use published to date (see Table 2) [17].

All of the published primary data on hospital teleneurology to date comes from a group in Northern Ireland based in Belfast who provided neurologic services to distant rural hospitals. A real-time, two-way audiovisual platform with a medical professional at the remote site to assist in the neurologic examination was implemented as a means of extending neurologic expertise to rural facilities, acknowledging that commuting time is expensive and unproductive. Technological aspects of note

Table 2 Teleneurohospitalist evidence

Authors	Year	Design	Outcomes	Comment
Craig J, Russell C, Patterson V, Wootton R	1999	Post-intervention survey	Generally accepted by patients and providers	Established basic feasibility and acceptability of teleneurologic consultation for hospitalized patients
Craig J, Chua R, Russell C, Patterson V, Wootton R.	2000	Retrospective review, pre-cohort study	Case mix similar between the two comparator sites	Established similarity of comparator sites prior to a cohort study
Craig J, Patterson V, Russell C, Wootton R	2000	Feasibility pilot	23/25 patients evaluated by teleneurohospitalist had definite diagnosis at the time of consult or after initial investigations	Teleneurologic consultation is feasible and an effective means of evaluating inpatients across various indications
Craig J, Chua R, Russell C, Wootton R, Chant D, Patterson V	2004	Cohort study	Similar length of stay and resource utilization between teleneurologic intervention hospital and control hospital	Teleneurohospitalist consultation is an effective and efficient means of providing inpatient neurology service
Rubin MN, Wellik KE, Channer DD, Demaerschalk BM	2013	Systematic review	Few studies	Few studies Recommend studies focused on quality, outcomes and cost

included the use of synchronous two-way audiovisual connectivity, minimum upload speed of 384 kbps via integrated services digital network (ISDN), within a hub-and-spoke model of care delivery. The group published the results of a patient- and provider-based survey after implementation in one hospital in the late 1990s which, in brief, identified general acceptance of two-way audiovisual communication as an acceptable means of providing neurologic care across a range of inpatient neurologic complaints [18]. In order to more rigorously study their implementation of hospital teleneurology, the group sought to compare costs and outcome in patients for whom they provided service by standard means (e.g., telephone and infrequent visits) versus teleneurology. To support the validity of the comparison between the medical centers in question, the group published a retrospective case-mix survey and found that neurologic cases and elements of care were essentially equivalent between the institutions for the time studied [19].

Having established patient and provider acceptance of hospital teleneurology, a more formal feasibility study is detailed in a manuscript [20] which scrutinized teleneurologic consultation in 25 consecutive inpatients in a rural hospital in Northern Ireland within the National Health Services. The consultation took place between the rural hospital and the regional tertiary care center in Belfast. There was no staff neurologist at the rural hospital, but one of the neurologists from the Belfast institution made biweekly visits to the hospital to see patients with neurologic complaints. Outcome, which was essentially adjudication of the diagnosis made during teleconsultation, was tracked by this neurologist during a face-to-face visit with the patients who were transferred to Belfast, seen during a biweekly visit at the hospital, or seen as an outpatient. The predefined reasons for teleconsultation included headache, weakness, disturbance of consciousness, sensory disturbance, dizziness/unsteadiness, confusion, visual disturbance, and tremor. Other inclusion criteria for the study cohort included age >13 and “no other symptoms that normally would suggest conditions outside of the nervous system.” The consultation was provided by senior neurologists who guided a neurologic examination provided by the local internal medicine physician at the rural hospital. A definite diagnosis was made for 17 of the 25 patients and the diagnosis was unchanged at follow-up. In another six patients, a differential diagnosis was provided and diagnosis was clear after recommended investigations were performed. The other two patients were thought to have epilepsy or nonepileptiform spells; one patient diagnosed with epilepsy by teleconsultation was later thought to have nonepileptic spells and the diagnosis was unclear in the other patient at the time of last follow-up. Other diagnoses made include stroke, “nonstructural disease,” transient ischemic attack, benign essential tremor, seizure, and acute brachial neuropathy.

After publishing their proof-of-concept feasibility study and establishing rough equivalence of neurologic case mix and care between the two institutions studied, the next manuscript by Craig et al. [21] details their cohort study of early teleneurologic consultation in the same rural hospital studied previously as compared to usual care in a hospital of similar size, resources, and population served which had no neurologist on site. The indications for consultation included headache, alteration of consciousness, weakness, sensory disturbance, dizziness/balance disturbance, confusion, speech disturbance, visual disturbance, memory loss, tremor, and neuralgia. Teleneurologic consultation was provided as described above. The neurologists continued their usual practice of twice-monthly physical visits to the hospital that also offered teleneurologic consultation. They studied all patients over the age of 12 admitted to either hospital with the aforementioned neurologic symptoms during a 24-week period and tracked length of stay, mortality, and use of healthcare resources in the hospital and within 3 months from hospital discharge.

There were no significant demographic differences between the studied populations, which included patients at the intervention hospital with and without teleneurologic consult and standard mode of consultation at the other hospital. A total of 164 patients were seen at the intervention hospital, 111 by teleneurologic consultation and 53 in person. A total of 128 patients were seen at the other hospital. The mean age at the intervention and other hospital were, respectively, 56 and 60 years. The frequency of any particular neurologic complaint was generally similar between teleneurologic and in-person consultations and between hospitals. The particular neurologic complaints addressed by teleneurologic consultation, in descending order of frequency, included alteration of consciousness (27 %), weakness (21 %), headache (20 %), speech disturbance (11 %), other (8 %), incoordination/dizziness (7 %), and confusion (6 %). This reflected the overall group at the intervention hospital (e.g., teleneurologic and in-person consultation) where the complaints addressed included alteration of consciousness (30 %), weakness (19 %), headache (18 %), speech disturbance (10 %), confusion (10 %), incoordination/dizziness (8 %), and other (7 %). The frequency of particular neurologic complaints at the other hospital (e.g., no teleneurologic consultation) was different as compared to the intervention hospital, although the top three indications were similar in both hospitals: weakness (28 %), headache (18 %), alteration of consciousness (14 %), confusion (14 %), incoordination/dizziness (12 %), speech disturbance (9 %), and other (5 %). The primary endpoint was length of hospital stay; mean length of stay was 7.2 days in the teleneurologic consultation group, 10 days in the same hospital without teleneurologic consultation, and 11.6 days in the other hospital. Median length of stay was 3 days in all groups. Secondary measures focused resource utilization (use of neuroimaging, transfers to the tertiary care center, outpatient appointments, major change in diagnosis at follow-up, etc.) were similar between the groups at the intervention hospital and the other hospital. The conclusion of this study was that teleneurohospitalist consultation was an effective and efficient means of providing inpatient neurology service from a distance.

Teleneurohospitalist Models

The neurohospitalist model of practice is new and diverse in general, and this certainly holds true for teleneurohospitalist practice. There are no published models of teleneurohospitalist practice to date; however, from clinical experience, one can generically categorize current teleneurohospitalist practitioners. The “academic model," named as such, as this is the dominant model employed by telemedicine specialists in a university setting, makes use of a "hub-and-spoke" configuration, with the academic center serving as the hub and the remote sites in need of neurologic expertise as the spokes. Hospital teleneurology can be practiced as an independent service line or as an adjunct to telestroke. An advantage of this model would be the finite number of teleneurohospitalists, often with expertise, to develop spoke relationships, predictable practice patterns, and scholarly patient databases with a focus on quality, outcomes, and health economics. A disadvantage would be the relative paucity of university-based neurohospitalists and ability to meet clinical demand. A third-party model provides clinical services to a remote site by hired teleneurohospitalists at various sites. This is the model employed by the larger-scale, for-profit teleneurologic practices. An advantage of this model may be cost, provided overhead costs can be kept low, as well as the possibility of expanding the provider pool with relative ease. Disadvantages may include delays in response time due to high volumes, lack of standardized credentialing and various providers with less predictable practice patterns. There are also mixed models of a core staff providing most coverage, hired staff for coverage gaps, and designated mid-level providers to assist in consultations, all with the hope of providing the longitudinal advantages of the academic model and mitigating the disadvantages of a limited workforce.

Future Directions

Given the nascency of neurohospitalist practice as an academic subspecialty within neurology, and its corresponding dearth of supporting medical literature, research needs are many and priority difficult to assign. The Belfast group has provided the field with at least initial evidence that the practice of teleneurologic consultation is technically feasible and provides acceptable clinical results. Douglas et al. [22] provide compelling evidence that the neurohospitalist model can improve the quality of care and patient outcomes. It is perhaps not unreasonable to expect a similar benefit from teleneurohospitalist consultation, especially in light of the findings of the Belfast group, although this has yet to be extensively studied. To follow the fundamental question of "can we do it?" the field requires larger feasibility and validation studies, perhaps stratified by neurologic subspecialty, as well as investigations of other basic questions along the lines of "should we do it?" (e.g., outcome research) and "at what cost?" (e.g., health economic research).

Another consideration is whether or not teleneurohospitalist practice is a boon or a bane to neurologists. Ostensibly, any means of extending service and expertise to patients—especially to those ill enough to be hospitalized—should be beneficial. An indirect effect of a readily available, reliable, and relatively inexpensive teleneurohospitalist (as compared to a full-time in-person consultant neurologist), however, may be the displacement of in-person providers and may stunt the growth of this exciting new subfield of neurology. On the other hand, extension of service lines have the possibility of increasing revenue indirectly by securing a referral base, or perhaps directly if covered by private or government insurance. This is at the stage of speculation for now. There is no reason to believe, however, that hospital teleneurology cannot become the unequivocally beneficial service to patients that telestroke has been demonstrated to be, and, with hope, dedicated study will bear this out in time.

Teleneurology in general is considered mainstream. According to a recent survey of large North American academic neurology practices, enthusiasm for teleneurological practice is high [23]. In that survey, many of the programs contacted who did not provide teleneurological consultation at the time planned to do so within the next year. It remains unclear as to what degree the practice of hospital teleneurology is growing. The authors are advocates of adoption of teleneurological practices so long as they are carried out in a scholarly manner, including tracking of patient data and quality and performance measures such that clinical and cost effectiveness can be determined. Teleneurological consultation for inpatients, much like the practice of neurohospitalist medicine, is an exciting advance which holds much promise [24]. Dedicated hospital neurology research is needed, particularly for its use in various practice settings outside of acute consultation, as a patient and professional education tool, and its economic ramifications. The construction of an evidence base describing its impact on clinical outcomes and quality of care in all phases of inpatient neurology care represents a promising frontier in clinical neurologic research.

References

1. Barrett KM, Freeman WD. Emerging subspecialties in neurology: neurohospitalist. Neurology. 2010;74(2):e9–10.
2. Freeman WD, Gronseth G, Eidelman BH. Invited article: is it time for neurohospitalists? Neurology. 2008;70(15):1282–8.
3. Freeman WD, Vatz KA. The future of neurology. Neurol Clin. 2010;28(2):537–61.
4. Josephson SA, Engstrom JW, Wachter RM. Neurohospitalists: an emerging model for inpatient neurological care. Ann Neurol. 2008;63(2):135–40.
5. Likosky D, Shulman S, Restrepo L, Freeman WD. Survey of neurohospitalists: subspecialty definition and practice characteristics. Front Neurol. 2010;1:9.
6. Handschu R, Littmann R, Reulbach U, Gaul C, Heckmann JG, Neundorfer B, et al. Telemedicine in emergency evaluation of acute stroke: interrater agreement in remote video examination with a novel multimedia system. Stroke. 2003;34(12):2842–6.
7. Shafqat S, Kvedar JC, Guanci MM, Chang Y, Schwamm LH. Role for telemedicine in acute stroke. Feasibility and reliability of remote administration of the NIH stroke scale. Stroke. 1999;30(10):2141–5.
8. Wang S, Lee SB, Pardue C, Ramsingh D, Waller J, Gross H, et al. Remote evaluation of acute ischemic stroke: reliability of National Institutes of Health Stroke Scale via telestroke. Stroke. 2003;34(10):e188–91.
9. Craig JJ, McConville JP, Patterson VH, Wootton R. Neurological examination is possible using telemedicine. J Telemed Telecare. 1999;5(3):177–81.

10. Pascoe DA. A pupil gauge. Anaesthesia. 1980;35(10):1021.
11. Meeker M, Du R, Bacchetti P, Privitera CM, Larson MD, Holland MC, et al. Pupil examination: validity and clinical utility of an automated pupillometer. J Neurosci Nurs. 2005;37(1):34–40.
12. Hoffmann T, Russell T, Thompson L, Vincent A, Nelson M. Using the Internet to assess activities of daily living and hand function in people with Parkinson's disease. NeuroRehabilitation. 2008;23(3):253-61.
13. Rubin MN, Wellik KE, Channer DD, Demaerschalk BM. Systematic review of teleneurology: methodology. Front Neurol. 2012;3:156.
14. Rubin MN, Wellik KE, Channer DD, Demaerschalk BM. A systematic review of telestroke. Postgrad Med. 2013;125(1):45–50.
15. Rubin MN, Wellik KE, Channer DD, Demaerschalk BM. Role of telemedicine in providing tertiary neurological care. Curr Treat Options Neurol. 2013;15(5):567–82.
16. Rubin MN, Wellik KE, Channer DD, Demaerschalk BM. Systematic review of telestroke for post-stroke care and rehabilitation. Curr Atheroscler Rep. 2013 Aug;15(8):343.
17. Rubin MN, Wellik KE, Channer DD, Demaerschalk BM. Systematic review of teleneurology: neurohospitalist neurology. Neurohospitalist. 2013;3(3):120–4.
18. Craig J, Russell C, Patterson V, Wootton R. User satisfaction with realtime teleneurology. J Telemed Telecare. 1999;5(4):237–41.
19. Craig J, Chua R, Russell C, Patterson V, Wootton R. The cost-effectiveness of teleneurology consultations for patients admitted to hospitals without neurologists on site. 1: A retrospective comparison of the case-mix and management at two rural hospitals. J Telemed Telecare. 2000;6 Suppl 1:S46–9.
20. Craig J, Patterson V, Russell C, Wootton R. Interactive videoconsultation is a feasible method for neurological in-patient assessment. Eur J Neurol. 2000;7(6):699–702.
21. Craig J, Chua R, Russell C, Wootton R, Chant D, Patterson V. A cohort study of early neurological consultation by telemedicine on the care of neurological inpatients. J Neurol Neurosurg Psychiatry. 2004;75(7):1031–5.
22. Douglas VC, Scott BJ, Berg G, Freeman WD, Josephson SA. Effect of a neurohospitalist service on outcomes at an academic medical center. Neurology. 2012;79(10):988–94.
23. Benjamin P, George NJS, Reminick JI, Rajan B, Beck CA, Abraham, Biglan KM, Dorsey ER. Telemedicine in leading US neurology departments. Neurohospitalist. 2012;2(4):123–28.
24. Freeman WD KMB, Vatz KA, Demaerschalk BM Future neurohospitalist: teleneurohospitalist. Neurohospitalist. 2012;2(4):132–43.

Telemedicine and Parkinson's Disease

Denzil A. Harris and E. Ray Dorsey

Abbreviations

HIPAA	Health Insurance Portability and Accountability Act
MDS-UPDRS	Movement Disorder Society-Unified Parkinson's Disease Rating Scale
OTN	Ontario Telemedicine Network
UPDRS	Unified Parkinson's Disease Rating Scale
VHA	Veterans Health Administration

The Growth of Telemedicine is Fueled by Advances in Technology

The prospect of using technology to facilitate access to care for individuals living with Parkinson's disease in remote areas of the USA has been in development for at least the last two decades [1]. Pioneering studies demonstrated that motor assessments of Parkinson's disease could be conducted remotely [2–4] and may act as a means for individuals to receive better health care [1]. The connectedness of society via advances in communication technologies has steadily increased over the last decade [5]; however, medicine has yet to fully integrate safe and simple technologies into current practice in order to dictate the coming era of patient care.

Our efforts to provide high-performing patient-centered care for individuals with Parkinson's disease has been bolstered by new applications of existing technologies.

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This model provides the potential for our services to reach a greater number of individuals living with Parkinson's disease, many of whom have infrequent access to specialty care. The lack of access to care delivery in the health system of the USA has resulted in a geographical deficit, which hinders the provision of patient care that is safe, effective, efficient, personalized, timely, and equitable [6]. The use of telemedicine capitalizes on advances in telecommunications and health-care technology to address present and future demands for Parkinson's disease care.

Telemedicine Can Help to Reduce Barriers to Care

The ability of patients to access care or maintain regular appointments with Parkinson's disease specialists is significantly affected by disability, distance from providers, and the national distribution of providers [7]. As the incidence of Parkinson's disease continues to increase nationally and worldwide, current discrepancies in providing care will be exacerbated by the increasing need for disease management and care coordination services. This accelerated trend of individuals with neurological conditions needing care is expected to be significant during the early twenty-first century. From 2010 to 2030, the number of individuals in the USA 65 years or older with Parkinson's disease is expected to increase by 77 %, from 300,000 to 530,000 [8]. The present state of care for Parkinson's disease in the USA is inadequate to match the expected increase in demand for comprehensive neurologic care in the near future.

Currently, more than 40 % of Medicare beneficiaries with Parkinson's disease do not see a neurologist [9]. The inability to meet regularly with a neurologist has detrimental outcomes for such patients. Patients with Parkinson's disease who do not see a neurologist have been shown to be 14 % more likely to have a hip fracture, 21 % more likely to be placed in a skilled nursing home facility, and 22 % more likely to die [10]. Yet, the current supply of neurologists in the USA is sufficient to meet demand for most neurologic care [9]. The present number of International Parkinson and Movement Disorders Society (MDS) physician members (approximately 600–700 physicians) could likely care for approximately 500,000 Americans with Parkinson's disease [8]. Adoption of telemedicine can help to transform clinical care and greatly increase access to specialists for individuals living outside of the current coverage areas of American neurologists.

Various applications of technology for patient care have emerged recently in neurology subspecialties; however, many are still centered on hospital-based care (e.g., tele-ICU [11] or telestroke [12]). Although these models of providing care may facilitate timely remote neurological assessment and therapeutic decision making for patients with conditions such as ischemic stroke [13], they are still prohibitively expensive to deploy and use [14]. Our model of providing care via telemedicine requires the use of readily available, existing technology which is often already established in both clinician and patient settings. This is an economically sustainable strategy for managing Parkinson's disease care for current patients and for the expected demand of the near future.

Telemedicine is Well Suited for Parkinson's Disease

Parkinson's disease is clinically determined by assessing the presence of two of the following cardinal features: asymmetric rest tremor, slowness of movement (bradykinesia), rigidity, and postural instability [15]. The presence of secondary motor symptoms, such as freezing of gait, flexed posture, and dysarthria, is also commonly observed in Parkinson's disease [16, 17]. Interactive videoconferencing has been used in early studies [18] to examine patients with Parkinson's disease using the Hoehn and Yahr score [19] and the Unified Parkinson's Disease Rating Scale (UPDRS) [20], while recent studies have demonstrated that using web-based video visits to conduct a "modified" UPDRS produces valid and reliable results in comparison to in-person assessments [7, 21]. In addition to the ease of visual assessment over videoconferencing, movement disorders such as Parkinson's disease tend to limit mobility and require ongoing multidisciplinary care [22, 23]. Telemedicine minimizes the need for long-distance travel to provider institutions, and allows for the optimization of a multidisciplinary team approach by streamlining communication between care providers.

Standard telemedicine visits between patients and the movement disorder specialist last between 30 and 60 minutes. Visits include a routine clinical assessment, including updates on medical history and medications, neurologic examination, and discussion of recommendations [3]. The neurological examination is comprised of components of the UPDRS, including analysis of rest tremor, action tremor, finger taps, hand movements, toe taps, and gait. Although examination of muscle rigidity and postural instability in accordance with the Movement Disorder Society-Unified Parkinson's Disease Rating Scale (MDS-UPDRS) [24] cannot be assessed visually during a virtual visit, analysis of these tests may not add significant diagnostic or predictive benefit [25, 26]. In contrast, assessments of rest tremor and movement are easily conducted over videoconferencing since clinical evaluation is largely visual [3].

Visits can be conducted using a laptop or desktop computer equipped with secure, Health Insurance Portability and Accountability Act (HIPAA) compliant Internet-based videoconferencing software, high-speed Internet, and a web camera with an embedded microphone. Providers may give patients access to software by sending necessary information via an e-mail link and facilitating any necessary technological support by phone. Setup of the equipment is nonintensive and can be coordinated for use with both clinician and patient computers. To improve visual quality, providers and patients are suggested to utilize a light source emerging from behind the computer, thereby illuminating the face and body for high visualization on the respective screens of patient and clinician. To improve audio quality, both patient and provider should maintain a reasonable distance from the web camera or computer microphone and background room noise should be minimized.

Studies Demonstrate the Feasibility and Acceptability of Telemedicine

Telemedicine for Parkinson's disease has been assessed for feasibility and acceptability through clinical studies varying in size and study duration. Recently, a randomized, controlled clinical trial of telemedicine for Parkinson's disease demonstrated that not only is web-based videoconferencing feasible for care in the home, but it also provides value to patients, and may offer similar clinical benefit to that of in-person care [7]. Subsequent studies examining "virtual care visits" have shown that patients have been satisfied with such care and appreciate the care received, convenience, and comfort and personal nature of the visit despite distance of the physician [27].

The care paradigm for Parkinson's disease also shifts in favor of the patient during telemedicine visits when compared to in-person visits. Patients may spend nearly 80 % of their time traveling and waiting for care during a traditional visit in the clinic of a specialist, while only having a short visit with the physician [7]. During telemedicine visits, patients may spend as little as 30 % of their scheduled time for computer startup and connecting to the virtual office. The majority of time is therefore spent with the physician for clinical purposes [7].

Concerns about telemedicine from the patient perspective are generally associated with using unfamiliar technology, connection quality, and the availability of information for the specialist examination (e.g., lack of temperature, blood pressure, pulse, etc.) [27]. Although the power and range of current technologies continue to improve, it is inevitable for nonconformities in access to standard technology to exist due to the heterogeneity in quality of wired or wireless connections, software, and hardware. Wider acceptability of telemedicine for Parkinson's disease would require greater outreach to rural populations and better addressing the initial learning necessary for older individuals to adopt telemedicine as a useful source of care [28].

Barriers to the Adoption of Telemedicine

The primary barriers preventing the spread of telemedicine in the USA include reimbursement and licensure. Telemedicine has the potential to thrive for Parkinson's disease and other neurologic care services when these barriers are overcome.

Reimbursement

Based on success in Canada [29], the Veterans Health Administration (VHA) medical system, and integrated care networks in the USA [30], telemedicine is a powerful model for providing care when limits to reimbursements are minimized. As of January 2014, 43 states and the District of Columbia provide varying forms of

Medicaid reimbursement for telehealth services. However, only 19 states and the District of Columbia require private insurance plans to cover telehealth services [31]. In order for patients to receive the long-term benefits of telemedicine, reimbursement policies will have to change.

Licensure

Medical practice for major health-care providers is steadily moving towards a national system; however, physicians are still limited by restrictions on practice across state lines [32]. If a physician seeks to practice in more than one state, he or she would typically apply directly to one of the 70 medical and osteopathic boards within the USA and its territories [33, 34]. Eleven state boards currently issue a special-purpose license, telemedicine license or certificate, or license to practice medicine across state lines [33]. At present, a proposed Interstate Medical Licensure Compact aims to allow eligible physicians to apply for expedited licensure in participating states [34]. Expansion of robust telemedicine services therefore has the potential to proceed at a rapid pace as regulatory barriers continue to diminish.

Telemedicine Models for Parkinson's Disease Care

Various models are developing in medicine for telemedicine (Table 1). The value of telemedicine models for chronic conditions, especially Parkinson's disease, is derived from the many applications based on patient location and the low cost of implementation relative to emerging models for acute conditions such as stroke. While medical centers still lag in their adoption of telemedicine alongside traditional in-clinic care, organizations such as the VHA system, the Ontario Telemedicine Network, state departments of corrections, and the Kaiser Permanente Integrated Managed Care Consortium have successfully adopted various forms of telemedicine which can be appropriately employed for varying patient populations. Providers, therefore, have much autonomy in catering telemedicine to the needs and distinctive features of both the targeted patient population and the size and revenue model of the clinic.

Conclusions

Telemedicine for Parkinson's disease is a prototypical model of care for managing chronic conditions in the home. Technology-enabled solutions for providing care to individuals with Parkinson's disease will be necessary to meet the increasing demand for specialty care. As the cost of existing and emerging telecommunication and health-care service technologies continues to decrease, the pervasiveness of

Table 1 Telemedicine models for acute versus chronic conditions

Condition	Patient location	Providers	Expense	Revenue model
Acute conditions (e.g., stroke)	Hospital emergency department (ED)	Stroke neurologist at major medical centers	High	Maintain patients in satellite hospital
		Private companies		Obtain stroke certification for center (builds brand)
				Receive limited third-party reimbursement
Chronic conditions (e.g., Parkinson's disease)	Nursing homes, medical institutions, prisons	Few medical centers	Low	Receive reimbursement in health professional shortage areas
				Receive contracted payments
	Satellite clinic	Few medical centers	Low	Provide care at lower cost to generate savings in capitated (at risk) health systems
		Veterans Health Administration (VHA)		
		Ontario Telemedicine Network		
	Homes	Few medical centers	Very low	Reduce clinic space cost
		Few private practitioners		Provide care at lower cost to generate savings in capitated health systems
		Kaiser Permanente		
		Specialty/boutique care		

such technologies will steadily rise. Despite the present barriers to providing care via telemedicine, individuals living with Parkinson's disease have already begun to benefit from the home-centered and low-cost care facilitated by web-based videoconferencing. Targeted outreach to individuals in underserved populations can expand the scope of current telemedicine services and expand the reach of providers. As a new model for providing specialty care, telemedicine requires providers to embrace experimentation and deviation from the status quo in order to identify optimal designs of technology-based patient care. The ultimate success of telemedicine for Parkinson's disease will be dictated by Medicaid reimbursement policies for telehealth services, facilitation of cross-state practices by limiting unnecessary licensure barriers, and establishment of partnerships that are invested in implementing and maintaining programs.

References

1. Hubble JP, Pahwa R, Michalek DK, Thomas C, Koller WC. Interactive video conferencing: a means of providing interim care to Parkinson's disease patients. Mov disord. 1993;8(3):380–2.
2. Cubo E, Gabriel-Galan JM, Martinez JS, Alcubilla CR, Yang C, Arconada OF, et al. Comparison of office-based versus home Web-based clinical assessments for Parkinson's disease. Mov disord. 2012;27(2):308–11.
3. Dorsey ER, Deuel LM, Voss TS, Finnigan K, George BP, Eason S, et al. Increasing access to specialty care: a pilot, randomized controlled trial of telemedicine for Parkinson's disease. Mov disord. 2010;25(11):1652–9.
4. Goetz CG, Stebbins GT, Wolff D, DeLeeuw W, Bronte-Stewart H, Elble R, et al. Testing objective measures of motor impairment in early Parkinson's disease: Feasibility study of an at-home testing device. Mov disord. 2009;24(4):551–6.
5. ITU. Measuring the Information Society 2013. Geneva: International Telecommunication Union, 2013. http://www.itu.int/en/ITU-D/Statistics/Documents/publications/mis2013/MIS2013_without_Annex_4.pdf. Accessed 18 Aug 2014.
6. Institute of Medicine (U.S.). Committee on Quality of Health Care in America. Crossing the quality chasm: a new health system for the 21st century. Washington, D.C.: National Academy Press; 2001. xx, 337 pp.
7. Dorsey ER, Venkataraman V, Grana MJ, Bull MT, George BP, Boyd CM, et al. Randomized controlled clinical trial of "virtual house calls" for Parkinson disease. JAMA Neurol. 2013;70(5):565–70.
8. Dorsey ER, Constantinescu R, Thompson JP, Biglan KM, Holloway RG, Kieburtz K, et al. Projected number of people with Parkinson disease in the most populous nations, 2005 through 2030. Neurology. 2007;68(5):384–6.
9. Dorsey ER, George BP, Leff B, Willis AW. The coming crisis: obtaining care for the growing burden of neurodegenerative conditions. Neurology. 2013; 80(21):1989–96.
10. Willis AW, Schootman M, Evanoff BA, Perlmutter JS, Racette BA. Neurologist care in Parkinson disease: a utilization, outcomes, and survival study. Neurology. 2011;77(9):851–7.
11. Kumar S, Merchant S, Reynolds R. Tele-ICU: efficacy and cost-effectiveness approach of remotely managing the critical care. Open Med Inform J. 2013;7:24–9.
12. Kulcsar M, Gilchrist S, George MG. Improving stroke outcomes in rural areas through telestroke programs: an examination of barriers, facilitators, and state policies. Telemed J E Health. 2014;20(1):3–10.
13. Aita MC, Nguyen K, Bacon R, Capuzzi KM. Obstacles and solutions in the implementation of telestroke: billing, licensing, and legislation. Stroke. 2013;44(12):3602–6.

14. Sapirstein A, Lone N, Latif A, Fackler J, Pronovost PJ. Tele ICU: paradox or panacea? Best Pract Res Clin Anaesthesiol. 2009;23(1):115–26.
15. Factor SA, Feustel PJ, Friedman JH, Comella CL, Goetz CG, Kurlan R, et al. Longitudinal outcome of Parkinson's disease patients with psychosis. Neurology. 2003;60(11):1756–61.
16. Jankovic J. Parkinson's disease: clinical features and diagnosis. J Neurol Neurosurg Psychiatry. 2008;79(4):368–76.
17. Nutt JG, Bloem BR, Giladi N, Hallett M, Horak FB, Nieuwboer A. Freezing of gait: moving forward on a mysterious clinical phenomenon. Lancet Neurol. 2011;10(8):734–44.
18. Hubble JP. Interactive video conferencing and Parkinson's disease. J Kans Med Soc. 1992;93(12):351–2.
19. Hoehn MM, Yahr MD. Parkinsonism: onset, progression and mortality. Neurology. 1967;17(5):427–42.
20. Parkinson's Disease Foundation (U.S.). Recent developments in Parkinson's disease. New York: Raven Press; 1986. pp. 153–63, 293–304.
21. Biglan KM, Voss TS, Deuel LM, Miller D, Eason S, Fagnano M, et al. Telemedicine for the care of nursing home residents with Parkinson's disease. Mov Disord. 2009;24(7):1073–6.
22. Achey M, Aldred JL, Aljehani N, Bloem BR, Biglan KM, Chan P, et al. The past, present, and future of telemedicine for Parkinson's disease. Mov Disord. 2014;29(7):871–83.
23. van der Marck MA, Bloem BR, Borm GF, Overeem S, Munneke M, Guttman M. Effectiveness of multidisciplinary care for Parkinson's disease: a randomized, controlled trial. Mov Disord. 2013;28(5):605–11.
24. Goetz CG, Tilley BC, Shaftman SR, Stebbins GT, Fahn S, Martinez-Martin P, et al. Movement Disorder Society-sponsored revision of the Unified Parkinson's Disease Rating Scale (MDS-UPDRS): scale presentation and clinimetric testing results. Mov Disord. 2008;23(15):2129–70.
25. Abdolahi A, Scoglio N, Killoran A, Dorsey ER, Biglan KM. Potential reliability and validity of a modified version of the Unified Parkinson's Disease Rating Scale that could be administered remotely. Parkinsonism Rel Disord. 2013;19(2):218–21.
26. Kerr GK, Worringham CJ, Cole MH, Lacherez PF, Wood JM, Silburn PA. Predictors of future falls in Parkinson disease. Neurology. 2010;75(2):116–24.
27. Venkataraman V, Donohue SJ, Biglan KM, Wicks P, Dorsey ER. Virtual visits for Parkinson disease: a case series. Neurol Clin Pract. 2014;4(2):146–52.
28. Shprecher D, Noyes K, Biglan K, Wang D, Dorsey ER, Kurlan R, et al. Willingness of Parkinson's disease patients to participate in research using internet-based technology. Telemed J E Health. 2012;18(9):684–7.
29. Brown EM. The Ontario Telemedicine Network: a case report. Telemed J E Health. 2013;19(5):373–6.
30. Pearl R. Kaiser Permanente Northern California: current experiences with internet, mobile, and video technologies. Health Aff. 2014;33(2):251–7.
31. NCSL. State Coverage for Telehealth Services: National Conference of State Legislatures; 2014. http://www.ncsl.org/research/health/state-coverage-for-telehealth-services.aspx. Accessed 18 Aug 2014.
32. Institute of Medicine Board on Health Care Services. The role of Telehealth in an evolving health care environment: Workshop Summary. Washington, DC: National Academies Press (US); 2012.
33. FSMB. Telemedicine Overview: Board-by-board approach. Federation of State Medical Boards, 2013. http://library.fsmb.org/pdf/grpol_telemedicine_licensure.pdf. Accessed 18 Aug 2014.
34. Steinbrook R. Interstate medical licensure: major reform of licensing to encourage medical practice in multiple states. JAMA. 2014;312(7):695–96.

Teleneuropathology

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Telepathology and Teleneuropathology Literature

The first papers using the term “telepathology” were published in 1986 and 1987 [41, 64, 66, 67]. Becker and his colleagues at the Armed Forces Institute of Pathology, in Washington, D.C., were early adopters of teleneuropathology [4]. Today, the telepathology literature is growing at an accelerating rate. There are 869 “telepathology” papers listed in the PubMed database as of June 1, 2014. Many additional telepathology papers are listed as “digital pathology” papers, “virtual microscopy” papers, or “whole-slide imaging” (WSI) papers [72, 12, 10]. Although many of these telepathology papers are relevant to teleneuropathology, only 1–2 % of the telepathology papers in the PubMed database actually use the term “teleneuropathology” in their title [17, 18, 23, 30, 28, 31, 59, 61, 62, 63, 77]. It is interesting to note that telepathology papers on other surgical pathology subspecialties such as dermatopathology, renal pathology, or cytopathology are also underrepresented [20, 27, 32, 40, 43, 44, 47, 48, 53, 58, 60, 73, 74, 76, 75, 8]. As a practical matter, telepathology papers, both those drawn from the general telepathology literature

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and those dealing with other pathology subspecialties, are often applicable to teleneuropathology as well.

Telepathology Equipment Classification

In this chapter, we provide an up-to-date guide to telepathology and teleneuropathology equipment systems currently being marketed. A basic knowledge of this topic could be important for some neurologists since the type of equipment being used can affect their laboratory's performance [61, 29, 28]. Our immediate objective is to provide neurologists and neuropathologists with a working framework for understanding the major categories of telepathology systems, including their major strengths and limitations. Until telepathology equipment standards and guidelines, with specific equipment recommendations, are published sometime in the future, it will be incumbent upon neurologists to pay some attention to the methodology being offered by their own in-house teleneuropathology laboratory or the outside reference laboratories used by their neurosurgeons. The 2014 edition of the American Telemedicine Association's (ATA's) Clinical Guidelines for Telepathology does not endorse a specific type of telepathology system or recommend telepathology system equipment specifications, such as digital image resolution requirements, image compression, or color standards [51].

Currently, in the commercial telepathology equipment marketplace, there are many telepathology equipment vendors. They sell a variety of types of telepathology systems, some of which are based on fundamentally better technologies than others [57]. A partial consolidation within the telepathology equipment industry has taken place over the past 5 years. Table 1 shows the US patent portfolios of the leading telepathology and digital pathology equipment companies in terms of numbers of issued patents. It reflects the consolidation taking place in the telepathology equipment industry. At present, there is no single dominant telepathology equipment vendor [10].

A number of issues to be addressed by pathologists when selecting a telepathology imaging system specifically for use in teleneuropathology have been discussed by Evans and his colleagues at the University of Toronto, Canada. Their work is based on extensive practical experience with teleneuropathology [17, 18]. Interest-

Table 1 The leading four commercial digital pathology patent owners in the USA. (From [10], with permission)

Patent owner (initial assigned acquired by the current owner)	Number of patents awarded	Number of patent applications pending	Total
Leica (Aperio)	50	9	59
Olympus (Bacus)	30	6	36
DMetrix (University of Arizona)	30	5	35
Ventana (Bioimagene)	15	5	20

ingly, this group of pathologists consists of five urological pathologists (i.e., prostate, urinary bladder, testis, etc. experts), not neuropathologists, as discussed elsewhere [72]. Their success, functioning as neuropathologists, underlines the fact that subspecialty surgical pathologists can be flexible and accept responsibilities that lie well outside their ordinary domains of surgical pathology practice [6].

Using teleneuropathology on a regular basis, the University of Toronto telepathologists, functioning as teleneuropathologists, have diagnosed several hundred nervous system frozen section cases. These cases originate at a neurosurgical institute located approximately a mile away from their offices. As part of a protocol for establishing their teleneuropathology frozen section practice, the group compared, sequentially, static-image-enhanced dynamic-robotic telepathology with WSI. WSI emerged as their current technology of choice [17]. This pathology group's ability to rapidly assemble geographically decentralized pathologists into "virtual" ad hoc diagnosis consensus groups on the fly, during urgent teleneuropathology frozen section case readout sessions, is credited with the high quality and sustainability of their teleneuropathology frozen section service (Evans, personal communication).

Classification of Telepathology Systems

Table 2 shows an updated classification of telepathology systems [74, 51]. Currently, dynamic-robotic/static-image-enhanced WSI would be our system of choice if funding were not an issue. Although such systems are currently preferred by a few laboratories in North America, low-cost real-time telepathology systems, such as television microscopy (i.e., a basic video camera mounted on a light microscope) and static-image telepathology, remain options worth considering, especially for laboratories in underdeveloped countries without the economic or infrastructure resources to support more advanced technologies [2].

Table 2 Telepathology system classification[a]. (Modified from Weinstein et al. 2012)

Imaging system	Year
Real-time imaging	
Television microscopy	1952
Dynamic-robotic telepathology	1986
Static image telepathology	
Store-and-forward telepathology	1987
Whole-slide imaging (automated)	1991
Whole-slide imaging (operator-directed)	1994
Multimodality telepathology	
Static-image-enhanced dynamic-robotic telepathology	1989
Dynamic-robotic/static-image-enhanced whole-slide imaging	2011

[a] Mobile telepathology will be added to the next iteration of this classification [21, 26, 52]

Robotic-dynamic telepathology (real-time imaging) and static image telepathology were developed concurrently by independent groups of innovators in the mid-1980s (Table 2). These two technologies were regarded as competing technologies until the mid-1990s when dynamic-robotic telepathology was shown to be more accurate. WSI is a more recent innovation [69].

Static Image Telepathology

The introduction of static imaging telepathology was initially enabled by the introduction of relatively inexpensive low-capacity image grabber boards (< 100k pixels) for first- and second-generation personal computers in the early 1980s [67, 34]. The storage capacity of such image grabber boards has increased one-million-fold since then.

Static image telepathology involves the asynchronous capture of image files [65]. This use of the term "asynchronous" refers to the fact that static digital images, either whole-slide images (i.e., basically giant static images) or relatively small, single-histopathology-field static images, are captured and stored for later viewing, typically by a telepathologist using an off-site imaging workstation.

In order for static image telepathology to be used in the single-histopathology-field imaging mode, the histopathology image field selection is typically made by a local, on-site pathologist. This function cannot be delegated to a laboratory technologist or a physician assistant (PA). Alternatively, field selection can be done by a remote telepathologist if the static image telepathology system incorporates a dynamic-robotically controlled motorized microscope, similar to the ones used for dynamic-robotic real-time telepathology. The main advantage of dynamic-robotic–*static image telepathology* over dynamic-robotic real-time telepathology is that dynamic-robotic–static image telepathology requires less telecommunications bandwidth.

Shimosato and Yagi tested a high-definition television (HDTV)-equipped dynamic-robotic–*static image telepathology* system at the National Cancer Center in Tokyo in 1988 and found that this type of system was cumbersome to use and unacceptably time consuming for examining remote slides. Thus, this mode was abandoned (Weinstein, unpublished observations, 1988) [56, 78]. Currently, the designation "dynamic-robotic" is used exclusively in the context of real-time video imaging.

Dynamic-Robotic Telepathology

Robotic telepathology was first used for operator-controlled robotic video microscopy real-time imaging in 1986 [66, 67, 33]. This was one of the earliest uses of robotic technology in medicine. Robotic surgery had been first performed just 2 years earlier, in 1984.

The first robotic-dynamic telepathology systems leveraged the then recent addition of an S-232 port to high-end motorized light photomicroscopes by the Japanese company Olympus [68, 38, 34]. This innovation enabled the external control of motorized photomicroscope functions from a personal computer keyboard for the first time. The next step in creating a robotic telepathology system was to link the local computer used to control the motorized photomicroscope to a distant computer via telecommunications, thus enabling operator control of the computer-driven motorized microscope functions from a distance [34, 37]. A stream of real-time video images was obtained from a video camera mounted on a C-ring on top of the motorized photomicroscope. Early versions of these systems used satellites for their broadband telecommunications. Today, both the remote microscope control functions and the video image transmission can be over the terrestrial broadband Internet.

The dynamic-robotic telepathology system operator, the "telepathologist," has full control over positioning of the histopathology slide in the *X*- and *Y*-axes, for microscopic field selection, and for focusing in the *Z*-axis. Depending on the bandwidth available, the image capture rates, and the image file sizes, there could be a noticeable "lag" in the responsiveness of the system to operator commands. The imposition of a robotic component in any procedure decreases efficiency and can have an impact on the service provider and system user satisfaction [34].

Whole-Slide Imaging

WSI refers to a digitized glass slide image that has been produced with a WSI slide scanner (Fig. 1). The WSI of the glass slide accurately represents the histopathology or cytopathology materials on the glass slide at high resolution. Initially, the WSI of the glass slide is captured as a single *Z*-axis image representation of the original

Fig. 1 Dynamic-robotic/static-image-enabled whole-slide imaging (*WSI*) scanner. Aperio® Scanscope scanner. (Leica Microsystems, Inc. Buffalo Grove, IL, USA)

glass slide. The topography of the specimen, as represented by the digital image, is uneven and actually highly variable in height with reference to the underlying glass slide upon which the specimen is mounted. The topography of the image represented in this *Z*-axis is predetermined by multipoint autofocusing. Multiple *Z*-axis scans at various heights can be stored as a large digital image stack.

For viewing, the operator uses a generic computer workstation equipped with brand-specific software. The software mimics the operator controls used for operating a conventional light microscope. For example, there is a set of icons representing microscope objective lenses at various magnifications (i.e., 4×, 10×, 20×, and 40×). Clicking on one of these icons changes the magnification of the image of the WSI on the viewing screen. The field is repositioned using a click-and-drag function.

When WSI was introduced in the 1990s, the production of a single WSI often took 12–24 h or longer. These WSI were produced by electronically stitching together galleries of individually photographed single static images [34]. The individual static images were acquired with a light microscope equipped with 20× or 40× objective lenses. Because of the long production times, such WSIs were of little use in clinical settings but were used primarily for education and testing applications [11]. However, image acquisition and processing rates steadily improved throughout the 1990s. By 2004, a 1.5-cm^2 standardized histopathology tissue section mounted on a glass slide was converted into a WSI in less than 1 min, setting a new WSI throughput record. The 1.5-cm^2 standardized tissue section had been introduced nearly two decades earlier, as part of the initial telepathology study in Chicago [67]. The "one-minute scan" was accomplished using an innovative array microscope developed and patented at the University of Arizona College of Optical Sciences in Tucson [70, 71]. One-minute throughput scan times were rapidly adopted as the de facto WSI scanning throughput time standard for the WSI field.

Until the "one-minute scan" was achieved, an approach to accelerate the WSI scanner throughput was to offer the option of allowing the system operator to prioritize regions of interest for initial scanning, rather than operate the system in the totally automating roster scanning mode. This is referred to as "operator-directed whole-slide imaging" (Table 2).

A recent advance in WSI systems design has been the incorporation of a means for capturing *Z*-axis (i.e., up-and-down focusing of tissue and cells) digital information, either as continuous sampling in the form of up-and-down focusing of a real-time video stream, utilizing a dynamic-robotic microscope built into the WSI scanner, or by capturing discontinuous as *Z*-axis image stacks using *Z*-axis height presets (i.e., 0.1-, 0.2-, or 0.5-μm steps).

Multimodality Telepathology

Today's dynamic-robotic telepathology systems typically incorporate an optional static imaging function which enables the telepathology system operator to photograph and archive individual static images of regions of interest and/or diagnostic areas. This combination of modalities, dynamic-robotic real-time imaging, and individual microscopic field static imaging was introduced by Nordrum and Eide in 1991 and became the technology of choice for doing telepathology in the US Department of Veterans Affairs for many years [45, 15, 16, 13]. Typically, a few static images of diagnostic fields are archived for each case [6]. These can be used: to document what the diagnosing telepathologist regarded as diagnostic fields, for quality assurance purposes, for insertion into surgical pathology reports, for surgical pathology conferences, for education programs, and for illustrations in publications [35, 36].

The complex term "static-image-enhanced WSI" may appear redundant but it is not. In this context, the use of the WSI modifier "static-image-enhanced telepathology" refers to the archiving of individual small static images, typically a subset of images derived from the WSI slide image file. Gross static images of the entire glass slide, as used in the first generation of dynamic-robotic telepathology systems, would be redundant since, today, a low-magnification view of the WSI itself serves as the tissue map in the WSI scanners' navigation system.

For real-time imaging using a dynamic-robotic/static-image-enhanced WSI system, a WSI of a histopathology section is first captured by WSI scanning. This whole-slide image is used as a tissue map in the WSI scanner's navigation system. This WSI, while superimposed on the actual tissue section, is viewed by the telepathologist during the identification of "regions of interest" on the histopathology slide. This is done while the original histopathology glass slide is still present in the WSI scanning device's motorized light microscope stage. This WSI tissue map also serves as a point of reference when entering the dynamic-robotic microscopy viewing mode, in order to robotically explore the actual tissue section with the robotically controlled "through focus" modality turned on [74]. In practice, the telepathology system operator would toggle back and forth between the WSI imaging mode and the real-time "through-focus mode" imaging mode [74].

Alternatively, three-dimensional WSI systems have preassigned settings for the height spacing for *Z*-axis digital image stacks representing "regions of interest." These may be small *Z*-stacks representing isolated regions of interest, or large *Z*-stacks, representing stacks of the giant WSI files. Fast, high-capacity storage systems, such as those used in cloud computing, are required to handle the vast amounts of digital information that is represented in a *Z*-stack of whole-slide images at high resolution. High-speed data processing, storage, and networking systems combine to enable the acquisition of a large number of *Z*-axis WSI digital image stacks in near real time. WSI of Z-stacks at 0.1-μm height intervals are useful for searching for, and characterizing, microorganism size, shape, and staining properties in tissue sections and other applications [74].

Table 3 shows a comparison of the individual imaging modalities available in telepathology systems. These components are used as building blocks in various combinations in multimodality telepathology systems [49].

To some extent, the introduction of WSI rendered moot the issue of microscopic histopathology field selection. Theoretically, the off-site telepathologist could now download a giant digital image representing an entire glass slide. In practice, this proved to be an oversimplification since some additional useful information is

Table 3 Individual imaging components of telepathology systems

Telepathology modality	Image system	Remote control	Images/case	Image selection	Average time to review	Bandwidth requirements	Cost
Static	Still	No[b]	Limited	Local pathologist	Variable	Low	Low
Dynamic real time	Real time	Yes	Unlimited	Telepathologist	Short	Medium–high	High
WSI	Still	No	Unlimited	Telepathologist	Short	Variable	Variable

WSI whole-slide imaging

[a]Modified from [33] with permission

[b]Dynamic-robotic–static imaging telepathology has been tested but proved impractical [26, 56]

gained from the up-and-down focusing of a pathologist using conventional light microscopy. While it is true that the entirety of the tissue sections in two dimensions is represented in the digital images produced by WSI, it should be remembered that a single WSI represents only a single plane, in the *Z*-axis, of three-dimensional slabs of tissue. Histopathology tissue sections have thickness. Additional imaging would be necessary to capture all of the information in histopathology sections. For the large majority of teleneuropathology cases, sampling a single optical plane suffices [17]. However, for certain types of surgical pathology cases, such as those for which identification of bacteria or parasites in tissue sections is important, single-optical-plane sampling may turn out to be inadequate. Fortunately, such cases are uncommon in teleneuropathology practices.

Telepathology and Teleneuropathology Validation Studies

Many telepathology validation studies have been published. The “gold standard” for pathology tissue diagnoses remains traditional light microscopy. Generally, dynamic-robotic telepathology and WSI, individually, outperform static image telepathology [25, 39, 7, 9, 14, 16, 50, 19].

In a large teleneuropathology study, Evans et al. at the University Health Network in Toronto, Canada, systematically compared dynamic-robotic teleneuropathology with single-optical-plane WSI teleneuropathology, using these two technologies sequentially for the evaluation of 983 frozen sections from 790 patients at a single site. This occurred in an active neurosurgical practice setting [17], and this service remains active today. For the study group, 88 % of the cases were single frozen section cases. Under actual neurosurgical practice conditions, total turnaround times averaged 19.98 min for dynamic-robotic telepathology cases and 15.68 min for WSI cases. Both values satisfy College of American Pathologists (CAP) laboratory accreditation criteria [46]. Pathologists averaged 9.65 min to review a frozen section slide by dynamic-robotic telepathology versus 2.25 min by WSI, a fourfold decrease. Their diagnostic accuracy was 98 % for both imaging modalities. The overall case deferral rate was 7.7 %, and was essentially the same for both imaging modalities. Since 2006, WSI has been their method of choice [17]. Their WSI system did not include a module for creating *Z*-stacks of digital images. Lack of an "up and down" focusing feature was not a problem for either teleneuropathology frozen section diagnosis or intraoperative cytology interpretation by WSI [17, 18].

Horbinski and Wiley at the University of Pittsburgh Medical Center have also analyzed and compared two types of teleneuropathology systems being used by their teleneuropathology frozen section service [29]. They provide teleneuropathology for several clinical sites, unlike the Toronto teleneuropathology program which services a single site. Their discordance rates were not significantly different between conventional light microscopy and telepathology. However, they experienced higher case deferral rates (as high as 20 %) than those reported by the Toronto practice.

In Horbinski and Wiley's analysis of hundreds of teleneuropathology cases in Pittsburgh, they found that teleneuropathology can be used to diagnose both common and challenging tumors. Differences in outcomes for teleneuropathology cases originating from their various clinical sites were related to the different surgeries performed at their individual locations as much as the teleneuropathology diagnostic modality used [29]. With respect to their higher case deferral rates, ranging up to 20 % of cases from some sites, they point out that the causes of case deferral rate were actually multifactorial. Tissue sampling apparently was a factor. In their frozen section practice, the cytology smears were using a sampling of biopsy tissue, thus making it more difficult to confidently say that there was no tumor in a biopsy. In general, for their frozen section service, "defer" tends to be favored as the first line in intraoperative diagnosis. Horbinski and Wiley explain that their relatively high case deferral rate on frozen section cases was magnified by the fact that, with teleneuropathology as used in their practice, the specimen was prepared by a remote, on-site PA without the teleneuropathologist actually seeing the gross tissue. This raised their threshold for rendering a definitive diagnosis on frozen sections [29, 28]. Addition of a video grossing workstation to their frozen section laboratory setup might help ameliorate this problem [1]. A grossing workstation is used for visualizing gross specimens at a distance. The telepathologist can guide the on-site medical technologist in selecting areas of tissue for dissection into frozen section tissue blocks. In summary, Horbinski and Hamilton found that overall diagnostic accuracy for frozen section teleneuropathology seemed slightly lower than having an on-site neuropathologist reading out frozen sections. These differences were not statistically significant. They concluded that the use of teleneuropathology for frozen section readouts is preferable to having a general surgical pathologist handle difficult neuropathology consultations [28].

Telepathology and Teleneuropathology Applications

Telepathology has been successfully used for intraoperative frozen section consultation; primary diagnosis; peer-to-peer secondary consultation; expert second opinions; rapid cytology consultation; special studies such as immunohistochemistry,

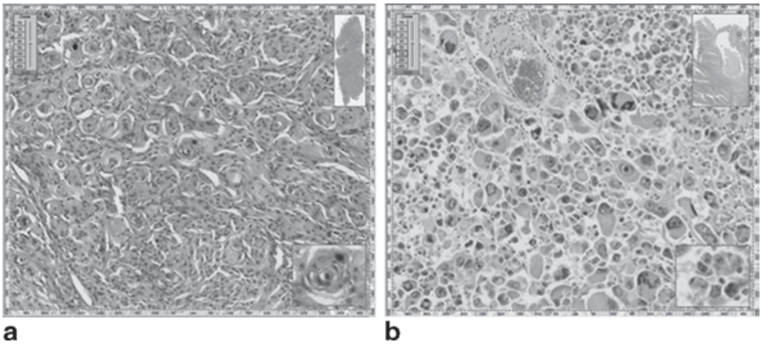

Fig. 2 Whole-slide images of paraffin-embedded, hematoxylin and eosin (*H&E*)-stained brain specimens. *Upper right* in each plate shows a thumbnail image of the glass slide at low magnification. The graphic-imposed *square* marks the area displayed in the main viewing field. *Lower right* of each specimen image in the main window shows a small magnified image. Tissue sections were magnified 10× using a whole-slide imaging (WSI) scanner. *Left:* Meningioma. There are prominent whorls of benign-appearing tumor cells. *Right:* Highly anaplastic lung carcinoma, metastatic to brain. Aperio® Slide Scanner (Buffalo Grove, IL, USA)

fluorescence in situ hybridization (FISH), and chromogenic in situ hybridization (CISH) quality assessment (QA); consensus conferences; multidisciplinary conferences (e.g., tumor board); morbidity and mortality conferences; and even patient consultations (Fig. 2). There are peer-reviewed publications for each of these telepathology and digital pathology clinical applications [69, 72, 54].

Currently, the most important use of telepathology in a neuropathology laboratory is in the area of intraoperative frozen section consultations, as described above under the section "Telepathology and Teleneuropathology Validation Studies" [17, 18, 22, 23, 28–30. Neuropathology frozen section services are especially challenging in terms of the rapid case turnaround times expected, as well as the laboratory environment in which frozen section consultations take place [46]. The time from the receipt of a fresh tissue sample from an operating room until the issuing of a frozen section pathology report should be less than 20 min. To accomplish this, the telepathologist should be on standby while the frozen sections are being produced, mounted on glass slides, stained, coverslipped, and then digitized into a WSI. When teams of telepathologists are used to render the frozen section diagnoses, coordinating on-service schedules adds another level of complexity to the frozen section operation.

As described in detail by Evans et al., neurosurgical frozen sections are used to microscopically confirm a known diagnosis, assure that a lesion is appropriately sampled, establish a previously undiagnosed disease or condition, determine if a neoplasm is malignant or benign, determine if a malignant tumor is a primary tumor or a metastasis, determine the subtype of a primary tumor, and make an estimate of the grade of a tumor (Evans et al. 2010). In an early, large Polish multisite study of the feasibility of using Internet-based robotic teleneuropathology, the study set of neuropathology cases represented 29 "truth" diagnosis for brain lesions. These cases ranged from the dysembryoplastic neuroepithelial tumor to the glioma mixtum oligoastrocytoma. This was intended to represent the range of diagnostic entities actually seen on the home institution's neuropathology frozen section service [59]. The mean diagnostic accuracy for three teleneuropathologists was 95 %. Many of the diagnostic entities would be unfamiliar to general surgical pathologists.

Primary diagnoses, based on the remote examination of paraffin-embedded tissues, have been successfully rendered using a number of different telepathology imaging modalities (Table 3). Rendering primary diagnoses on some types of specimens may be especially difficult using digital imaging in place of traditional light microscopy. Based on our experience with conventional light microscopy, the following types of pathology specimens have been identified as being especially dependent on imaging multiple focal planes (*Z*-axis imaging) in tissue sections. In surgical pathology, identifying and classifying microorganisms can be challenging. This includes certain bacteria, fungi, and parasites, such as speciation of malaria. With respect to tumors, identifying mitotic figures and differentiating normal from abnormal mitotic figures can be problematic without up-and-down focusing. Examples of challenging cytology cases would include body fluids because of the tendency of cells to aggregate into balls. Cells in fine-needle aspirates can also "ball up," into aggregates greater in diameter than the thickness of a single-*Z*-axis-plane digital image [55] (Weinstein and Graham, unpublished observations, 2013).

There is growing interest in using telepathology and teleneuropathology for special studies. One approach is to transport paraffin tissue blocks or frozen tissue to reference laboratories for processing and then posting WSIs on the Internet. The originating pathologist can pull up the images on a video monitor, analyze them, and then generate the surgical pathology report for the patient's medical record. Types of cases include those requiring specialized processing and staining including immunohistochemistry, FISH, and CISH [72].

Telepathology-enabled QA programs for surgical pathology services can be of value, especially for hospitals staffed with a single pathologist [24, 6].

Challenges in Teleneuropathology

Neuropathology is one of the most highly specialized areas of surgical pathology practice. A few years of additional training in neuroscience and neuropathology, beyond general pathology training, are often required to become a board-certified neuropathologist. As a practical matter, many academic pathologists in North America with other areas of pathology subspecialty expertise (i.e., dermatopathology, renal pathology) would not be expected to provide cross coverage on a neuropathology frozen section service. Therefore, when nonneuropathologists are asked to cover neuropathology services, most often for logistical reasons, they may turn to a teleneuropathologist for expert second opinions [17, 28].

What is interesting is that this teleneuropathology frozen section service also can be staffed by nonneuropathologist service providers collaborating to determine a consensus diagnosis, rather than functioning alone. A model program for this has been up and running in Canada for nearly a decade. Evans is part of a group of five uropathologists (i.e., specialists in urinary bladder, prostate, and testis pathology) at the University of Toronto which addressed the need to provide immediate neurosurgical intraoperative frozen section services for patients in a different building, located a mile away, by organizing themselves into a "virtual" diagnostic group. They are all linked into a centralized server and are routinely available to examine the frozen section slides together. Members of the group share responsibility for rendering neuropathology frozen section diagnoses, with the idea being that multiple nonspecialists are better suited to handle neuropathology frozen section cases than individual general pathologists [17]. Their group has also done pioneering work in assessing different types of telepathology equipment in an actual clinical setting.

The practice of neuropathology is inherently challenging, even for experts. The pace of change in neuropathology is such that it is increasingly difficult for even full-time neuropathologists to keep current in all areas of expertise constituting this discipline. There are many factors that come into play. The spectrum of neuropathologies associated with diseases ranging from viral infections to central nerve system tumors is large. It follows that the wide spectrum of recognized disorders constituting neuropathology today makes it especially challenging for general pathologists who do not do some neuropathology interpretation on a regular basis to sign out neuropathology cases [59]. Another reality in clinical practice is that even expert neuropathologists can be under pressure to survey and distill large amounts of pathologic, molecular, genetic, and clinical information relating to diverse disorders, not infrequently within a very limited amount of time [46]. On the other hand, the management of brain lesions depends heavily on the neuropathological diagnosis. The accuracy of these diagnoses is of the utmost importance for the daily clinical practices of neurologists.

Currently, the definitive diagnosis of many neurological diseases remains dependent on direct examination of tissues obtained by biopsy. With the complexity, diversity, and difficulty of this specialty, achieving a broader geographic accessibility to expert neuropathologists from the existing pool of neuropathologists could make teleneuropathology cost-effective for many pathology departments and group practices that do not have on-site neuropathologists.

In addition to US and Canadian staffing needs, there is a worldwide need for well-trained neuropathologists capable of making these diagnoses and communicating their findings in a language that is fully understood by treating physicians. It has been estimated that, worldwide, there is a total of 50,000 pathologists of whom 20,000 practice in the USA. The large majority of subspecialty surgical pathologists actually practice in the USA [74]. On the other hand, many countries have few if any general pathologists and virtually no neuropathologists. In geographic locations where no experienced local neuropathologists are available, there is a basic need for remote pathology consultations including remote pathology diagnosis. At present, this situation is often addressed by the local physicians sending stained and unstained histological slides of paraffin-embedded block, or the paraffin blocks themselves, to referral centers in other countries for second opinions. This may delay obtaining a diagnosis for many days or even several weeks. Thus, teleneuropathology can serve as a fast and reliable means to improve the accuracy of neuropathological diagnoses and expedite patient care.

There are shared benefits for neurosurgeons and neuropathologists, which increases the attractiveness of teleneuropathology even further. Neurosurgeons can directly view the video images being seen in real time by the consulting teleneuropathologists, while the actual whole-slide images of their patient's frozen sections are being examined. This allows the neurosurgeon to see on a flat-screen video screen exactly what the teleneuropathologist is viewing without having to leave the operating room to go to the frozen section room at another location. Neurosurgeons who value seeing their patient's intraoperative frozen sections themselves may find this to be a significant benefit. Bringing the frozen section examinations into the operating room using bidirectional video conferencing has the collateral benefit of reassuring the neurosurgeon, during the procedure, that their patient's biopsy is being processed and studied in a timely manner. In our experience as pathologists, this seems to reduce the need for surgical staff in the operating room to place follow-up phone calls to the on-duty frozen-section teleneuropathologist, and, thus, improves efficiency in the frozen section laboratory.

Regulatory Issues, Practice Guidelines, and Reimbursement for Services

In the USA, approval by the US Food and Drug Administration (FDA) for use of telepathology for rendering primary surgical pathology diagnoses and other applications is currently eagerly awaited [3]. Companies are supporting clinical trials to generate the required clinical data to support their US FDA applications. The Canadian FDA governmental approval process for rendering primary surgical diagnoses using telepathology appears to be further along than the one in the USA [5].

Another area in which progress is being made is in the area of creating standards and clinical guidelines for telepathology. Standards and clinical guidelines were published by the Telepathology Special Interest Group of the American Telemedicine Association (ATA) in 1999 [79]. Revised ATA telepathology standards and guidelines will be published in the near future [51]. British telepathology guidelines are available online [42].

With respect to reimbursement for telepathology services, in the USA, telepathology services are covered for rural patients: by Medicare for all 50 states, by Medicaid in the majority of states, and by many third-party payers. Extending coverage to urban patients remains a significant challenge.

Disclosure Dr. Ronald S. Weinstein cofounded Corabi International Telemetrics, Inc., in 1985 and DMetrix, Inc., in 2001.

References

1. Almagro UA, Dunn BE, Choi H, Recla DL, Weinstein RS. The gross pathology workstation: an essential component of a dynamic-robotic telepathology system. Cell Vision 1996;3:470–3. http://www.americantelemed.org/docs/default-source/standards/clinical-guidelines-for-telepathology.pdf?sfvrsn=4.
2. Baak JP, van Diest PJ, Meijer GA. Experience with a dynamic inexpensive video-conferencing system for frozen section telepathology. Anal Cell Pathol. 2000;21:169–75.
3. Bauer TW, Schoenfield L, Slaw RJ, Yerian L, Sun Z, Henricks WH. Validation of whole slide imaging for primary diagnosis in surgical pathology. Arch Pathol Lab Med. 2013;137:518–24.
4. Becker RI Jr, Specht CS, Jones R, Rueda-Pedraza ME, O'Leary TJ. Use of remote video microscopy (telepathology) as an adjunct to neurosurgical frozen section consultation. Hum. Pathol. 1993;24:909–11.
5. Bernard C, Chandrakanth SA, Cornell IS, Dalton J, Evans A, Garcia BM, et al. Guidelines from the Canadian Association of pathologists for establishing a telepathology service for anatomic pathology using whole-slide imaging. J Pathol Inform. 2014;5:15.
6. Braunhut BL, Graham AR, Lian F, Webster PD, Krupinski EA, Bhattacharyya AK, Weinstein RS. Subspecialty surgical pathologist's performances as triage pathologists on a telepathology-enabled quality assurance surgical pathology service: a human factors study. J Pathol Inform. 2014;5:18.
7. Campbell WS, Lele SM, West WW, Lazenby AJ, Smith LM, Hinrichs SH. Concordance between whole-slide imaging and light microscopy for routine surgical pathology. Hum Pathol. 2012;43:1739–44.
8. Collins BT. Telepathology in cytopathology: challenges and opportunities. Acta Cytol. 2013;57:221–32.
9. Cornish TC, Swapp RE, Kaplan KJ. Whole-slide imaging: routine pathologic diagnosis. Adv Anat Pathol. 2012;19:152–9.
10. Cucoranu IC, Parwani AV, Vepa S, Weinstein RS, Pantanowitz L. Digital pathology: a systematic evaluation of the patent landscape. J Pathol Inform. 2014;5:16.
11. Dee FR. Virtual microscopy in pathology education. Hum Pathol. 2009;40:1112–21.
12. Della Mea V. 25 years of telepathology research: a bibliometric analysis. Diagn Pathol. 2011;6(S1):26.
13. Della Mea V, Cataldi P, Pertoldi B, et al. Combining dynamic- and static-robotic techniques for real-time telepathology. In: Kumar S, Dunn BE, Editors. Telepathology, vol. 8. Berlin: Springer; 2009. p. 79–89.
14. DPA (Digital Pathology Association). Validation of digital pathology in a healthcare environment. White paper. Lowe A, Chlipala E, Elin J, Kawano Y, Long RE, Tillman D. 2011. https://digitalpathologyassociation.org/_data/files/DPA-Healthcare-White-Paper–FINAL_v1.0.pdf. Accessed 20 Feb 2014.
15. Dunn BE, Choi H, Almagro UA, Recla DL, Krupinski EA, Weinstein RS. Routine surgical pathology in the Department of Veterans Affairs: experience-related improvements in pathologist performance in 2200 cases. Telemedicine J. 1999;5:323–37.
16. Dunn BE, Choi H, Recla DL, Kerr SE, Wagenman BL. Robotic surgical telepathology between the Iron Mountain and Milwaukee Department of Veterans Affairs Medical Centers: a 12-year experience. Hum Pathol. 2009;40:1092–9.
17. Evans AJ, Chetty R, Clarke BA, Croul S, Ghazarian DM, Kiehl TR, Perez Ordonez B, Ilaalagan S, Asa SL. Primary frozen section diagnosis by robotic microscopy and virtual slide telepathology: the University Health Network experience. Hum Pathol. 2009;40:1070–81.
18. Evans AJ, Kiehl TR, Croul S. Frequently asked questions concerning the use of whole-slide imaging telepathology for neuropathology frozen sections. Semin Diagn Pathol. 2010;27:160–6.
19. Evans AJ, Perez-Ordonez B, Asa SL. Primary diagnosis by whole slide imaging (WSI) telepathology: University Health Network (UHN) goes live. Mod Pathol. 2014;27(S2):399A.

20. Fisher SI, Nandedkar MA, Williams BH, Abbondanzo SL. Telehematopathology in a clinical consultative practice. Hum Pathol 2001;32:1327–33.
21. Frierson HF Jr, Galgano MT. Frozen-section diagnosis by wireless telepathology and ultra-portable computer: use in pathology resident/faculty consultation. Hum Pathol. 2007;38:1330–1334.
22. Ghaznavi F, Evans A, Madabhushi A, Feldman M. Digital imaging in pathology: whole-slide imaging and beyond. Annu Rev Pathol. 2013;8:331–59.
23. Gould PV, Saikali S. A comparison of digitized frozen section and smear preparations for intraoperative neurotelepathology. Anal Cell Pathol (Amst). 2012;35:85–91.
24. Graham AR, Bhattacharyya AK, Scott KM, Lian F, Grasso LL, Richter LC, Henderson JT, Carpenter JB, Lopez AM, Barker GP, Weinstein RS. Virtual slide telepathology for an academic teaching hospital surgical pathology quality assurance program. Hum Pathol. 2009;40:1129–36.
25. Halliday BE, Bhattacharyya AK, Graham AR, Davis JR, Leavitt SA, Nagle RB, McLaughlin WJ, Rivas RA, Martinez R, Krupinski EA, Weinstein RS. Diagnostic accuracy of an international static-imaging telepathology consultation service. Hum Pathol. 1997;28:17–21.
26. Hartman DJ, Parwani AV, Cable B, Cucoranu IC, McHugh JS, Kolwitz BJ, Yousem SA, Palat V, Reden AV, Sloka S, Lauro GR, Ahmed I, Pantanowitz L. Pocket pathologist: a mobile application for rapid diagnostic surgical pathology consultation. J Pathol Inform. 2014;28:5.
27. High MA. Teledermatology, teledermatopathology, interstate dermatopathology and the law. Semin Cutan Med Surg. 2013;32:224–9.
28. Horbinski C, Hamilton RL. Application of telepathology for neuropathologic intraoperative consultations. Brain Pathol. 2009;19:317–22.
29. Horbinski C, Wiley CA. Comparison of telepathology systems in neuropathological intraoperative consultations. Neuropathology. 2009;29:655–63.
30. Horbinski C, Fine JL, Medina-Flores R, Yukako Y, Wiley CA. Telepathology for intraoperative neuropathologic consultations at an academic medical center: a 5-year report. J Neuropathol Exp Neurol. 2007;66:750–9.
31. Hutarew G, Schlicker HU, Idriceanu C, Strasser F, Dietze O. Four years' experience with teleneuropathology. J Telemed Telecare. 2006;12:387–91.
32. Jen KY, Olson JL, Brodsky S, Zhou XJ, Nadasdy T, Laszik ZG. Reliability of whole slide images as a diagnostic modality for renal allograft biopsies. Hum Pathol. 2013;44:888–94.
33. Kaplan KJ, Weinstein RS, Pantanowitz L. Telepathology. In: Pantanowitz L, Balis U, Tuthill M, Editors. Pathology informatics: modern practice & theory for clinical laboratory computing. Chicago: American Society for Clinical Pathology Press; 2012. p. 257–72.
34. Kayser K, Szymas J, Weinstein RS. Telepathology: telecommunications, electronic education and publication in pathology. New York: Springer; 1999. p. 1–186.
35. Kayser K, Szymas J, Weinstein RS. Telepathology and telemedicine: communication, electronic education and publication in e-health. Berlin: VSV Interdisciplinary Medical Publishing; 2005. p. 1–257.
36. Kayser K, Molnar B, Weinstein RS. Digital pathology virtual slide technology in tissue-based diagnosis, research and education. Berlin: VSV Interdisciplinary Medical Publishing; 2006. pp .1–193.
37. Kayser K, Borkenfeld S, Djenouni A, Kayser G. History and structures of telecommunication in pathology, focusing on open access platforms. Diagn Pathol. 2011;6:110–7.
38. Krupinski E, Weinstein RS, Bloom KJ, Rozek LS. Progress in telepathology: system implementation and testing. Adv Pathol Lab Med. 1993;6:63–87.
39. Li X, Gong E, McNutt MA, Liu J, Li F, Li T, Anderson VM, Gu J. Assessment of diagnostic accuracy and feasibility of dynamic telepathology in China. Hum Pathol. 2008;39:236–42.
40. Lopez AM, Graham AR, Barker GP, Richter LC, Krupinski EA, Lian F, Grasso LL, Miller A, Kreykes LN, Henderson JT, Bhattacharyya AK, Weinstein RS. Virtual slide telepathology enables an innovative telehealth rapid breast care clinic. Hum Pathol. 2009;40:1082–91.
41. Louis DN, Young RH. The Castleman era (1952–1974). In: Louis DN, Young RH, Editors. Keen minds to explore the dark continents of disease: a history of the pathology services

at the Massachusetts General Hospital. Boston: Massachusetts General Hospital Publisher; 2011. p. 81–115.

42. Lowe J. Telepathology: guideline from the Royal College of Pathologists. 2013. http://www.rcpath.org/Resources/RCPath/Migrated%20Resources/Documents/G/G026_Telepathology_Oct13.pdf. Accessed 20 Feb 2014.
43. McLaughlin WJ, Schifman RB, Ryan KJ, Manriquez GM, Bhattacharyya AK, Dunn BE, Weinstein RS. Telemicrobiology: feasibility study. Telemed J. 1998;4:11–7.
44. Nakayama I, Matsumura T, Kamataki A, Uzuki M, Saito K, Hobbs J, Akasaka T, Sawai T. Development of a teledermatopathology consultation system using virtual slides. Diagn Pathol. 2012;7:177.
45. Nordrum I, Engum B, Rinde E, Finseth A, Ericsson H, Kearney M, Stalsberg H, Eide TJ. Remote frozen section service. A telepathology service in northern Norway. Hum Pathol. 1991;22:514–8.
46. Novis DA, Zarbo J. Interinstitutional comparison of frozen section turnaround times. A College of American Pathologists Q-probe study of 32868 frozen sections in 700 hospitals. Arch Pathol Lab Med. 1997;121:559–67.
47. Pantanowitz L, Parwani AV, Khalbuss WE. Digital imaging for cytopathology: are we there yet? Cytopathology. 2011a;22:73–4.
48. Pantanowitz L, Valenstein PN, Evans AJ, Kaplan KJ, Pfeifer JD, Wilbur DC, Collins LC, Colgan TJ. Review of the current state of whole slide imaging in pathology. J Pathol Inform. 2011b;2:36.
49. Pantanowitz L, Wiley CA, Demetris A, Lesniak A, Ahmed I, Cable W, Contis L, Parwani AV. Experience with multimodality telepathology at the University of Pittsburgh Medical Center. J Pathol Inform. 2012;3:45–53.
50. Pantanowitz L, Sinard JH, Henricks WH, Fatheree LA, Carter AB, Contis L, Beckwith BA, Evans AJ, Lal A, Parwani AV. College of American Pathologists Pathology and Laboratory Quality Center. Validating whole slide imaging for diagnostic purposes in pathology: guideline from the College of American Pathologists Pathology and Laboratory Quality Center. Arch Pathol Lab Med. 2013;137:1710–22.
51. Pantanowitz L, et al. Telepathology Clinical Guidelines Work Group of the American Telemedicine Association, May, 2014. Forthcoming 2014.
52. Park S, Parwani A, Satyanarayanan M, Pantanowitz L. Handheld computing in pathology. J Pathol Inform. 2012;3:15
53. Reyes C, Ikpatt OF, Nadji M, Cote RJ. Intra-observer reproducibility of whole slide imaging for the primary diagnosis of breast needle biopsies. J Pathol Inform. 2014;5:5.
54. Romero G, Cable W, Lesniak A, Tseytlin E, McHugh J, Parwani A, Pantanowitz L. Digital pathology consultations—a new era in digital imaging, challenges and practical applications. J Digit Imaging. 2013;26:668–77.
55. Sharma A, Bautista P, Yagi Y. Balancing image quality and compression factor for special stains whole slide images. Anal Cell Pathol. 2012;35:101–6.
56. Shimosato Y, Yagi Y, Yamagishi K, et al. Experience and present status of telepathology in the National Cancer Center Hospital, Tokyo. Zentralbl Pathol. 1992;138:413–7.
57. Sinard JH. Practical pathology informatics. New York: Springer; 2006. pp 265–86.
58. Speiser JJ, Hughes I, Mehta V, Wojcik EM, Hutchens KA. Mobile teledermatopathology: using a tablet PC as a novel and cost-efficient method to remotely diagnose dermatopathology cases. Am J Dermatopathol. 2014;36:54–7.
59. Szymas J, Wolf G, Papierz W, Jarosz B, Weinstein RS. Online internet-based robotic telepathology in the diagnosis of neuro-oncology cases: a teleneuropathology feasibility study. Hum Pathol. 2001;32(12):1304–8.
60. Thrall M, Pantanowitz L, Khalbuss WE. Telecytology: clinical applications, current challenges and future benefits. J Pathol Inform. 2011;2:51.
61. Walter GF. Teleneuropathology: a means to improve the correctness of neuropathological diagnoses in clinical practice. Crit Rev Neurosurg. 1999;9:1–11.

62. Walter GF, Walter KFJP. Legal pitfalls in teleneuropathology. Methods Inf Med. 2003; 42:255–9.
63. Wechsler LR, Tsao JW, Levine SF, Swain-Eng RJ, Adams RJ, Demaerschalk BM, Hess DC, Moro E, Schwamm LH, Stern BJ, Zuckerman SJ, Bhattacharya P, Davis LE, Yurkiewicz IR, Alphonso AL. Teleneurology applications. Report of the Telemedicine Work Group of the American Academy of Neurology. Neurology. 2013;80:670–6.
64. Weinstein RS. Prospects for telepathology. Hum Pathol. 1986;17:433–4.
65. Weinstein RS. Static image telepathology in perspective. Hum Pathol. 1996;27:99–101.
66. Weinstein RS, Bloom KJ, Rozek LS. Telepathology: system design and specifications. SPIE Proceedings Visual Comm Image Processing. 1987a;845:404–7.
67. Weinstein RS, Bloom KJ, Rozek LS. Telepathology and the networking of pathology diagnostic services. Arch Path Lab Med. 1987b;111:646–52.
68. Weinstein RS, Bhattacharyya AK, Graham AR, Davis JR. Telepathology: a ten-year progress report. Hum Pathol. 1997;28:1–7.
69. Weinstein RS, Descour MR, Liang C, Bhattacharyya AK, Graham AR, Davis JR, Scott KM, Richter L, Krupinski EA, Szymus J, Kayser K, Dunn BE. Telepathology overview. From concept to implementation. Hum Pathol. 2001;32:1283–99.
70. Weinstein RS, Descour MR, Liang C, Barker G, Scott KM, Richter L, Krupinski EA, Bhattacharyya AK, Davis JR, Graham AR, Rennels M, Russum WC, Goodall JF, Zhou P, Olszak AG, Williams BH, Wyant JC, Bartels PH. An array microscope for ultrarapid virtual slide processing and telepathology. Design, fabrication, and validation study. Hum Pathol. 2004;35:1303–14.
71. Weinstein RS, Descour MR, Liang C, Richter L, Russum WC, Goodall JF, Zhou P, Olszak AG, Bartels PH, Reinvention of light microscopy. Array microscopy and ultrarapidly scanned virtual slides for diagnostic pathology and medical education. In: Virtual Microscopy and Virtual Slides in Teaching, Diagnosis and Research, CRC Press, 2005; p. 9–35.
72. Weinstein RS, Graham AR, Richter LC, Barker GP, Krupinski EA, Lopez AM, Erps KA, Bhattacharyya AK, Yagi Y, Gilbertson JR. Overview of telepathology, virtual microscopy, and whole slide imaging: prospects for the future. Hum Pathol. 2009;40:1057–69.
73. Weinstein RS, Graham AR, Barker GR. Second opinion telepathology services for cancer patients. In: Ternullo J, Editor.Thought leaders in medical informatics. Minneapolis-St. Paul: Bierbaum Publishing; 2012a. p. 16–28.
74. Weinstein RS, Graham AR, Lian F, Braunhut BL, Barker GR, Krupinski EA, Bhattacharyya AK. Reconciliation of diverse telepathology system designs. Historic issues and implications for emerging markets and new applications. APMIS. 2012b;120:256–75.
75. Wilbur DC. Digital cytology: current state of the art and prospects for the future. Acta Cytol. 2011;55:227–38.
76. Wilbur DC, Madi K, Colvin RB, Duncan LM, Faquin WC, Ferry JA, Frosch MP, Houser SL, Kradin RL, Lauwers GY, Louis DN, Mark EJ, Mino-Kenudson M, Misdraji J, Nielsen GP, Pitman MB, Rosenberg AE, Smith RN, Sohani AR, Stone JR, Tambouret RH, Wu CL, Young RH, Zembowicz A, Klietmann W. Whole-slide imaging digital pathology as a platform for teleconsultation: a pilot study using paired subspecialist correlations. Arch Pathol Lab Med. 2009;133:1949–53.
77. Wiley CA, Murdoch G, Parwani A, Cudahy T, Wilson D, Payner T, Springer K, Lewis T. Interinstitutional and interstate teleneuropathology. J Pathol Inform. 2011;2:21–8.
78. Winokur TS, McClellan S, Siegal GP, Reddy V, Listinsky CM, Conner D, Goldman J, Grimes G, Vaughn G, McDonald JM. An initial trial of a prototype telepathology system featuring static imaging with discrete control of the remote microscope. Am J Clin Pathol. 1998;110:43–9.
79. Yagi Y, Weinstein R, Gilbertson J, members of the ATA's telepathology special interest group. Clinical guidelines for telepathology. American Telemedicine Association. 1999.

Tele-Epilepsy and Tele-Electroencephalography

Matthew Hoerth

Introduction

Electroencephalography (EEG) was born out of advancements in technology. As technology has advanced, so has the ability to record cerebral electrical activity. It is only natural that with the expanded ability to transfer large amounts of data very quickly across vast distances, tele-EEG would follow. Likewise, the clinical practice of epilepsy and evaluation of seizure-like events lends itself well to the ever-advancing field of telemedicine. In general, physicians who are involved in interpreting EEGs are also those who care for patients with epileptic disorders. The epileptologist is typically one who is comfortable with the advancing technologies of the modern world and will evolve easily into the emerging roles required in the current state of telemedicine.

This chapter explores the advancement of technology that has taken place to bring medicine to this current era of EEG and how it can be applied in tele-EEG. Also, the applied roles of tele-epilepsy in the context of tele-EEG and general teleneurology are discussed.

Tele-EEG

Historical Perspectives of Electroencephalography

Alongside neuroimaging, the EEG is the most common test ordered for the evaluation of seizures and seizure-like events. This noninvasive test simply records the electrical signals that the brain produces. Although several physicians and physiologists reported the electrical phenomena occurring in animals several decades prior,

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Fig. 1 Example of one of the first two-channel EEGs recorded. *EEG* electroencephalogram

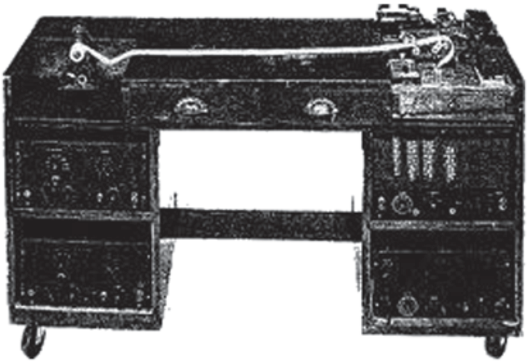

Fig. 2 Grass Model I: Two-channel recording device used clinically in 1938.

Hans Berger, a German physiologist and psychiatrist, has been credited with recording the first human EEG in 1924. These EEGs were only one or two channels and demonstrated the posterior dominant rhythm (Fig. 1). After about 10 years, the EEG began to be used in clinical situations (Fig. 2). This was made possible after the discovery of interictal epileptiform patterns by Gibbs, Davis, Lennox, and Jasper [1].

As technology advanced, so did the EEG recordings. Initially, the recordings were just a few channels. Over the years, more and more channels were added, to where 21- or 32-channel recordings became the standard. In addition, the quality of the recordings improved. With advancements of electronics, high- and low-frequency filters yielded cleaner records and, with the ability to change the filter settings and montages during recordings, abnormalities became better defined. Due to these technical advances, the field of epilepsy developed, requiring further, not only specialized physicians, but also specialized technologists to record the EEGs.

The next major leap forward came with analog-to-digital conversion. Prior to this, when a waveform was questioned on an ink and paper recording, one would have to hope this would occur again after settings were changed in order to view it in a different way. Once the recordings were computerized, the recorded data could be processed after the recording was completed, and, therefore, viewed in any way the interpreter wished. Obviously, this was a major advantage.

However, the conversion to digital technology also had several drawbacks. Initially, the issue of *aliasing* was a problem (Fig. 3). Aliasing results from a sampling rate lower than what is required to display a waveform. The frequency displayed would be a lower/slower multiple of what was truly occurring from the generator (brain). Again, with the advancement of technology, higher sampling rates became possible, and, therefore, aliasing is no longer a limiting factor on standard record-

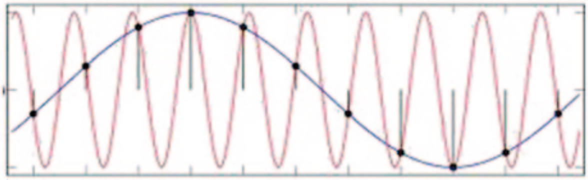

Fig. 3 Aliasing is demonstrated by the *blue line*. If the *red* waveform represents the true frequency of the brain waves, the *black dots* represent the points at which an analog-to-digital converter samples. The *blue line* is then created by the processor, but only represents a fraction of the true frequency

ings. The technological advancement that has been crucial is the improvement in monitor resolution to visualize these digital waveforms.

The increased ability to record massive amounts of data digitally also required the storage of said data. Initially, video-EEG monitoring occurred utilizing a video tape recorder pointed at the ink-and-paper recording simultaneously with a split screen showing the patient. This technology required a technician to be physically sitting by the patient and EEG recording machine to insure the recording was taking place properly. Obviously, this was typically limited to only a few hours in an outpatient setting and was quite labor intensive.

With the digital EEG, a digital video feature can be included in standard recordings. The downside to this technology is that it then requires maintenance and storage of the massive amounts of data collected. A typical patient can stay 4–7 days in a video-EEG epilepsy monitoring unit (EMU). All of the recorded data needs to be reviewed, edited, clipped, and stored. This is also quite labor intensive. In the current era, not only are trained physicians and trained EEG technologists required, but collaboration from information technology is also required to be successful.

Despite the abovementioned complications that have occurred with the advancement of technology, technology has led to improvement in patient care. The most recent technological advancement that has impacted EEG is that of compact and wireless technology. EEG recording systems are becoming smaller and more portable. Ambulatory EEG units are now available with high-definition video. Many inpatient EEG recording systems can be wirelessly connected to the Internet. This allows for recordings to take place even when the patient is taken from the hospital bed for other tests. Magnetic resonance imaging (MRI)- and computerized tomography (CT)-compatible EEG leads have also increased the ease of use in the hospital setting. “Neurotelemetry” units are being established in many referral centers because of this technology. Soon, many patients in the neuro-intensive care unit (ICU) will have their brains’ electrical activity monitored just as patients in the cardiac-ICU have their hearts monitored. Along with improved computerized data analysis tools, one can only imagine the opportunity for advancement in patient care for these types of patients in the near future [1, 2].

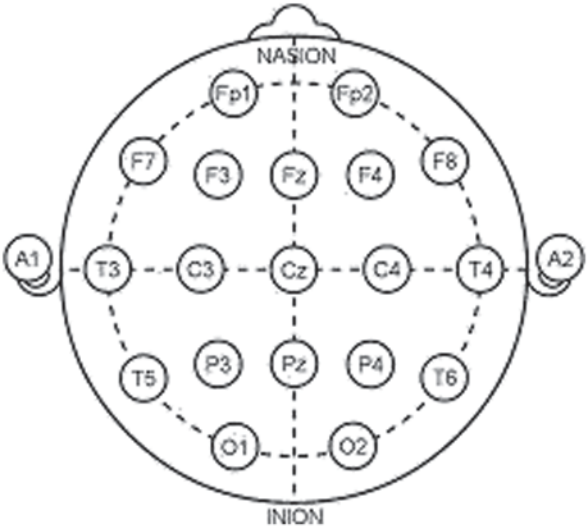

Fig. 4 International 10–20 system of electrode placement. The letters preceding the numbers represent the region of the brain. Odd-numbered electrodes are on the *left,* and even on the *right*. Numbers are smaller towards midline, with z representing zero

Fundamentals of EEG Recordings

The American Clinical Neurophysiology Society has established minimal technical requirements for recording clinical EEGs [3]. It should be stressed that what has been outlined are the minimum standards for simply an adequate study, and it is suggested that these requirements be surpassed.

Basically, the electrodes should be evenly distributed throughout the scalp and recorded simultaneously. Sixteen channels of recording are considered the minimum; however, most EEGs include 21 channels, with one additional channel of ECG recording. These electrodes should be placed according to the International Clinical Neurophysiology 10–20 system (Fig. 4). This system systematically spaces the electrodes evenly around the head at 10 or 20 % intervals [4]. Adequate electrical safety measures should be employed. Conducting the recording utilizing multiple standard montages is recommended. To insure technical quality, calibration montages should be utilized and recorded briefly to exclude equipment artifact. In addition, impedances should not exceed 5kΩ. The amplitudes of the EEG are typically amplified and recorded at 7 mcV/mm. At this setting, most cerebral-generated electrical potentials create a deflection of 5–10 mm on the monitor and can be viewed without difficulty. Filter settings should not be so restrictive as to distort the signal; therefore, low frequency filters should not be set to greater than 1 Hz and high frequency no less than 70 Hz. Paper speed should be 3 cm/s in typical situations. It should be noted that wide-screen monitors may need to be calibrated and will likely exceed the standard 10 s per page. If this calibration is done incorrectly, it may be difficult to accurately interpret the EEG as frequencies may be misinterpreted.

These minimum technical standards were established not only to insure a minimum quality of any recording but also to attempt to standardize the practice of clinical EEG. By doing this, it is hoped that health-care providers can communicate easily regarding test results, no matter where the test is recorded. Ideally, all EEGs recorded would be done by a registered EEG technologist.

EEG Types

Multiple different types of EEGs exist, which depends primarily on the length of the recording. There are advantages and disadvantages to each. The health-care provider must choose the appropriate test for the appropriate situation. Longer recordings tend to have higher technical requirements and, therefore, may be more difficult to apply in tele-EEG.

The routine EEG is the most commonly used EEG since it takes the least technical expertise and technical support to execute. It is considered standard of care for the evaluation of seizure-like events and epilepsy. This recording is required to be at least 20 min in length. Ideally, electrical activity during drowsiness and stage II sleep is recorded [3]. In addition, activation procedures, including photic stimulation and hyperventilation, are utilized to increase the diagnostic yield of the test. The major limitation to this examination is that since the recording is relatively brief, it typically only records interictal phenomena. At times, multiple recordings may be needed to detect abnormalities. Also, it should be noted that a small percentage of patients will never have an interictal abnormality, and it is only with a seizure that the EEG is noted to be abnormal [5].

The ambulatory EEG is a longer recording and is analogous to the Holter monitor for cardiologists. This is a portable unit that can be applied, and the patient may take it home with them for a specified length of time. These portable units have a button that can be pressed in order to signify if a typical event in question occurs, and the patient is asked to keep a diary of events. The manner in which this is recorded varies from center to center. Some centers have equipment that will only record prespecified portions of the day in addition to push button events, such as 20 min out of every hour. Others may have equipment that records continuously and will also allow for concordant high-definition video. The biggest limitation to the ambulatory EEG is technical quality. One or multiple electrodes may become dislodged, which can severely limit the interpretation of the data. Furthermore, the large amount of data collected needs to be processed and reviewed, which may be a time-consuming process [6].

A similar type of recording in the hospitalized setting would be what is termed the “trend EEG”. A patient in the hospital who has altered mental status, recurrent seizures, or seizure-like events may benefit. A trend recording is recorded at the bedside onto a local computer, with the data being downloaded at a later time. The requirements for the frequency of data review have not been standardized, but most centers will do this once or twice a day. The major disadvantage is that treating clinicians are not able to react immediately to changes in the EEG patterns as they are occurring, but could only react at specific intervals after which the EEG has been reviewed. The trend EEG can be done with or without concurrent video.

Perhaps the most comprehensive testing is video-EEG monitoring. This occurs in many tertiary care EMUs. However, this can be applied to a variety of settings, including comatose patients in the ICU. The patient has electrodes applied with simultaneous video recording. This video-EEG data is being fed live to someone who is watching the data. The person who is monitoring this live data differs from center to center, but is typically nursing staff, certified EEG technologists, or simply a "monitoring technician" who has been trained to observe for abnormal behavior and not usually held responsible for any EEG interpretation. Obviously, this type of monitoring requires significant amounts of equipment, technical support, trained personnel, and institutional support to be successful. A note should be made that when doing this type of monitoring, most centers have the ability to remotely view the live data.

Technical Issues

In the remote environment, as in tele-EEG, the most challenging aspect will be incorporating advancing technology into practice. The earliest report of tele-EEG was published in 1975. The article reported the telephonic transmission of EEG signals. The electrodes were applied at the remote hospital and plugged into the preamplifier. The signal was then sent telephonically, and the recording was actually conducted at the hub (referral center) site. The current practice of EEG is different, in that the recordings are stored at the remote site, and interpreting neurologist will remotely access the data. The comments noted by the authors in the first tele-EEG article from 1975 have not changed. They emphasized that the quality of the EEG interpretation is dependent on the quality of the recording [7].

In order to provide tele-EEG services, one must first establish a means by which to acquire the EEG. This requires two main components, an EEG machine and someone to apply the electrodes and run the study. An analogy can be made to radiologists in the manner which they obtain their images. There is no one universally accepted format in which the data is acquired. Currently, there are several companies who manufacture devices that have the capability of recording EEG data. Because recording clinical neurophysiologic signals is a relatively specialized field, many of the companies that make recording devices for EEG, also make devices that record sleep studies, EMGs, evoked potentials, or intraoperative neurophysiologic monitoring. Depending on the need, one piece of equipment could be purchased to fulfill multiple roles. There is a range in the cost of these devices, where increased quality/features come with increased price.

In terms of equipment ownership, the most common and easiest solution would be that the local institution purchases and owns the machine. Currently, the way in which fees are reimbursed for EEG can be split into two components: the technical fee for recording the EEG, and the professional fee for interpreting the EEG. This works well for the telemedicine environment, where the reimbursement is naturally split. The local institution would then also need to hire and employ the technician running the studies.

Perhaps more of a challenge than the equipment would be finding someone to set up and run the EEG. There are relatively few registered EEG technologists trained each year. To become registered, an EEG technologist would undertake a 1–2-year training program as well as pass a standardized examination. This examination is administered by the American Board of Registration of Electroencephalographic and Evoked Potential Technologists (ABRET) [8]. The goal of the examination of this nonprofit organization is to insure that EEGs are being acquired with at least the minimum technical standards (as outlined above). Although having a registered EEG technologist recording every EEG is ideal, this may not be practical as they are relatively rare. Many smaller institutions may need to be resourceful, pulling other individuals, such as respiratory therapists or electrocardiogram (EKG) technicians, to run these studies. Of course, limitations regarding the technical quality of the recording may occur. It is the responsibility of the interpreting physician, where appropriate, to deem specific studies uninterpretable when quality is poor.

Once the study is recorded, the data needs to be appropriately made available to the interpreting neurologist. Likely, the most efficient way in which this occurs is to provide remote access to the spoke (local) institution. This remote access must be done securely as to not violate any patient privacy laws. Many institutions already have methods in which their in-house physicians can appropriately remotely access the medical record and other resources. The IT department of the spoke hospital can potentially "piggyback" onto an already-existing system to allow access to an EEG reading station. With current technology, it is possible that the connection speed can be as fast as if the interpreting physician was sitting in the spoke hospital, fast enough to even allow for live video streaming, if desired. Again, it is vital that proper information security measures be undertaken.

After the study is accessed and interpreted by the neurologist at the hub institution, the physician must provide results in a timely manner to the spoke institution. The details on the time frame in which results are provided, as well as the manner in which it is provided, would need to be agreed upon between the hub and spoke institutions. For instance, it would be reasonable for the results of a routine EEG be available in the local institution's medical record within 24–48 h from the time the study was made available to the hub neurologist. Although agreements can be made, obviously the needs of the patient come first. There may be times in which clinical decisions need to be made quickly, and direct contact with the ordering physician needs to occur.

From a medical record perspective, the report needs to be kept at the institution in which the study was completed. Agreements also need to be made in order to determine how this occurs. For instance, is access to the dictation system provided to the hub neurologist by the local hospital or does the hub institution create a patient account for the teleservices provided and have the record sent to the spoke institution? Any number or reasonable arrangements can be made.

The storage of the acquired information can also provide challenges. It is recommended that this occur locally, and would typically be the responsibility of the spoke institution. EEG data can take a significant amount of space, and, when it is linked to video, the space requirements increase greatly. Requirements exist for medical records that dictate how far back information must be kept and may vary by region. Pruning and clipping of EEG data may be appropriate. Most EEG systems have appropriate capabilities to search a large database of acquired EEGs, but limitations on local storage may become a problem. Local IT departments may need to work with the department that acquires the EEGs to determine what is appropriate, reasonable, and capable for the institution in regard to archiving the data.

The details in this section above have emphasized the limitations and issues that may be encountered when establishing a tele-EEG practice. Likely, many of these challenges have already been encountered at the hub institution. A collaborative and cooperative environment between the hub and spoke institutions is necessary for success.

Tele-Epilepsy

Of the various subspecialty evaluations in neurology, the clinical practice of the diagnosis and treatment of patients with epileptic seizures lends itself well to telemedicine. Since epilepsy is a paroxysmal disorder, a large majority of patients function relatively normally on a daily basis. It is only when their seizures occur that they have a disability. The diagnosis is primarily based on a detailed clinical history, with supporting neuroimaging and EEG data.

Relatively, few patients with chronic epilepsy have abnormal neurologic examinations. The typical findings on exam are related to medication side effects. The top complaints include cognitive disturbance and gait imbalance. Mental status examination and gait examination can be easily accessed through an audio–video connection.

Acute Care

Currently, the majority of the telemedicine care of the seizure patient that is being conducted is in the acute care setting via the tele-neurohospitalist. Especially when paired with a tele-EEG program, high-quality specialty care can be provided to patients in virtually any location. In the hospital setting, there is a wide variety of acuity that can present to the neurologist for evaluation. There are some patients who may have had an acute seizure-like event and are admitted to establish a diagnosis for their spell and to rule out any potentially life-threatening cause. Others may present in status epilepticus and require intensive care services and pharmacologic coma. In some cases, it may be appropriate for the spoke hospital to continue to care for the patient in status. In others, transfer is necessary. The standard protocol for status epilepticus includes doses of benzodiazepines typically followed by fosphenytoin. When a patient fails to respond to two medications, he or she is considered to be in refractory status epilepticus. Refractory status epilepticus requires continuous EEG services. Certainly, transfer can be considered in cases that are not refractory; however, most spoke hospitals would not have continuous EEG, and transfer would be required.

Ambulatory Care

The ideal use of telemedicine for ambulatory epilepsy care would be to have the initial evaluation of the patient be conducted at the hub site with diagnostic testing and follow-up visits conducted at the spoke site. An initial detailed history and examination to evaluate for any focal neurologic deficits is absolutely necessary. Current guidelines suggest that a patient who has been diagnosed with epilepsy and is on an antiseizure medication should be seen by a neurologist at least once per year for clinical monitoring of their condition. If a patient also has a local general neurologist (or reliable internist), any number of possibilities could exist in terms of follow-up appointments. An annual tele-visit with an epilepsy subspecialist can be conducted with interim visits conducted locally. As conducted with other models of ambulatory telemedicine care, a rotating schedule of appointments could be established at the hub hospitals at predefined days of the week/month/quarter depending on the need. Newer methods of telemedicine applications, such as in-home visits, can also be considered.

Epilepsy Monitoring Unit

It is not recommended that EMUs be established at remote sites in a hub-and-spoke model, being exclusively staffed with telemedicine epilepsy specialists. The indications for admission to an EMU are spell classification, medication management of an epilepsy patient, or presurgical evaluation for epilepsy surgery. The complexity of the coordination of care for these patients necessitates an on-site epileptologist. The National Association of Epilepsy Centers has outlined requirements for EMU certification [9]. However, it should be noted that remote access to patient data is highly utilized in most EMUs. As noted above, with current technology, fluid streaming of video-EEG data can be established through remote access. This has allowed the epileptologist staffing an EMU, rapid and efficient access to the patient's clinical condition.

Conclusion

Epilepsy and EEG are subspecialties in neurology that will nicely follow the ever-evolving practice of telemedicine. As noted historically, EEG has evolved and improved in concert with technology. It has and will continue to adapt to the advances in telemedicine. Epilepsy specialists are already comfortable with the remote access technology that is being utilized at their home institution. In the near future, it is likely that the practice of tele-epilepsy will be common for those patients in underserved remote areas, as with other specialties.

References

1. Schomer D, Lopes da Silva F. Niedermeyer's electroencephalography: basic principles, clinical applications, and related fields. Philadelphia: Lippincott Williams & Wilkins; 2011.
2. Daube J, Rubin D. Contemporary neurology series: clinical neurophysiology. 3rd ed. New York: Oxford University Press, 2009.
3. American Clinical Neurophysiology Society. "Minimum Technical Requirements for Performing Clinical EEG". American Clinical Neurophysiology Society Guidelines. 2008. http://www.acns.org/pdf/guidelines/Guideline-1.pdf. Accessed 5 Jan 2014.
4. American Clinical Neurophysiology Society. "Minimum Technical Requirements for Performing Clinical EEG". American Clinical Neurophysiology Society Guidelines. 2008. http://www.acns.org/pdf/guidelines/Guideline-5.pdf. Accessed 5 Jan 2014.
5. Salinsky M, Kanter R, Dasheiff RM. Effectiveness of multiple EEGs in supporting the diagnosis of epilepsy: an operational curve. Epilepsia. 1987;28(4):331-4.
6. Chang BS, Schachter SC, Schomer DL. Atlas of ambulatory EEG. Amsterdam: Elsevier Academic Press; 2005.
7. Schear HE, Rowe WJ, Pori J. Telephonic transmission of electroencephalograms. Clin Electroencephalogr. 1974;5:24–30.
8. Why Earn Credentials?. American Board of Registration of Electroencephalographic and Evoked Potential Technologists. 2014. http://abret.org/candidates/credentials/why-should-i-become-credentialed/. Accessed 5 Jan 2014.
9. Guidelines for Epilepsy Centers. National Association of Epilepsy Centers. 2007. http://www.naec-epilepsy.org/spec_care/guidelines.htm. Accessed 5 Jan 2014.

The Emerging Relevance of Telemedicine in Sleep Medicine

Joyce K Lee-Iannotti and James M Parish

Sleep is an essential part of maintaining physical and mental well-being. Sleep disorders are among the most common clinical problems in medicine. It is estimated that approximately 70 million Americans suffer from chronic sleep problems, with insomnia being the most common disorder, followed by sleep apnea, and then restless legs syndrome [1]. Insufficient or non-restorative sleep can significantly impair a person's quality of life [2] and has been linked to injuries, chronic debilitating diseases (e.g., strokes, cardiac disease, atrial fibrillation, pulmonary hypertension, cancer), mental illness, increased health-care costs, and loss of work productivity [3]. Almost 20 % of all serious car crash injuries in the USA are associated with driver sleepiness.

Despite the prevalence and known health consequences of sleep dysfunction, sleep disorders are severely underdiagnosed and undertreated by non-sleep physicians. This is likely due to the lack of public awareness and large gaps in public access to sleep-trained specialists, particularly in rural, underserved regions [4]. Advances in information technology and telecommunication can improve health services. Telemedicine is an emerging, effective tool that has the potential to overcome obstacles in the diagnosis and treatment of sleep disorders by offering increased access to sleep specialists, enhancing in-home health-care support, and providing cost-effective professional education and ongoing assessments.

Early research examining the role of telemedicine in insomnia is reassuring. Insomnia is the most common sleep disorder, affecting 10 % of the general population, increasing in prevalence with advancing age [5]. Lichstein et al. [6] showed that cognitive behavior therapy (CBT) administered through telehealth communications for co-occurring insomnia and depression symptoms was effective in older adults. Their study involved five patients with concomitant diagnoses of insomnia

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and depression, who received ten sessions of CBT via Skype from their primary care physician's office in rural Alabama. Patients exhibited clinically meaningful improvement in both insomnia and depression (questionnaire, sleep diary, and Insomnia Severity Scale measures) at posttreatment, and these gains were maintained at 2-month follow-up. The authors concluded that telehealth may be an effective tool to treat both insomnia and comorbid depression in adults, particularly in underserved populations. This study also suggested that using tele-technology may be well tolerated, even in technologically naïve patients. Future studies are needed in this area, however.

The majority of research on the role of telemedicine in sleep has focused on the diagnosis and the treatment of sleep apnea. Obstructive sleep apnea (OSA) is a growing health concern in the USA, and it is estimated that at least one in five US adults suffer from sleep apnea. Recent large clinical studies have shown profound health consequences associated with OSA, most notably cerebrovascular and cardiovascular complications [3]. In 2009, Spaulding et al. [7]conducted a pilot telehealth service to a sleep laboratory in Garden City, Kansas, located 600 km from the Kansas University Medical Center. Videoconferencing was used for sleep evaluation, polysomnography (PSG) study follow-up, and patient monitoring. Six telemedicine clinics were held over a 6-month period, consisting of 18 new patient evaluations and four follow-up visits. The majority of cases were for OSA syndrome. They found that telemedicine was effective for physician–patient interaction, even allowing for acceptably accurate evaluation of the upper airway architecture. In addition to this study, previous studies have shown that telemedicine interactions are very similar to traditional face-to-face services in terms of communication, clinical outcomes and participant satisfaction [8–10].

Increasing public awareness among patients and physicians regarding OSA has led to a growing demand for diagnostic sleep studies. In-laboratory PSG remains the gold standard for diagnosing OSA. However, due to limited availability and costs associated with facility-based PSG (US$ 2200–3000/night), home sleep testing (HST) is now being offered more widely as a screening tool for OSA. Despite the greater accessibility with HST and reduced cost (estimated less than US$ 1000 per study), the results are often less reliable due to questionable technology and lack of sleep technician monitoring. A recent meta-analysis [11] comparing home sleep studies with laboratory PSGs in diagnosing OSA found that the respiratory disturbances indices (RDI) on portable studies were 10% lower on average compared to facility-based PSG, but there were no significant differences in oxygenation means or nadir. Portable studies were 13% more likely to give poor recordings than in-laboratory PSG examinations ($P=0.0001$.) However, portable studies revealed most conditions, with cost-effectiveness seen through 35–88% lower costs than in-laboratory studies. The authors concluded that while HSTs provide similar diagnostic information to facility-based PSGs, they may underestimate the overall sleep apnea severity. Further, while home studies appeared to be more cost-effective, the costs may be offset by the higher rate of inadequate examinations. Remote tele-monitoring of home studies by certified sleep technicians may offer a solution to the current inadequacies of ambulatory studies. Real-time attended home PSG through telematic data transmission was shown to decrease failure rates of home sleep studies in a recent paper published by Bruynell et al. [12]. The group implemented telematics transmission using the Dream (portable PSG device) and Sleepbox (dual port wireless system, enabling short-range communication with the Dream system and audiovisual communication with the Skype computer program) technologies. Twenty-one patients were studied. A sleep laboratory nurse performed remote monitoring. In the case of sensor loss, the nurse would contact the patient and educate them on proper replacement of the lead. Two successful Skype interventions resulted in readjustment of the defective probes (nasal cannula and electroencephalography, EEG). Ninety percent of the studies were considered to be of excellent quality. The use of telemedicine reduced the failure rate from 24 to 10% [13]. An additional benefit of tele-support in sleep medicine is the potential ability to perform in-hospital monitoring in areas where sleep studies would otherwise be impossible (e.g., stroke unit, intensive care unit). Early studies from Farney et al. [14] reported successful nocturnal PSG in a non-sleep, inpatient hospital setting using standard sleep equipment, in conjunction with a Health Insurance Portability and Accountability Act (HIPPA)-compliant virtual private network with monitoring from sleep-certified technicians. Future considerations can include sleep studies performed in nursing homes, stroke rehabilitation units, and hospitals in underserved parts of the world.

Dellca et al. [15] went further to show that a simple, telemetric system could allow for effective, remote continuous positive airway pressure (CPAP) titration in patients already diagnosed with. The study involved one-night home CPAP titration performed on 20 patients. A telemetric unit, based on the conventional general packet radio service (GPRS) mobile phone network and connected to a commercial CPAP device, was adjusted remotely by a sleep technician for changing requirements in pressure and mask leaks, based on ongoing assessment of respiratory events. After 1 week, a full in-laboratory PSG was performed with the chosen CPAP pressure setting on the home titration study to evaluate for efficacy. Results showed that the home-titrated CPAP study was comparable to an attended, in-laboratory study.

Lastly, several prior studies have investigated the role of telemedicine in ongoing monitoring of sleep apnea patients on CPAP and the impact on CPAP compliance. The rate of CPAP discontinuation in the first 3 years is estimated to be between 12 and 25% [16]. Fox et al. [17] found that CPAP therapy improved with the use a web-based telemedicine system after the initiation of treatment. In that study, 39 patients with moderate-to-severe OSA were randomized to either standard care with an auto-titrating positive airway pressure (APAP) machine or an APAP machine that transmitted physiologic information (i.e., adherence, air leak, residual apnea hypopnea index) daily to a website that was viewed by a sleep specialist. Patients in the standard arm were seen in person-to-person follow-up at 2 days, 4–6 weeks, 8 weeks, and 3 months post-PAP initiation. In the telemedicine arm, patients had daily data downloaded remotely, which was reviewed by a coordinator. The patient was contacted if the data demonstrated problems with the APAP unit or due to lack of adherence. In-person visits then occurred at 4–6 weeks and at 3 months. After 3 months, the mean CPAP adherence was significantly greater in the telemedicine arm compared to the standard arm. Interestingly, only 67 additional minutes of technical time was required for the telemedicine arm versus the standard arm. More studies are required to determine the causes of improved compliance (e.g., increased motivation, less equipment issues, more patient accountability) and to determine the feasibility of continuing monitoring on a long-term basis (>3 months). A larger, randomized controlled trial of 250 patients with sleep apnea by Sparrow et al. [18] showed that using an automated telephone-linked communication (TLC) system on a weekly basis for the first month, then monthly for 11 months to monitor and communicate compliance data and counseling was effective in improving adherence. At 12 months, CPAP use was significantly greater in the intervention arm. Studies with similar design also showed that patients were equally satisfied with their provider and care whether they were seen in person or via video [19].

Telemedicine has been defined as “the use of information and communication technology to deliver health services, expertise and information over distance, geographic, time, social and cultural barriers” [20]. Telemedicine has strong and convincing potential to overcome many obstacles in the effective diagnosis and treatment of various sleep disorders. Using telemedicine, more patients can gain access to sleep specialists and receive enhanced care locally or even within their own homes. Tele-sleep can also be more cost-effective than the traditional means of sleep evaluation and allow performance of sleep studies in nontraditional settings (e.g., intensive care unit, nursing home, stroke rehabilitation units, etc.). Although more research is needed, the use of telemedicine in the field of sleep medicine has shown promising results to date.

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References

1. Partinen M, Hublin C. Epidemiology of sleep disorders. Philadelphia, Elsevier, Saunders, 2005.
2. Zammit GK, Weiner J, Damato N, et al. Quality of life in people with insomnia. Sleep. 1999;22(Suppl 2):S379-85. [Medline].
3. National center for chronic disease prevention and health promotion, division of population health. program updates 2002–2003. www.cdc/gov/cfs/porgrams.
4. Seibert PS, Whitmore TA, Parker PD, et al. The emerging role of telemedicine in diagnosing and treating sleep disorders. J Telemed Telecare. 2006;12:379–81.
5. Ohayon, M. Epidemiology of insomnia: what we know and what we still need to learn. Sleep Med Rev. 2005;6:97–111.
6. Lichstein KL, Scogin F, Thomas SJ, et al. Telehealth cognitive behavior therapy for co-occurring insomnia and depression symptoms in older adults. J Clin Psychol. 2013;69:1056–65.
7. Spaulding R, Stevens D, Valasquez SE. Experience with telehealth for sleep monitoring and sleep laboratory management. J Telemed Telecare. 2011;17:346–49.
8. Nelson EL, Miller EA, Larson KA. Reliability associated with the Roter Interaction Analysis System (RIAS) adapted for the telemedicine context. Patient Edu Couns. 2010;78:72–8.
9. Hersh WR, Hickam DH, Severance SM, et al. Diagnosis, access and outcomes: update of the systematic review of telemedicine services. J Telemed Telecare. 2006;12(Suppl 2):S3-S31.

10. Agha Z, Schapira RM, Laud PW, et al. Patient satisfaction with physician-patient communication during telemedicine. Telemed J E Health. 2009;15:830–839.
11. Ghegan MD, Angelos PC, Stonebraker AC, et al. Labodies: a ratory versus portable sleep studies: a meta-analysis. Laryngoscope. 2006;116:859–64.
12. Bruyneel M, Van der Broecke S, Libert W et al. Real-time attended home-polysomnography with telematic data transmission. Int J med Inform. 2013;82:696–701.
13. Farney RJ, Walker JM, Cloward TV, et al. Polysomnography in hospitalized patients using a wireless wide area network. J Clin Sleep Med. 2006;2:28–34.
14. Masa JF, Corral J, Periera R, et al. Effectiveness of home respiratory polygraphy for the diagnosis of sleep apnea and hypopnea syndrome. Thorax. 2011;66:567–73.
15. Dellaca R, Montserrat JM, Govoni L, et al. Telemetric CPAP titration at home in patients with sleep apnea-hypopnea syndrome. Sleep Med. 2011;12:153–7.
16. Engleman HM, Wild MR. Improving CPAP use by patients with sleep apnea/hypopnea syndrome. Sleep Med Rev. 2003;7:81–99.
17. Fox N, Hirsch-Allen AJ, Goodfellow E, et al. The impact of a telemedicine monitoring system on positive airway pressure adherence in patients with obstructive sleep apnea: a randomized control trial. Sleep. 2012;35(4):477–81.
18. Sparrow D, Aloia M, Demolles DA, et al. A telemedicine intervention to improve adherence to continuous positive airway pressure: a randomized control trial. Thorax. 2010;65:1061–6.
19. Parikh R, Touvelle M, Wang H, et al. Sleep telemedicine: patient satisfaction and treatment adherence. TelemedJ E-Health. 2011;17(8):609–14.
20. Reid J. A telemedicine primer: understanding the issues. Billings, MT., Innovative Medical Communications; 1996.

Teledementia

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Introduction

Behavioural neurology is the branch of neurology dealing with the mental, cognitive, emotional and social aspects associated with neurological disorders. This may include cognitive and behavioural disturbances caused by a global dysfunction, e.g. delirium and dementia; neurobehavioral symptoms caused by focal lesions, e.g. aphasia and amnesia or neuropsychiatric manifestations of neurological disorders, e.g. depression, mania and psychosis.

Specifically, dementia is a clinical syndrome where there is significant decline in memory and cognition impeding on the ability to perform activities that allow perpetuation of independent living in the community [1]. This may include changes in the areas of short- and long-term memory, language and speech ability, visuospatial ability, mood and personality [1]. Alzheimer's disease (AD) is the most common form of dementia and may be preceded by mild cognitive impairment, where there is cognitive decline which is greater than expected for age and education, but has not yet interfered with activities that sustain independent living in the community [1, 2]. In later stages of AD, there is an acquired decline in behaviour and development of neuropsychological symptoms of dementia (BPSD). The occurrence of BPSD often threatens the social and emotional fabric of the household. Dementia is common amongst the older population, with a prevalence of approximately 24 million people globally [3]. Incidence increases with age with rates of 84.9 per 1000 person-years above 85 years of age [4].

Diagnoses and management of dementia can be a challenge for primary care providers and specialist input may be necessary but difficult to access, particularly in rural settings. Moreover, behavioural disturbances in dementia add to the logistic difficulties in transferring these patients to larger centres for assessment which in itself can add to anxiety and confusion by placing patients in unfamiliar environments.

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With the advancement of technology, various health service providers and research groups have explored the possibility of diagnosing and managing such disorders at a distance. This is particularly important, as there is a rising burden due to an aging population. To this end, various applications of telehealth in the initial assessment and subsequent management of dementia have been developed worldwide.

Patient Care

Diagnosis at a Distance

Assessment of cognitive function via videoconferencing using standardized assessment tools has been shown to correlate well with face-to-face diagnosis [5–17]. Cognitive instruments used include the Mini-Mental State Examination (MMSE) [5, 7–10, 13–16], Standardized MMSE (SMMSE) [17, 18], the Clock Face test [9, 10], the Blessed Dementia Scale (BDS) [13], Short Blessed test (SBT) [11–13], Rowland Universal Dementia Assessment Scale (RUDAS) [6], Rivermead Behavioral Memory Test (RBMT) [16], Hierarchich Dementia Scale (HDS) [16] and the Cambridge Examination for Mental Disorders of the Elderly (CAMDEX) test [19]. Likewise, psychiatric assessment using the Geriatric Depression Scale (GDS) [7, 8, 17] and Brief Psychiatric Rating Scale (BPRS) [8], showed largely similarly encouraging results. This consistency in clinical assessment between telemedicine and in-person consultation is evident even in non-English-speaking countries such as France [9], Hong Kong [16] and South Korea [13].

Differences in test scores were observed in specific components, e.g. written component of the MMSE test or where hearing difficulties impede understanding and impair focus on tasks [9, 10, 14, 17]. Limitations of videoconferencing include the difficulty in scoring pentagrams in MMSE compared to in-person scoring or fax [14], although this could be overcome by supplementing videoconferencing with transmission of written material through fax or e-mail. Specific patient groups are also unable to be assessed via videoconferencing, such as those with severe hearing impairment or severe dysphasia, if they require an interpreter, are medically unstable, or have delirium [6]. Additionally, not all aspects of physical examinations can be carried out over videoconferencing and engaging a local medical practitioner at the remote site can help in gathering this information [15].

As part of a state-wide telehealth project, a protocol for diagnosing AD remotely for patients in rural areas within Western Australia (WA) was developed incorporating laboratory and imaging results made available to the reviewing physicians. In other models, rather than working independently, geriatricians work in partnership with nurses, and other allied health professionals at the remote end of the video conference, who perform assessments under the direction of the specialist physician [18]. In WA, telemedicine assessments were compared with face-to-face assessments performed by geriatricians on subjects ($n=20$), mostly living in the community, with symptoms of cognitive impairment referred by general

Table 1 Intraclass correlations for assessment instruments performed by direct and remote assessment

Test	Medium	Mean or median value (SD)	Range	Intraclass correlation (95% confidence interval)
MMSE	Remote	24.2 (3.7)	17–30	0.89 (0.75–0.96)
	Direct	23.3 (3.6)	16–29	
GDS	Remote	2.6 (2.1)	0–6	0.78 (0.43–0.91)
	Direct	2.8 (2.1)	0–10	
IQCODE	Remote	3.8 (0.7)	3–5	0.88 (0.71–0.95)
	Direct	4.2 (0.6)	3–5	
ADL	Remote	3.0 (2.4)	0–7	0.96 (0.92–0.99)
	Direct	3.0 (2.3)	0–7	
IADL	Remote	A (Median: 13 subjects scored A)	A–D	0.88 (0.71–0.95)
	Direct	A (Median: 14 subjects scored A)	A–C	

MMSE Mini-Mental State Examination—normal greater than 24, *GDS* normal less than 5, *IQCODE* Informant Questionnaire for Cognitive Decline in the Elderly—normal less than 3, *ADL* activities of daily living—normal 0–1, *IADL* instrumental ADL—normal scores A

Table 2 Diagnosis from direct and remote assessments of patient

Diagnoses	Direct	Remote
No mental illness	8	7
Alzheimer's disease	9	10
Mixed	3	2
Depression	0	1
Total	*20*	*20*

practitioners [20]. Assessment tools included the SMMSE [21], GDS [22], Katz assessment of activities of daily living (ADL) [23], instrumental ADL (IADL) [24] and the Informant Questionnaire for Cognitive Decline in the Elderly (IQCODE) [25], which were compared to face-to-face assessment by a geriatrician using the International Classification of Diseases (ICD)-10 criteria for AD (Table 1) [20]. SMMSE and GDS were previously validated with a pilot trial and demonstrated high correlation between direct and remote interviews with scores of 0.90 and 0.78, respectively [17]. These assessment tools were further analysed using the Bland–Altman method [26] which detected that the majority of tools yielded similar results although there was a tendency in IQCODE scores to reflect less cognitive impairment in direct assessments suggesting that carers may be more forthcoming if there was personal contact with the doctor [20]. However, all things considered, the protocol demonstrated good agreement between the two groups for the diagnosis of AD (Table 2) [20]. This largely mirrors the results from other studies, [12, 13, 18, 27] although it should be noted that the level of agreement can vary slightly depending on the complexity of the cases [27].

Furthermore, apart from the presence of dementia, the pathological diagnosis or subtype of dementia can also usually be established accurately via the same protocol of videoconferencing with prior laboratory examination and imaging studies [28]. Physical examination did not appear to contribute significantly to the diagnosis of dementia [28].

The telephone has also been used to administer cognitive assessment tools, as a cost-effective method, which is also readily available [29]. A systematic review investigating the reliability of cognitive impairment screening in older adults using assessment tools over the telephone, found the MMSE, used in conjunction with the Delirium Symptom Interview [30], to be a useful technique, which correlates well with face-to-face assessment. Further studies to validate its use is still required but it appears useful as a screening tool to identify patients who need a comprehensive face-to-face assessment or to monitor the progress of management over time rather than for the diagnosis of dementia or delirium [29].

Besides establishment of diagnosis, telemedicine can be used to determine further management such as medical advice, social support services and establishment of resultant level of care requirements and possible entry into residential care [17]. In Australia, videoconferencing has also been used to assess testamentary capacity, hold family conferences and provide education and support for carers [17]. Its use as a triage tool for discharge planning recommendations, i.e. home, inpatient rehabilitation, low care or high care, showed high level of concordance with face-to-face assessment with substantial cost savings [31, 32]. Interestingly, clinicians' more conservative decision-making process when using online assessments is reflected, and borderline or complex patients tended towards referral for inpatient rehabilitation [32]. In this way, the reliability of remote assessments is maximised and face-to-face assessments are reserved for those cases where confirmed diagnosis cannot be established online.

Similarly, telemedicine can also complement traditional clinical care such as in the Copper Ridge telemedicine programme which allowed dementia-afflicted residents of long-term care facility access to physician care through videoconferencing, leading to a decline in number and days of hospitalizations [33]. Apart from dementia, the use of telemedicine for inpatient neurology consultation, diagnosis and monitoring has also been shown to be feasible with acceptable clinical results in a literature review on neurohospitalist neurology [34].

Telemonitoring

Diagnosis of Dementia

Telemonitoring can be used to assist in early diagnosis. Japanese researchers installed infrared sensors in subjects residing alone at home to monitor number of outings and sleep pattern since this population often present late in the disease [35]. They found that the group with impaired cognition, as measured by MMSE scores, went out less and tended to have sleep problems, and this could be used to indicate early dementia [35].

Management of Dementia

In the area of management strategies, telemonitoring offers extra collateral information. Effective behavioural management strategies in dementia rely heavily on identifying precipitants, consequences and actual behaviour to introduce appropriate modification [36]. Specific details in such situations may slip the minds of caregivers, and home video monitoring provides health-care professionals with video data for thorough analysis, in a multidisciplinary setting, where feedback to carer can help behaviour change and consequent increase in carer confidence and reduction in stress [36].

Management of specific complications of dementia have also become targets for telemonitoring. Wandering can be a problematic behaviour in dementia which has the potential to endanger patients and cause additional stress to families when the patient goes missing. A telemonitoring device can be employed to send out reminders when the patient approaches danger zones or wanders too far [37]. Wireless systems for continence management in dementia-impaired patients in institutional care facilities such as nursing homes and hospitals are also being developed to reduce delays in responding to the need for diaper changes and prevent undesired consequences such as poor hygiene and skin breakdown [38].

Engagement in brain-fitness regime at home in subjects with mild cognitive impairment or early dementia is another area of application [39]. Besides improvement of areas of arithmetic, memory and idea association, such a programme can improve mood symptoms which can be indicative of early disease [39]. Under supervision of medical specialists, programmes such as this can assist in early diagnosis and management to prevent further deterioration of cognitive status [39].

Carer Support

Family members who act as carers in patients with dementia often undergo significant stress and burden, resulting in physical and mental health problems and increased mortality [40]. Ninety percent of patients with dementia eventually develop disruptive behaviours such as vocalisations, wandering and physical aggression, which are all linked to associated carer burden [41]. Adequate support can reduce such burden and avoid premature nursing home care [42].

The Counselling and Diagnosis in Dementia (CANDID) service in the UK was developed roughly a decade ago, offering carers of young people with dementia direct access by telephone and e-mail, to trained nurses and counsellors, who provide emotional support and general advice [43]. Clinical advice requests are routed via general practitioners to a consultant neurologist and a psychiatrist for review, and patients who are registered on the database can call for specific clinical information which can result in management changes through letters to their general practitioners [43]. The programme had a rapid uptake amongst carers since its inception and achieved its aims of providing a source of contact for patients and carers and also providing clinical advice to general practitioners [43]. Similarly, successful Internet and telephone-based programmes are also available to carers of dementia patients in the USA which demonstrates a cost-effective mechanism in the relief of stress and depression amongst carers, utilising online educational resources, message boards for caregiver community building, and access to other useful sites [44, 45].

Technical Considerations

The physical setup required for videoconferencing includes a computer, video camera, television screen, and a microphone and speaker which make up a videoconferencing unit at the patient and physician site, respectively. Technical difficulties are likely to improve with experience with the technology so users should persist at the initial stage to derive greater benefit from the system [12]. Setup and maintenance costs associated with a basic system are relatively inexpensive, particularly if compared to costs of setting up a physical site [33]. Moreover, the setup is similar to videoconferencing for other specialties which also compares favourably to in-person consultations, [46] resulting in further cost savings and simultaneously increasing access to a wide range of specialties which offer telemedicine.

Where video-capturing occurs in the patient's residence, such as in the area of telemonitoring for behavioural modification, a "go-back-in-time" digital system should be used, which saves recording prior to the trigger activation so that precipitating events can be reviewed and targeted [36]. Since caregivers are required to utilise these technologies, care should be taken to reduce necessary manipulation to a minimum. Automatic running of as many aspects as possible is beneficial to making it more acceptable to older caregivers [36].

Besides physical infrastructure, initial and ongoing training of involved persons, such as residential staff, is important to enable them to use the technology competently and efficiently, which can in turn increase their perception of the usefulness of the technology [47]. A single full-time telehealth coordinator can also help to schedule consultations, provide training and technical support for ongoing programmes [7]. The implementation of a new project is also best undertaken by senior-level clinicians and academics to ensure there is no deviation from clinical and patient focus [7].

Ethical Considerations

Ethical issues in telemedicine in dementia poses unique challenges for the healthcare professional and can result in poor uptake of remote medical assessments described in our experience in Perth [47]. Separately, in telemonitoring, the fine line between a good level of surveillance and infringement of privacy is thin and in consideration of new technologies, a framework (Fig. 1) to address ethical concerns has been developed [48].

At the core of the ethical model, humanistic concerns relate to the need for respect for patients and their family members in teleconsultations [48]. Research in new technologies should attempt to minimise disruption in the home environment and allow for participation in the least intrusive manner [48]. Privacy and confidentiality should be upheld and safeguards in the gathering, storage and retrieval of data from such systems should be built in, especially since many may view video monitoring as an invasion of privacy [47]. Consent in cognitive impairment is also controversial and surrogate consent often needs to be sought in such cases [47]. Ethical principles of justice and distributional fairness should also be taken into account and extra attention paid to underserved populations [48]. Last but not least, these technologies must first, do no harm. For example, the possibility of reduced clinic attendance by patients can arise when technologies are introduced as this can lead to a false sense of security that one is being watched closely all the time [48]. In other words, access to telehealth services should not impede normal interaction between caregivers and health professionals [47].

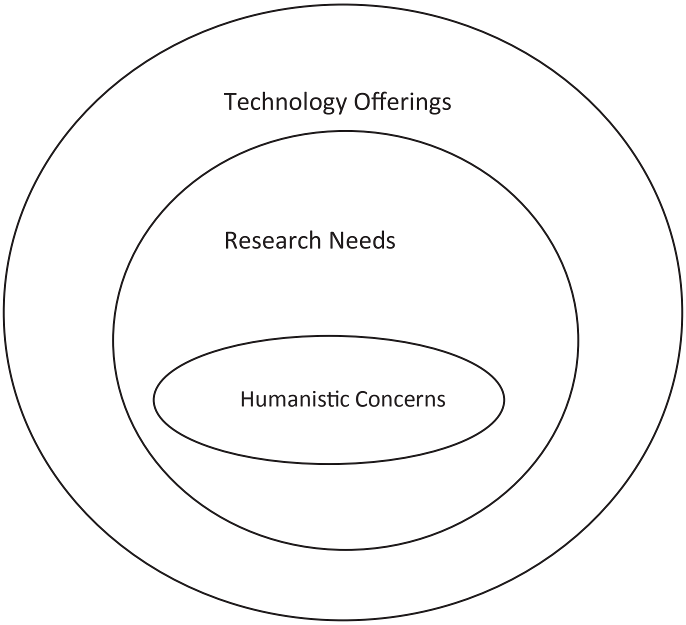

Fig. 1 Ethical model for technology research and development [48]

Patient, Carer and Health-Care Professional Satisfaction

Videoconferencing was found to be acceptable to patients, carers and health-care workers [9, 47] with a high level of perceived usefulness, comparative efficacy to in-person or telephone consultation and willingness to repeat the experience [12]. Even in an inpatient setting in a rural gero-psychiatric unit, videoconferencing was found to be positively correlated with the patient's perception of treatment and telehealth benefits and their derived satisfaction [49]. Furthermore, this acceptance is also evident in other ethnicities [13, 16, 37]. Despite this, some studies found a participant preference for face-to-face consultation which largely stems from the desire for human contact during a consultation [9, 47]. Indeed, situations such as the disclosure of a serious diagnosis can be difficult in telehealth settings, but this can be mitigated by the presence of experienced staff at the remote site [15]. It is important to note that in situations where health care cannot be accessed locally, patients have reported preferring telemedicine to travelling [15, 16].

Summary

Amongst disorders of behavioural neurology, diagnosis of dementia using telemedicine has been well studied and can likely be extrapolated to other areas. Standardized assessment tools appear to yield largely similar results between in-person and remote assessments. Despite its benefits, impediments to its increased use remain to be explored. The application of telemedicine in other areas of dementia also appear promising and use should be encouraged, albeit cautiously, in the face of ethical repercussions. Based on current evidence, underserved communities will benefit from telemedicine as a viable alternative to achieving more timely and accessible health care.

References

1. Ross GW, Bowen JD. The diagnosis and differential diagnosis of dementia. Med Clin N Am. 2002;86(3):455–76. PubMed PMID: 12168555. (Epub 2002/08/10. eng).
2. National Institute for Health and Clinical Excellence (NICE). Dementia: supporting people with dementia and their carers in health and social care. NICE. 2006:CG42 PDF.
3. Ferri CP, Prince M, Brayne C, Brodaty H, Fratiglioni L, Ganguli M, et al. Global prevalence of dementia: a Delphi consensus study. Lancet. 2005;366(9503):2112–7. PubMed PMID: 16360788. Pubmed Central PMCID: PMC2850264. (Epub 2005/12/20. eng).
4. Matthews F, Brayne C. The incidence of dementia in England and Wales: findings from the five identical sites of the MRC CFA Study. PLoS Med. 2005;2(8):e193. PubMed PMID: 16111436. Pubmed Central PMCID: PMC1188245. (Epub 2005/08/23. eng).
5. Ball CJ, Scott N, McLaren PM, Watson JP. Preliminary evaluation of a Low-Cost Videoconferencing (LCVC) system for remote cognitive testing of adult psychiatric patients. Br J Clin Psychol/Br Psychol Soc. 1993;32(Pt 3):303–7. PubMed PMID: 8251960. (Epub 1993/09/01. eng).

6. Wong L, Martin-Khan M, Rowland J, Varghese P, Gray LC. The Rowland Universal Dementia Assessment Scale (RUDAS) as a reliable screening tool for dementia when administered via videoconferencing in elderly post-acute hospital patients. J Telemed Telecare. 2012;18(3):176–9.
7. Saligari J, Flicker L, Loh PK, Maher S, Ramesh P, Goldswain P. The clinical achievements of a geriatric telehealth project in its first year. J Telemed Telecare. 2002;8(Suppl. 3):S3:53–5. PubMed PMID: 12661623. (Epub 2003/03/29. eng).
8. Grob P, Weintraub D, Sayles D, Raskin A, Ruskin P. Psychiatric assessment of a nursing home population using audiovisual telecommunication. J Geriatr Psychiatry Neurol. 2001;14(2):63–5. PubMed PMID: 11419568. (Epub 2001/06/23. eng).
9. Montani C, Billaud N, Tyrrell J, Fluchaire I, Malterre C, Lauvernay N, et al. Psychological impact of a remote psychometric consultation with hospitalized elderly people. J Telemed Telecare. 1997;3(3):140–5. PubMed PMID: 9489108. (Epub 1997/01/01. eng).
10. Montani C, Billaud N, Couturier P, Fluchaire I, Lemaire R, Malterre C, et al. "Telepsychometry": a remote psychometry consultation in clinical gerontology: preliminary study0. Telemed J: Off J Am Telemed Assoc. 1996;2(2):145–50. PubMed PMID: 10165357. (Epub 1996/07/01. eng).
11. Katzman R, Brown T, Fuld P, Peck A, Schechter R, Schimmel H. Validation of a short orientation-memory-concentration test of cognitive impairment. Am J Psychiatry. 1983;140(6):734–9. PubMed PMID: 6846631. (Epub 1983/06/01. eng).
12. Shores MM, Ryan-Dykes P, Williams RM, Mamerto B, Sadak T, Pascualy M, et al. Identifying undiagnosed dementia in residential care veterans: comparing telemedicine to in-person clinical examination. Int J Geriatr Psychiatry. 2004;19(2):101–8. PubMed PMID: 14758575. (Epub 2004/02/06. eng).
13. Lee J, Kim J, Jhoo J, Lee K, Kim K, Lee D, et al. A telemedicine system as a care modality for dementia patients in Korea. Alzheimer Dis Assoc Disord. 2000;14(2):94–101.
14. Ball C, Tyrrell J, Long C. Scoring written material from the mini-mental state examination: a comparison of face-to-face, fax and video-linked scoring. J Telemed Telecare. 1999;5(4):253–6. PubMed PMID: 10829378. (Epub 2000/06/01. eng).
15. Barton C, Morris R, Rothlind J, Yaffe K. Video-telemedicine in a memory disorders clinic: evaluation and management of rural elders with cognitive impairment. Telemed J E Health. 2011;17(10):789–93. doi:10.1089/tmj.2011.0083.
16. Poon P, Hui E, Dai D, Kwok T, Woo J. Cognitive intervention for community-dwelling older persons with memory problems: telemedicine versus face-to-face treatment. Int J Geriatr Psychiatry. 2005;20(3):285–6.
17. Loh PK, Ramesh P, Maher S, Saligari J, Flicker L, Goldswain P. Can patients with dementia be assessed at a distance? The use of Telehealth and standardised assessments. Intern Med J. 2004;34(5):239–42. PubMed PMID: 15151669. (Epub 2004/05/21. eng).
18. Martin-Khan M, Flicker L, Wootton R, Loh P, Edwards H, Varghese P, et al. The diagnostic accuracy of telegeriatrics for the diagnosis of dementia via video conferencing. J Am Med Dir Assoc. 2012;13(5):487.e19–24. doi:10.1016/j.jamda.2012.03.004.
19. Ball C, Puffett A. The assessment of cognitive function in the elderly using videoconferencing. J Telemed Telecare. 1998;4(Suppl. 1):36–8. PubMed PMID: 9640728. (Epub 1998/06/26. eng).
20. Loh PK, Donaldson M, Flicker L, Maher S, Goldswain P. Development of a telemedicine protocol for the diagnosis of Alzheimer's disease. J Telemed Telecare. 2007;13(2):90–4. PubMed PMID: 17359573. (Epub 2007/03/16. eng).
21. Molloy W, Clarnette R. Standardized mini mental state examination: a user's guide. Troy: Newgrange Press; 1999.
22. Sheikh J, Yesavage J. Geriatric Depression Scale (GDS): recent evidence and development of a shorter version. In: Brink TL, editor. Clinical gerontology: a guide to assessment and intervention. New York: Haworth Press; 1986.
23. Katz S, Ford AB, Moskowitz RW, Jackson BA, Jaffe MW. Studies of illness in the aged. The index of adl: a standardized measure of biological and psychosocial function. JAMA: J Am Med Assoc. 1963;185:914–9. PubMed PMID: 14044222. (Epub 1963/09/21. eng).

24. Duke University: center for the study of aging human development. Multidimensional functional assessment: the Oars methodology: a manual. 2nd ed. Durham: Duke University Medical Centre; 1978.
25. Jorm AF. A short form of the Informant Questionnaire on Cognitive Decline in the Elderly (IQCODE): development and cross-validation. Psychol Med. 1994;24(1):145–53. PubMed PMID: 8208879. (Epub 1994/02/01. eng).
26. Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet. 1986;1(8476):307–10. PubMed PMID: 2868172. (Epub 1986/02/08. eng).
27. Martin-Khan M, Varghese P, Wootton R, Gray L. Successes and failures in assessing cognitive function in older adults using video consultation. J Telemed Telecare. 2007;13(Suppl. 3):60–2.
28. Martin-Khan M, Varghese P, Wootton R, Gray L. Physical examination and diagnosis of dementia for video consultation. J Am Geriatr Soc. 2008;56(5):947–9.
29. Martin-Khan M, Wootton R, Gray L. A systematic review of the reliability of screening for cognitive impairment in older adults by use of standardised assessment tools administered via the telephone. J Telemed Telecare. 2010;16(8):422–8. doi:10.1258/jtt.2010.100209.
30. Albert MS, Levkoff SE, Reilly C, Liptzin B, Pilgrim D, Cleary PD, et al. The delirium symptom interview: an interview for the detection of delirium symptoms in hospitalized patients. J Geriatr Psychiatry neurol. 1992;5(1):14–21. PubMed PMID: 1571069. (Epub 1992/01/01. eng).
31. Gray L, Dakin L, Counsell S, Edwards H, Wootton R, Martin-Khan M. 'Online' geriatric assessment procedure for older adults referred for geriatric assessment during an acute care episode for consideration of reliability of triage decisions. BMC Geriatr. 2012;12. doi:10.1186/471-2318-12-10.
32. Dakin L, Cutler A, Wright O, Martin-Khan M, Varghese P, Gray L. Reliability of online geriatric consultation triage decisions: a pilot study. Australas J Ageing. 2011;30(4):239–40.
33. Lyketsos CG, Roques C, Hovanec L, Jones BN. Telemedicine use and the reduction of psychiatric admissions from a long-term care facility. J Geriatr Psychiatry Neurol. 2001;14(2):76–9.
34. Rubin MN, Wellik KE, Channer DD, Demaerschalk BM. Systematic review of teleneurology: neurohospitalist neurology. Neurohospitalist. 2013;3(3):120–4.
35. Suzuki T, Murase S, Tanaka T, Okazawa T. New approach for the early detection of dementia by recording in-house activities. Telemed J E-Health: Off J Am Telemed Assoc. 2007;13(1):41–4. PubMed PMID: 17309353. (Epub 2007/02/21. eng).
36. Williams K, Arthur A, Niedens M, Moushey L, Hutfles L. In-home monitoring support for dementia caregivers: a feasibility study. Clin Nurs Res. 2013;22(2):139–50.
37. Lin C, Lin P, Lu P, Hsieh G, Lee W, Lee R. A healthcare integration system for disease assessment and safety monitoring of dementia patients. IEEE Trans Inf Technol Biomed. 2008;12(5):579–86. (10.1109/TITB.2008.917914).
38. Wai AA, Fook VF, Jayachandran M, Biswas J, Nugent C, Mulvenna M, et al. Smart wireless continence management system for persons with dementia. Telemed J E-Health: Off J Am Telemed Assoc. 2008;14(8):825–32. PubMed PMID: 18954254. (Epub 2008/10/29. eng).
39. Boquete L, Rodriguez-Ascariz JM, Amo-Usanos C, Martinez-Arribas A, Amo-Usanos J, Oton S. User-friendly cognitive training for the elderly: a technical report. Telemed J E-Health: Off J Am Telemed Assoc. 2011;17(6):456–60. PubMed PMID: 21612520. (Epub 2011/05/27. eng).
40. Monin JK, Schulz R. Interpersonal effects of suffering in older adult caregiving relationships. Psychol Aging. 2009;24(3):681–95. PubMed PMID: 19739924. Pubmed Central PMCID: PMC2765123. (Epub 2009/09/11. eng).
41. Kunik ME, Snow AL, Davila JA, McNeese T, Steele AB, Balasubramanyam V, et al. Consequences of aggressive behavior in patients with dementia. J Neuropsychiatry Clin Neurosci. 2010;22(1):40–7. PubMed PMID: 20160208. (Epub 2010/02/18. eng).
42. Buhr GT, Kuchibhatla M, Clipp EC. Caregivers' reasons for nursing home placement: clues for improving discussions with families prior to the transition. Gerontologist. 2006;46(1):52–61. PubMed PMID: 16452284. (Epub 2006/02/03. eng).

43. Harvey R, Roques PK, Fox NC, Rossor MN. CANDID–Counselling and Diagnosis in Dementia: a national telemedicine service supporting the care of younger patients with dementia. Int J Geriatr Psychiatry. 1998;13(6):381–8. PubMed PMID: 9658273. (Epub 1998/07/11. eng).
44. Glueckauf RL, Ketterson TU, Loomis JS, Dages P. Online support and education for dementia caregivers: overview, utilization, and initial program evaluation. Telemed J E-Health: Off J Am Telemed Assoc. 2004;10(2):223–32. PubMed PMID: 15319052. (Epub 2004/08/21. eng).
45. Eisdorfer C, Czaja SJ, Loewenstein DA, Rubert MP, Argüelles S, Mitrani VB, et al. The effect of a family therapy and technology-based intervention on caregiver depression. Gerontologist. 2003;43(4):521–31.
46. Martin-Khan M, Wootton R, Whited J, Gray LC. A systematic review of studies concerning observer agreement during medical specialist diagnosis using videoconferencing. J Telemed Telecare. 2011;17(7):350–7.
47. Loh PK, Flicker L, Horner B. Attitudes toward information and communication technology (ICT) in residential aged care in Western Australia. J Am Med Dir Assoc. 2009;10(6):408–13. PubMed PMID: 19560718. (Epub 2009/06/30. eng).
48. Mahoney DF, Purtilo RB, Webbe FM, Alwan M, Bharucha AJ, Adlam TD, et al. In-home monitoring of persons with dementia: ethical guidelines for technology research and development. Alzheimer’s Dement. 2007;3(3):217–26.
49. Holden D, Dew E. Telemedicine in a rural gero-psychiatric inpatient unit: comparison of perception/satisfaction to onsite psychiatric care. Telemed J E-Health: Off J Am Telemed Assoc. 2008;14(4):381–4. PubMed PMID: 18570569. (Epub 2008/06/24. eng).

The Emerging Role of Telemedicine in the Evaluation of Sports-Related Concussion

Bert B. Vargas

Introduction

Every year in the USA 1.7–3.8 million sports-related concussions occur [1] among over 44 million children and 170 million adults engaged in organized athletic activities [2]. It is generally accepted that the reported incidence of concussion is a gross underestimate given the fact that countless individuals never present to a health-care provider because their symptoms are mild and self-limited or because they simply do not recognize the presence of concussion symptoms [3]. Concussion is a subtype of mild traumatic brain injury (mTBI) and is defined as a disruption of normal brain function [4] which can be caused by both direct and indirect forces on the brain [5]. Although the brain is protected to a large extent by the rigid skull and by surrounding cerebrospinal fluid, it is still susceptible to linear and torsional forces which can result in concussion even without direct trauma to the head. The anatomic limitations of the body to protect the brain from extreme external forces are why helmets (while effective for preventing injuries such as facial lacerations and skull fractures) are not designed to prevent concussion [5].

Post-concussive symptoms may include "dizziness" (frequently reported as imbalance, vertigo, light-headedness, or any combination of these symptoms), cognitive complaints, mental cloudiness or fogginess, and headache—which is the most common symptom of concussion and is reported in up to 85 % of athletes with a history of sports-related concussion [6]. Most post-concussive symptoms will resolve in adults within 7 days [5, 7]; however, youth and female athletes may experience symptoms that can last for several weeks [6, 8]. If concussed athletes are not identified or not provided an adequate time for recovery, they may continue to engage in activities which leave them susceptible to further concussion-related injuries which can result in a prolonged recovery, permanent neurological deficits, or (in rare cases) second-impact syndrome which can be fatal [9].

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Of note, professional football players have been reported to have a fourfold higher rate of mortality from neurodegenerative diseases including Alzheimer's disease, and amyotrophic lateral sclerosis (ALS) [10] and years of exposure to repeated concussions has been associated with the development of chronic traumatic encephalopathy (CTE) which shares a number of pathologic features with (but is distinguishable from) other tauopathies such as Alzheimer's disease [11]. It is unclear at this point to what degree genetic factors, age, sport, and number of concussions factor into the development of CTE.

Sports-related concussion has been recognized as a significant public health concern and numerous measures have been undertaken to help safeguard youth athletes including legislation in all 50 states mandating immediate removal from play for athletes suspected of having concussion and return to play only after official clearance by a provider trained in the evaluation and management of concussion. Additionally, many professional sports organizations including the National Football League, the National Hockey League, and Major League Baseball have also made rule changes in an effort to minimize athletes' exposure to potentially injurious situations including eliminating hits to the head, unnecessary contact with defenseless players, and attempting to minimize contact between base runners and catchers at home plate. Some conferences within the National Collegiate Athletic Association (NCAA) have also limited the number of full-contact football practices allowed during the week in an effort to minimize player risk for concussion. In 2013, the NFL unveiled an initiative to enhance the sideline evaluation of athletes with possible concussion by placing independent neurotrauma consultants on the sidelines. These consultants are specially trained in the evaluation of concussion and may be called upon by the team physician to evaluate an athlete and render a decision as to whether or not the athlete has sustained a concussion or other neurologic injury warranting immediate removal from play.

Although the NFL has successfully staffed each game with live in-person concussion specialists, similar medical coverage has not been uniformly employed at the collegiate or youth level—presumably because the number of teams needing coverage far outnumbers the number of providers available to provide care. This problem is compounded by the fact that only 42 % of high schools have an athletic trainer to care for student athletes—leaving coaches, officials, parents, and players with the responsibility of identifying and concussed athletes and providing appropriate sideline management [12]. These issues present a unique and troubling public health concern as it is amateur and youth athletes who are more susceptible to concussion and its aftereffects (compared to professional athletes) but have the fewest resources to identify, evaluate, and manage concussion. This disparity in access to health care also suggests that an important niche may exist for the use of telemedicine in sports.

The History of Telemedicine in TBI and Sports-Related Concussion

For many years, the US military has utilized telemedicine consultation via email for the asynchronous evaluation, management, and triage of combat soldiers in deployed locations [13]. Other studies have demonstrated the practicality and efficacy

Table 1 Shared features between teleconcussion and telestroke

	Teleconcussion	Telestroke
Serving a need for urgent or emergent assessment	Rapid identification of concussed athletes allows for removal from play and helps prevent needless exposure to further injury	Rapid identification and evaluation of acute ischemic stroke patients allows for the consideration of intravenous or intra-arterial thrombolysis and other endovascular treatments
Standardized assessment tools for evaluation	Maddocks Score, Sport Concussion Assessment Tool (SCAT3), King–Devick (K–D) test	National institutes of Health Stroke Scale (NIHSS)
Addressing needs of underserved populations	Only 42 % of high schools have access to an athletic trainer. Rural populations have limited access to specialized concussion care	Thrombolysis rates for acute ischemic stroke in rural communities are approximately 1–2 % compared to 20–25 % in metropolitan primary stroke centers
Standardized treatment protocols	State laws mandate immediate removal from play for athletes suspected of having concussion. Graded return to play protocols recommended by 2012 Zurich Guidelines	Guidelines provide specific inclusion and exclusion criteria for the use of thrombolytics as well as standardized evidence based acute care post-thrombolysis

of synchronous telemedical consultation for moderate TBI and traumatic intracranial hemorrhage in civilian populations [14, 15]. In 2013, the first published case report of telemedicine consultation specific to synchronous, audiovisual, sports concussion evaluation documented the remote evaluation of a concussed soccer player in a remote Arizona emergency department. This case report also documented the first-ever use of the term “teleconcussion” in the literature [16]. The authors concluded that telemedical evaluation of concussion appeared to be an effective means by which an athlete could be evaluated for signs and symptoms of concussion, be removed from play, and referred for specialty care. Unfortunately, the ability to adequately identify a normal asymptomatic athlete and safely return him or her to play could not be safely inferred from this experience and was suggested by the authors to be a possible focus for future research.

For many of the same reasons that telemedical evaluation of stroke patients has been so successful, [17, 18] sports-related concussion appears ideal for translation to a telemedicine model. Teleconcussion offers the ability to provide rapid, synchronous care to communities without concussion specialists where rapid assessment is important to ensure that athletes are removed from play and referred for additional emergency care if necessary. Additionally, given the requirement of clearance before return to play mandated by laws in every state, teleconcussion allows for communities without concussion specialists to access specialty care for return to play in accordance with state law. Other advantages include the fact that sideline evaluations are frequently performed with standardized concussion evaluation tools including the Maddox, SCAT3, and King–Devick (K–D) test, with clear guidance on the proper administration. A comparison of the conceptual parallels between teleconcussion and telestroke are outlined in Table 1.

Current Teleconcussion Applications

The first operational attempt at developing of a teleconcusison model for collegiate football occurred in 2013 as part of a research collaboration between Northern Arizona University (NAU) and Mayo Clinic. NAU is a public university located in Flagstaff, Arizona, with a student body numbering 26,000 and a football team that competes in the Big Sky Conference. Prior to the start of the season, the neurology teleconcussion team provided face-to-face baseline assessments for approximately 90 consenting players including a neurologic and concussion history, Sport Concussion Assessment Tool 3 (SCAT3), and K–D test . Beginning with their first game of the season, a mobile robotic unit (VGo robotic telepresence, http://www.vgo-com.com) was placed either on the sideline or in the athletic training room for all home and away games and was operated by a remote neurologist designated to be a "spotter." (Fig. 1) The remote neurologist watched the live broadcast of each game looking for contacts of an extreme or suspicious nature while also observing players for signs or symptoms of concussion (Fig. 2). The observations of the remote neurologist were meant to augment those of the sideline medical staff including the team physician and athletic trainers. Every player suspected of having a concussion (or who was felt to have experienced extreme or suspicious contact) was simultaneously evaluated in the athletic training room by both a member of the NAU medical team and the remote neurologist. A history of the incident was obtained and a SCAT3 and K–D Test were administered. Performance on these evaluations was calculated by both the face-to-face and remote examiners and a final "return-to-play" or "no-return-to-play" determination was made. Level of agreement between the face-to-face and remote assessment of performance on the SCAT3 and K-– test as well as the final medical decision was calculated. The results of this study are pending final analysis; however, the technical challenges appeared to be easy to address and overcome suggesting that replicating this model with multiple universities and sports teams is technically feasible.

Since the launch of this program at NAU, several other organizations at the collegiate and youth level have made attempts at establishing a teleconcussion network for evaluating concussed athletes. As of yet, there are no data in the medical or technical literature regarding the success, safety, or efficacy of teleconcussion programs [19].

Conclusion

Synchronous telemedicine consultations have been shown for a number of years to be safe and effective in delivering a breadth of neurologic care with a level of accuracy that is comparable to face-to-face interactions. Current case reports and anecdotal data suggest that teleconcussion is potentially effective for identifying

Fig. 1 Robotic telepresence unit on the sideline of a Northern Arizona Football Game

athletes with a history and observable abnormalities consistent with concussion; however, there are no studies which have established teleconcussion as safe for medical clearance of an athlete to return to play. Although the utility of telemedicine for return to play decision making seems intuitive, the concept is in its infancy and requires further studies to help develop algorithms for successful implementation and construction of sound business models. Teleconcussion addresses a number of issues facing both athletes and the providers that care for athletes. Primarily, teleconcussion addresses a disparity in the provision of concussion care to large

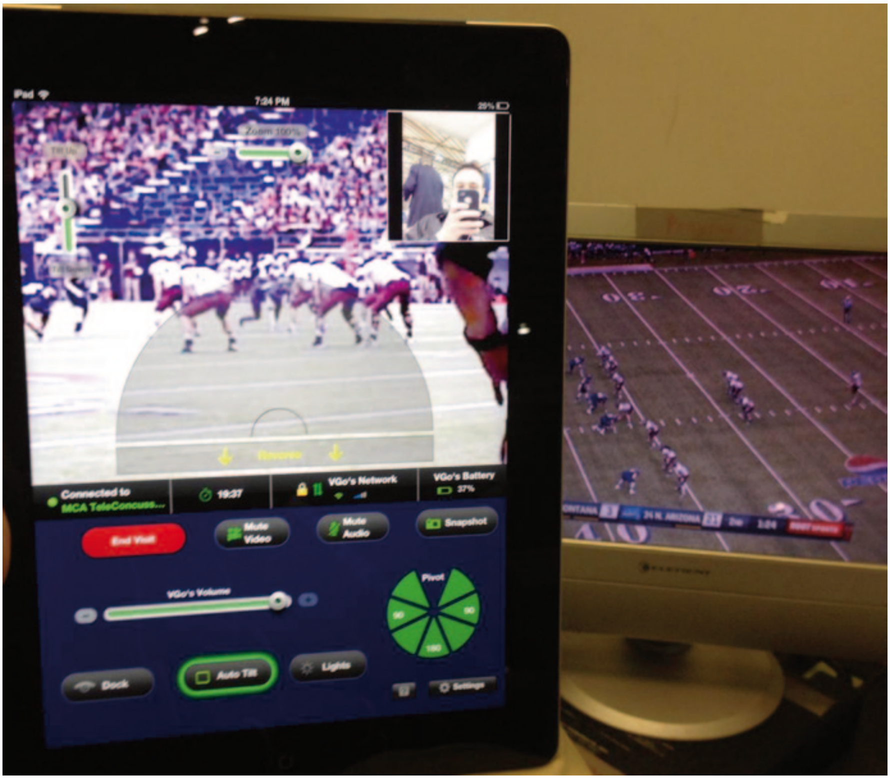

Fig. 2 Simultaneous viewing of both sideline and broadcast television coverage of sporting events allows the remote neurologist "spotter" multiple vantage points through which concussed athletes may be identified

populations that do not have immediate access to specialty care either because of a lack of an appropriate number of specialists for the volume of athletes or because the athletes are located in rural areas with limited access to specialists. Although teleconcussion is not formally being utilized at the professional level or the collegiate level, there are some clear advantages to having a remote specialist observing live broadcasts of sports contests as they have the ability to review game footage from multiple camera angles and from a vantage point that is different from that of the sideline staff while simultaneously providing telemedical evaluations and decision making at the time and location of suspected injury. As the increased availability of wireless internet and 3G and 4G mobile networks have made the technical aspects of providing teleconcussion coverage more feasible, the next most important areas of research and development should be centered on the evidence-based safety, efficacy, and reliability of providing remote concussion care to the millions of active youth and adult athletes in this country—especially those who are at greater risk of concussion.

References

1. Centers for Disease Control and Prevention. Concussion and mild TBI. CDC 2014. www.cdc.gov/concussion. Accessed 26 May 2014.
2. Daneshvar DH, Nowinski CJ, McKee AC, et al. The epidemiology of sports-related concussion. Clin Sports Med. 2011;30:1–17.
3. Vargas BB, Dodick DW. Posttraumatic headache. Curr Opin Neurol. 2012;25:284–9.
4. Giza CC, Kutcher JS, Ashwal S. Summary of evidence based guideline update: evaluation and management of concussion in sports. Neurology. 2013;80:2250–7.
5. McCrory P, Meeuwisse WH, Aubry M, et al. Consensus statement on concussion in sport: the 4th international conference on concussion in sport held in Zurich, November 2012. Br J Sports Med. 2013;47:250–8.
6. Seifert TD. Sports concussion and associated post-traumatic headache. Headache. 2013;53:726–36.
7. McCrea M, Guskiewicz KM, Marshall SW, et al. Acute effects and recovery time following concussion in collegiate football players. JAMA. 2003;290:2556–63.
8. Covassin T, Elbin RJ, Nakayama Y. Tracking neurocognitive performance following concussion in high school athletes. Phys Sportsmed. 2010;38:87–93.
9. Wetjen NM, Pichelmann MA, Atkinson JLD. Second impact syndrome: concussion and second injury brain complications. J Am Coll Surg. 2010;211:553–7.
10. Lehman EJ, Hein MJ, Baron SJ, Gersic CM. Neurodegenerative causes of death in retired National Football League players. Neurology. 2012;79:1970–1974.
11. McKee A, Stein T, Nowinski CJ, et al. The spectrum of disease in chronic traumatic encephalopathy. Brain. 2013;136:43–64.
12. Chrisman SP, Quitiquit C, Rivera FP. Qualitative study of barriers to concussive symptom reporting in high school athletics. J Adolesc Health. 2013;52:330–5.
13. Yurkiewicz IR, Lappan CM, Neely ET, et al. Outcomes from a US military neurology traumatic brain injury telemedicine program. Neurology. 2012;79:1237–43.
14. Fabbri A, Servadei F, Marchesini G, et al. Early predictors of unfavourable outcome in subjects with moderate head injury in the emergency department. J Neurol Neurosurg Psychiatry. 2008;79:567–73.
15. Klein Y, Donchik V, Jaffe D, et al. Management of patients with traumatic intracranial injury in hospitals without neurosurgical service. J Trauma. 2010;69:544–8.
16. Vargas BB, Channer DD, Dodick DW, et al. Teleconcussion: an innovative approach to screening, diagnosis, and management of mild traumatic brain injury. Telemed J E Health. 2012;18:803–6.
17. Meyer BC, Raman R, Hemmen T, et al. Efficacy of site-independent telemedicine in the STRokE DOC trial: a randomized prospective study. Lancet Neurol. 2008;7:787–95.
18. Demaerschalk BM, Bobrow BJ, Raman R, et al. Stroke team remote evaluation using a digital observation camera in Arizona: a platform for telemedicine. Telemed J E Health. 2009;15:691–9.
19. Kutcher JS, McCrory P, Davis G, et al. What evidence exists for new strategies or new technologies in the diagnosis of sport concussion and assessment of recovery. Br J Sports Med. 2013;47:299–303.

Teleneurology in Contemporary Graduate Medical Education

Eric R. Anderson

The landscape of neurology practice is changing and, consequently, training must adapt in order to maintain its relevance. We are entering an era of health-care reform where new care models emphasizing quality and value supersede older practice models reliant on quantity and fee for service. Many argue that the role of the neurologist in this new patient-centered paradigm is transitioning into a more consultative position [1]. Indeed, both political and financial forces are convening towards redefining the role of the specialist in the patient medical home.

The diminishing supply of neurologists in the era of health-care reform is predicted to be further outstripped by the demand [2, 3]. Wait times for neurologists are already prolonged in comparison to other specialties and are predicted to continue to increase in length as more Americans obtain health insurance [2]. In order to meet the increasing demand for neurology services, there has been a move towards virtual patient care, remote monitoring, mobile health, and telemedicine [4–7]. Indeed, several companies and organizations have recently been established to fulfill this need by providing neurologic consultation remotely. Academic centers have also followed suit and are increasingly offering or plan to offer telemedicine services [6]. Taken together, in order to continue to improve quality, value, and access, the future of neurology as a field will be increasingly reliant upon remote and virtual technologies.

As educators, it is upon us to produce independent neurologists competent to practice in this new health-care infrastructure. It is our duty to teach neurology trainees the different technological modalities that will allow us to continue to thrive as a discipline. Impending health-care system changes will enable us to provide efficient specialty care to our patients by leveraging novel technology within new care models.

The various technological facets of modern health care are an intrinsic component of contemporary graduate medical education. This includes training in billing,

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coding, health information technology (IT), and electronic medical records. Consequently, exposing neurology trainees to telemedicine and mobile health is becoming an essential part of graduate medical training.

As more neurologists begin to incorporate both telemedicine and mobile health into their practice, the need for structured and competent training in these modalities becomes apparent. Specific education in telemedicine for neurologists will be particularly useful due to the inherent reliance on the physical exam. Understanding the subtleties of the remote exam when the examiner is unable to personally touch the patient is important. Likewise, understanding what technical errors, artifact, and limitations of the technology mean in regard to exam findings is equally important. Learning to interface with a remote presenter, remote patient, and a remote physician is a valuable skillset outside of traditional training.

Curriculum

Proposed Curriculum Elements

Formal telemedicine training needs to be integrated into neurology graduate medical education in order to develop competent neurologist users, researchers, as well as technology and care model codevelopers. The curriculum should be designed to educate neurology trainees to understand the basic components of the technology and to employ it effectively in the evaluation and management of patients. The following is a discussion of potential topics that could be considered essential to a contemporary education in teleneurology.

Technical Background

Traditionally, the neurology trainee is exposed to only the most rudimentary concepts involved in the technical aspects of practice. As current generations are being increasingly educated in digital literacy, and technology becomes more pervasive, the level of technical understanding required to be effective concomitantly increases. In order to competently adapt to the changing landscape, there should be a commitment to understanding the constantly evolving technology utilized in practice.

Trainees should be exposed to a variety of telemedicine systems. An understanding of the key components of the underlying telemedicine network is important. Networking and security elements allow for the reliability of the network as well as the protection of patient data. These elements, as well as interface and design, are dynamic and continue to evolve as technology advances. Interfaces can include devices of varying sophistication from handheld mobile devices to robotic telemedicine units. Basic concepts need to be grasped, such as the minimum speeds required for various elements of digital data to be transmitted reliably. Trainees should also understand the concepts and reasoning behind the use of data encryption and virtual private networks in compliance with the Health Insurance Portability and Accountability Act of 1996.

The trainees should understand that specific delivery modalities are subject to different errors, artifacts, and technical nuances. For example, an intermittent connectivity problem during real-time videoconferencing may make it virtually impossible to properly assess or detect tremor. Likewise, a video lag behind streaming electrophysiologic data when assessing remote continuous video electroencephalogram may not allow for an immediate distinction between artifact and potentially epileptiform activity. Additionally, exams provided in a store and forward paradigm do not allow for real-time interaction and exam.

History and Evolution of the Field

Telemedicine is not a new concept. Its origins can be traced to as early as 1924 when the cover of a magazine publication entitled *Radio News* depicted a physician interacting with a patient via audio [8]. Telemedicine has recently been gaining enormous traction in clinical practice due to the increasing demand for services and the pervasiveness of current technology. Understanding the beginnings and evolutions of telemedicine practice as well as the barriers that it has overcome allows us a deeper understanding of the direction in which the field is heading and gives us a glimpse of what lies on the horizon. Likewise, understanding what roles that legal, political, and financial factors have played in both successful and unsuccessful telemedicine implementations would be of great value in navigating future endeavors. Recognizing the elements of practice that have historically been limited by technology, funding, and physician acceptability provides an important foundation for future quality and value improvements.

Impact on Health-Care Delivery/Outcomes

Remote telemedicine consultation is an innovative disruption of the health-care delivery status quo. It has been argued that teleneurology can replace a traditional practice as has been done in the cases of various specialist telemedicine service companies. Alternatively, others have leveraged this modality to augment their existing practice. Telemedicine, mobile health, and remote patient home monitoring are poised to transform the way that patients are managed and health care is delivered.

Cost, quality, and value are significant driving factors in health-care reform and new models of care are increasingly leveraging telemedicine to meet these goals. Quality of care is “the degree to which health care services for individuals and populations increase the likelihood of desired health outcomes and are consistent with current professional knowledge” [9]. Value has been defined as the health outcomes per dollar spent [10]. Trainees should understand how telemedicine can increase quality and value and decrease costs.

Despite the continued incorporation of technology into practice, research on costs, quality, and value is ongoing. Telestroke had recently been demonstrated to be a cost-effective endeavor [11, 12], which is an important fundamental in creating a financially sustainable care model. At this time, other uses including routine consults and follow-up visits do not currently have substantial data behind its costs, quality, or value [13].

Although improved access to specialty care was the initial motivation behind many telemedicine applications, there is now a directed focus towards the reduction of health-care costs and reducing the rates of cost escalation. These include efforts to increase competition in health services, to change methods for paying clinicians and institutions, to make patients more conscious of costs, and to identify and discourage overuse of health services. In this environment, the costs and cost-effectiveness of telemedicine applications compared to conventional health services are understandably central concerns of decision makers. It is important that trainees understand how the use of telemedicine may affect such measures including decreasing hospital length of stay and reducing hospital transfers.

Legal Concerns

Current technological innovation is unfortunately constrained by an antiquated legal system. Much of what is considered to be routine telemedicine work must fit into the confines of practice and licensure laws of each state, and potentially each hospital site that the physician might be credentialed at. Mobile health and remote patient monitoring will likely push the envelope for future legislation.

State licensure has evolved independently for each state, and the practice of medicine is presumed to occur wherever the patient is located. Should the physician wish to practice telemedicine regularly at a specific site, state licensure is typically required. The student should understand how to think of remote interstate medical practice as multiple, legally independent practices, with potentially differing liabilities and requirements at each site that must be met.

Appropriate and adequate training in telemedicine will likely come into play in legal liability and malpractice issues. Demonstration of appropriate training during residency, fellowship, or afterwards may reflect favorably upon the remote physician, should competency ever come into question, or the remote physician is named in a malpractice suit. This would involve not only being able to utilize the equipment and interfaces but also an understanding of how to navigate a remote patient encounter. In this regard, the benefits of formal telemedicine training are obvious.

Reimbursement

The business models that telemedicine networks operate on allow for long-term sustainability and ultimately lead to the success or failure of the implementation [14, 15]. Understanding of how telemedicine can financially augment ones practice and planning for start-up costs can be instrumental in the decision of how and when to make the next steps in implementation. Students should have a basic understanding of the different business models that allow for a telemedicine infrastructure to thrive. Introduction to new care models and financial reimbursement will allow for informed strategic decision making in regard to service areas and expansion.

At the time of this writing, recent revisions by the Center for Medicare Services regarding the coverage of telemedicine services have allowed for the expansion into the periphery of metropolitan areas. Additionally, in line with their long-term goals to improve quality, value, and accessibility, telemedicine and home telemedicine services are slowly being integrated into reimbursement models. Reimbursement schema in the era of health-care reform is a dynamic subject that is continuously evolving and necessitates ongoing attention and study.

Optimizing Telemedicine-Care Delivery with Health IT

As modern health-care delivery continues to be driven by outcomes and evidence-based medicine, an understanding of its implementation within the telemedicine framework is required. The integration of health IT with clinical practice allows for automated checks and streamlining workflow. Algorithmic approaches to patient encounters and automated quality measures are becoming recognized as a way to improve efficiency and provide standardized care to the general population [16, 17]. While such approaches have been studied within the confines of individual medical units and some companies with success, this has not been reliably documented in telemedicine models yet. Arguably, the most interesting question in this research is whether the data derived from multiple telemedicine sites for a specific type of encounter can be generalized to multisite populations in disparate demographic and geographical locations.

The Office of the National Coordinator for Health Information Technology is working towards the careful formulation and institution of evidence-based medicine into both order and value sets. Application of evidenced-based medicine within telemedicine-care delivery would ideally be standard practice, and fine-tuning this delivery with data mining is an ongoing goal that should be a familiar concept. An understanding of the development of these sets and employment in practice will streamline the telemedicine workflow and increase quality and value.

Potential Modalities to be Utilized for Learning

Many different approaches to student learning have been employed over the years in graduate medical education. Certain learning constructs have been found to be particularly effective and are regularly incorporated into trainee curriculums. Below are a few of the basic learning modalities that may be integrated into a training program in teleneurology.

Didactic

Didactic, or systematic, structured knowledge-based learning remains an important part of medical education and serves as the foundation from which a physician can build upon. Several different and varied approaches to knowledge-based education have been proposed including, but not limited to, traditional lectures, reading assignments, literature research, and review. Didactic learning has as large of a role in a formal teleneurology curriculum as it does in traditional neurology education.

Literature review remains an important part of knowledge-based learning, where the current databases of published information on a topic are scoured for pertinent evidence to specific treatment and management modalities. Peer-reviewed literature should continue to serve as a primary resource for continuing education throughout a neurologist's career. Literature review sessions can be designed to help trainees cope with the growing body of telemedicine publications and to assist in understanding relevant conclusions.

Problem-based learning evolved from didactics into a more active learning style that serves an important role in medical education. This systematic methodology utilizes practical problems to drive the curriculum and teach trainees essential problem-solving skills. Problem-based learning can be utilized in a telemedicine curriculum to discuss logistics of technical errors, privacy issues, and the general care of difficult-to-assess remote patients.

Experiential

Experiential learning or learning through practical experience and exposure is and has been a major component of graduate medical education. Such learning is traditionally composed of observation and participation in direct patient care. This type of learning is well suited to the utilization of telemedicine modalities. Such an experience can be structured with site visits with both the originating telemedicine site as well as the remote examiner. As competency and knowledge improve, a gradual supervised increase in autonomy and responsibilities would progress. It would be valuable for the student to understand the impact on patient care from the community partner's perspective as well as from the remote examiner. Additionally, the opportunity to work with assisting or presenting midlevels, technicians, and other providers also provide valuable perspective on the logistics of this care modality.

Telementoring

Telementoring, or being observed, supervised, and mentored remotely by an attending physician, is another way of utilizing telemedicine to facilitate learning. This can afford the resident or fellow working in distant hospital systems the opportunity to learn despite the physical absence of an attending physician on site. Such models may potentially meet the requirements for attending oversight of remotely located trainees.

Conclusion

Telemedicine is rapidly becoming incorporated into contemporary neurology practices, both academic and private. Competency in implementation, utilization, and incorporation into various modern health-care settings is becoming increasingly valuable. The importance of providing exposure and formal teaching in this subject matter to neurology trainees is paramount to preparing the next generation for practice in the modern era of health-care reform. The proposed curriculum subject matter can provide a potential framework to be employed in contemporary neurology training that will prepare the next generation to cultivate and develop the technological progress inherent in neurology.

Disclaimer Eric R. Anderson is a member of the neurology residency review committee for the Accreditation Council of Graduate Medical Education (ACGME), and views expressed within this work do not represent the views of this committee or the ACGME.

References

1. Hoch DB, Homonoff MC, Moawad H, Cohen BH, Esper GJ, Becker A, et al. The neurologist as a medical home neighbor. Neurol Clin Pract. 2013;3(2):134–40. PubMed PMID: 23914323. Pubmed Central PMCID: 3721236. (Epub 2013/08/06. Eng).
2. Freeman WD, Vatz KA, Griggs RC, Pedley T. The workforce task force report: clinical implications for neurology. Neurology. 2013;81(5):479–86. PubMed PMID: 23783750. Pubmed Central PMCID: 3776536. (Epub 2013/06/21. eng).
3. Dall TM, Storm MV, Chakrabarti R, Drogan O, Keran CM, Donofrio PD, et al. Supply and demand analysis of the current and future US neurology workforce. Neurology. 2013;81(5):470–8. PubMed PMID: 23596071. Pubmed Central PMCID: 3776531. (Epub 2013/04/19. eng).
4. Busis N. Mobile phones to improve the practice of neurology. Neurol Clin. 2010;28(2):395–410. PubMed PMID: 20202500. (Epub 2010/03/06. eng).

5. Freeman WD, Barrett KM, Vatz KA, Demaerschalk BM. Future neurohospitalist: teleneurohospitalist. Neurohospitalist. 2012;2(4):132–43. PubMed PMID: 23983878. Pubmed Central PMCID: 3726112. (Epub 2013/08/29. eng).
6. George BP, Scoglio NJ, Reminick JI, Rajan B, Beck CA, Seidmann A, et al. Telemedicine in Leading US Neurology Departments. Neurohospitalist. 2012;2(4):123–8. PubMed PMID: 23983876. Pubmed Central PMCID: 3726111. (Epub 2013/08/29. eng).
7. Hess DC, Audebert HJ. The history and future of telestroke. Nat Rev Neurol. 2013;9(6):340–50. PubMed PMID: 23649102. (Epub 2013/05/08. eng).
8. Gernsbak HE. Cover. Radio News Mag. April, 1924.
9. Lohr KN, Donaldson MS, Harris-Wehling J. Medicare: a strategy for quality assurance, V: quality of care in a changing health care environment. QRB Qual Rev Bull. 1992;18(4):120–6. PubMed PMID: 1630793. (Epub 1992/04/01. eng).
10. Porter ME. What is value in health care? N Engl J Med. 2010;363(26):2477–81. PubMed PMID: 21142528. (Epub 2010/12/15. eng).
11. Nelson RE, Saltzman GM, Skalabrin EJ, Demaerschalk BM, Majersik JJ. The cost-effectiveness of telestroke in the treatment of acute ischemic stroke. Neurology. 2011;77(17):1590–8. PubMed PMID: 21917781. Pubmed Central PMCID: 3198982. (Epub 2011/09/16. eng).
12. Switzer JA, Demaerschalk BM, Xie J, Fan L, Villa KF, Wu EQ. Cost-effectiveness of hub-and-spoke telestroke networks for the management of acute ischemic stroke from the hospitals' perspectives. Circ Cardiovasc Qual Outcomes. 2013;6(1):18–26. PubMed PMID: 23212458. (Epub 2012/12/06. eng).
13. Rubin MN, Wellik KE, Channer DD, Demaerschalk BM. Systematic review of teleneurology: neurohospitalist neurology. Neurohospitalist. 2013;3(3):120–4. PubMed PMID: 24167644. Pubmed Central PMCID: 3805445. (Epub 2013/10/30. eng).
14. Chen S, Cheng A, Mehta K. A review of telemedicine business models. Telemed J E Health. 2013;19(4):287–97. PubMed PMID: 23540278. (Epub 2013/04/02. eng).
15. Fanale CV, Demaerschalk BM. Telestroke network business model strategies. J Stroke Cerebrovasc Dis. 2012;21(7):530–4. PubMed PMID: 22819544. (Epub 2012/07/24. eng).
16. Martin M, Schall CT, Anderson C, Kopari N, Davis AT, Stevens P, et al. Results of a clinical practice algorithm for the management of thoracostomy tubes placed for traumatic mechanism. Springerplus. 2013;2:642. PubMed PMID: 24340246. Pubmed Central PMCID: 3858589. (Epub 2013/12/18. eng).
17. Fitzsimons M, Dunleavy B, O'Byrne P, Dunne M, Grimson J, Kalra D, et al. Assessing the quality of epilepsy care with an electronic patient record. Seizure. 2013;22(8):604–10. PubMed PMID: 23537634. (Epub 2013/03/30. eng).

Legal Considerations in the Use of Telemedicine in Neurology

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Neurologic disease, acute and chronic, is a major cause of death and disability in the USA and worldwide. As neurology advances as a diagnostic and therapeutic field, and with demand already far exceeding the capacity of the current workforce [1], teleneurology has been proposed as one means of extending neurologic expertise and best practices. The use of telemedicine for an acute stroke evaluation and management, termed "telestroke," was developed in an attempt to extend expertise provided by stroke specialists (see chapter "Telestroke"). Over a decade since its introduction into the medical literature, telestroke is in the mainstream of clinical practice. A role for general, nonstroke teleneurology is not as clearly defined as it is for stroke care [2] but active research and clinical implementation is promising for teleneurology. The legalities and legislation to date relevant to teleneurology practice are complex, outdated, or absent, representing a barrier to the use of teleneurology.

Legal Considerations of Teleneurology

In spite of a robust and growing evidence base supporting the use of telemedicine in general and neurology in particular, there are a host of legal considerations that constitute a barrier to more widespread implementation. Among them are disparate licensing and credentialing requirements between each state and nation. Furthermore, current means of coding telemedical care and arbitrary restrictions on eligibility for reimbursement serve as a financial disincentive to establish a teleneurology network. In addition, informed consent and privacy concerns are other considerations with legal ramifications that require special attention as compared to those elements during in-person medical consultations.

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Licensure

The essence of telemedicine is to disseminate medical expertise to patients and local providers irrespective of geographical boundaries. Currently, medical licensure and hospital credentialing processes run counter to that principle, as they are predicated almost entirely on geography. In the USA, medical licensure is under the purview of an individual state. Furthermore, in most states, a physician must be licensed in the state where a patient seeks care. Thus, a telemedicine physician must undergo the rigorous licensure process in nearly each and every state and US territory. The exceptions, who have a mechanism to grant a telemedical license for practitioners licensed in another state, include Alabama (ALA.CODE § 34–24-502), California (CAL. BUS. & PROF. CODE § 2052.5(b)), Louisiana (LA.REV. STAT.ANN. § 1276.1), Minnesota (MINN. STAT. § 147.032(1)), Montana (MONT.ADMIN.R. 24.156.802(5)), Nevada (NRS § 630.261(e)), New Mexico (NM STAT.ANN. 1978 § 61–6-6), Ohio (OH. REV.CODE ANN. § 4731.296(C)), Oregon (OR.REV. STAT.ANN. § 677.139), Tennessee (TCA § 63–6-209(b)), Texas (22 TEX.ADMIN.CODE § 174.12), and Guam (10 G.C.A. § 12202) [3, 4]. The Federation of State Medical Boards (FSMB) proposed the Model Act in 1995 which would afford a licensed physician in any state the privilege to practice telemedicine across state lines, limiting in-person medical care to the primary state of licensure. This Act has not been formally accepted by any state to date, although the aforementioned states that grant telemedicine licensure based on a medical license in good standing elsewhere in the USA have enacted its basic tenet. A recent piece of federal legislation (42 CFR §§ 482.12 and 482.22) helped to streamline the process of being credentialed for a telemedicine site by allowing the credentialing process of the hub site to effectively "transfer," so as to better avoid onerous, duplicative administrative barriers.

More recently, the FSMB-appointed State Medical Boards' Appropriate Regulation of Telemedicine (SMART) workgroup provided a model policy for "medical and osteopathic boards based on a thorough review of recent advances in technology and the appropriate balance between enabling access to care while ensuring patient safety" [5]. The SMART workgroup was tasked with contextualizing modern technology with the current climate of medical practice in order to make generic policy guidelines to assist individual states in adopting rational telemedicine regulations. The fundamental premise of the Model Policy is that telemedicine should be held to the same high professional and ethical standard of any other medical encounter, and that practitioners should "[p]lace the welfare of patients first" which is the principle that informs all subsequent recommendations. Regarding their specific recommendations surrounding licensure, the FSMB suggests that "A physician must be licensed by, or under the jurisdiction of, the medical board of the state where the patient is located. The practice of medicine occurs where the patient is located at the time telemedicine technologies are used. Physicians who treat or prescribe through online services sites are practicing medicine and must possess appropriate licensure in all jurisdictions where patients receive care." This policy stance is somewhat controversial in that it adheres to strict geographic considerations otherwise anathema to telemedicine but was crafted to ensure existing regulating bodies (e.g., state boards) could continue oversight of how medicine is practiced in their jurisdiction. The legislative landscape surrounding licensure for physicians practicing telemedicine is changing rapidly, and seemingly coalescing into a practicable "national standard," and the FSMB Model Policy was drafted to support that trend.

Reimbursement

Reimbursement mechanisms for medicine have not kept pace with the expanded clinical use of telemedicine. The Centers for Medicare and Medicaid Services (CMS), the most prominent payer in the US health-care system, requires that concurrent care by more than one provider be medically necessary (42 USC § 1395y(a)) as well as that the consultation is originated within arbitrary geographical constraints designated as rural for reimbursement of service. Although these stipulations are ostensibly reasonable, in practice only very few payments are provided for telemedically guided care of Medicare beneficiaries. In addition, the current federal definition of "rural" does encompass all underserved populations, thus a provider is given a financial disincentive to practice telemedicine in other nonrural underserved areas. Progress has been made in recent years; however, as 26 states have already enacted provisions that compel private insurers and/or Medicaid to cover a telemedical consultation with another 8 states proposing legislated coverage as of the end of April 2014 [6]. The lack of a clear federal standard—Medicare payments are considered a benchmark for most medical services—leads to general ambivalence as to how telemedical services should be reimbursed, which may impede investment of resources by physicians and industry. However, 21 states now compel private insurance providers to reimburse for telemedicine at the same rate as an in-person visit (at least under some clinical circumstances) with another 12 states proposing similar laws [7]. That said, the telemedicine reimbursement situation is ever-changing, as evidenced by the recent (April 2014) change in CMS policy allowing telemedicine consultations to arise from facilities other than the strictly defined rural "critical access hospitals," effectively expanding the scope of reimbursable telemedicine practice. Private insurance companies are sure to watch CMS policies on telemedicine coverage closely to inform their own policies.

Informed Consent

The nature of an interaction between a medical provider and patient, in person or via telemedicine, shapes the plan of care in a fundamental way. Although experienced providers of telemedical care may argue that a similar degree of warmth and empathy considered vital to a strong doctor–patient relationship is achievable as compared to in-person consultation, this has yet to be systematically studied and may not uniformly be the case. Among the more important elements of providing care of any sort is the informed consent process, which is heavily contingent upon the doctor–patient relationship. The FSMB Model Policy addresses informed consent in the following prescriptive manner [5]:

> Evidence documenting appropriate patient informed consent for the use of telemedicine technologies must be obtained and maintained. Appropriate informed consent should, as a baseline, include the following terms:
>
> - Identification of the patient, the physician and the physician's credentials;
> - Types of transmissions permitted using telemedicine technologies (e.g., prescription refills, appointment scheduling, patient education, etc.);
> - The patient agrees that the physician determines whether or not the condition being diagnosed and/or treated is appropriate for a telemedicine encounter;
> - Details on security measures taken with the use of telemedicine technologies, such as encrypting data, password protected screen savers and data files, or utilizing other reliable authentication techniques, as well as potential risks to privacy notwithstanding such measures;
> - Hold harmless clause for information lost due to technical failures; and
> - Requirement for express patient consent to forward patient-identifiable information to a third party.

An interesting recent study sought to evaluate the adequacy of the informed consent process for delivery of recombinant tissue plasminogen activator (rt-PA) for acute stroke patients evaluated by telestroke [8]. The adequacy of informed consent was adjudicated by two physicians who provide stroke care with regularity, a paralegal, a bioethicist, and a layperson. There was significant variability in their responses, but, overall, the group felt that the benefits, risks, and alternatives were adequately explained and understanding demonstrated in most (80 %) of the 20 cases scrutinized. The authors' conclusion was that a standardized tool should be in place for time-sensitive medical emergencies being evaluated by telemedicine such that informed consent is provided in a more uniform fashion. In the era of high-quality videoconferencing for medical consultations, one can make the argument that the informed consent process should be considered no different via telestroke than in person, so long as a concerted effort is made by the telemedicine physician to establish the doctor–patient connection in spite of geographical separation.

Privacy

The right to privacy of medical records is considered fundamental and is protected by federal law (45 CFR § 160) in the form of the Health Insurance Portability and Accountability Act (HIPAA). Compliance with HIPAA is necessary whether medical information is transmitted by hand or over the Internet. Privacy and security of the telemedicine systems can be maintained by Secure Site License (SSL) conditional access, data encryption, intruder alerts, and access logging and reporting. The integration of security features into modern telemedical hardware and software ensures HIPAA compliance for teleneurology consultations. Given the new ubiquity of smartphones and their high-quality videoconferencing capability, the desire to employ these inexpensive handheld devices for telemedicine must be matched by a HIPAA-compliant means of doing so, including the use of virtual private networks (VPN) or closed wireless networks.

Standard of Care

The FSMB, the American Medical Association, all states, the District of Columbia, and territories that have enacted statutes on telemedicine require that treatment provided via electronic means be held to the same standards of appropriate practice as those in traditional (i.e., face-to-face) settings. This requires that a physician be able to detect everything through telemedicine he or she would have during an in person physical examination notwithstanding the physician's restricted ability to see, touch, and smell the patient [9]. "The cyberconsultation may present an incomplete physical examination and, thus, an incomplete picture of the problem that the patient is experiencing, [which] may cause misdiagnosis and inappropriate treatment of the patient's illness…" [10]. Telemedicine providers must be able to utilize technology in such a manner that enables them to diagnose, treat, and provide follow-up care that meets the same standard of care that a traditional face-to-face encounter would provide. Failure to do so may create an independent cause for medical malpractice. Liability may also stem from the failure to use technology that is the standard for telemedicine or from negative outcomes resulting from the improper use of telemedicine technology.

The large majority of states use the "national standard," which requires medical providers to provide a level of care based on prevailing national practices. A small minority of states still uses the "locality rule" where standard of care is measured by local practices and customs. Telemedicine providers must be cognizant of the standard of care in the jurisdiction in which they are providing care and must be familiar with the local practices and customs when providing care in jurisdictions that follow the locality rule. This may require that telemedicine providers be knowledgeable of several different standards of care. In addition to the differing standards of care between states, the District of Columbia, and territories, telemedicine providers will also need to know the statutory requirements of state in which they treat patients. Some states, such as Florida, expressly prohibit the prescribing of controlled substances via telemedicine.

Although telemedicine has been employed for several years, case law is still scarce. This creates some uncertainty for telemedicine providers when it comes to liability. As telemedicine becomes more widely used, the standard of care required will become more definitive. It is not unthinkable, that with technology gains and increasing usage, telemedicine will become part of the standard of care, and providers who fail to employ telemedicine when indicated will be held liable. Until such time when the law catches up to telemedicine, providers must be vigilant on the varying standards of care and state laws in which they practice.

Telestroke-Specific Legal Concerns

Many of the legal and legislative issues exist for the use of telemedicine in general, but there are some that are particularly relevant to telestroke. Some who are wary of developing a telestroke network cite the lack of legal clarity at a federal level (or even in most states) as regards shared liability between hub and spoke sites in the case of a bad outcome. For the case of acute stroke, since it seems that the majority of stroke-related lawsuits come from thrombolysis, the only approved treatment for acute ischemic stroke, *not* being administered. Initiation of a process that affords emergency medicine providers access to stroke specialists and has been shown to increase thrombolysis use should mitigate this concern. That said, there is still a role for establishing clear legal agreements between hub and spoke sites, be they via federal law or on an individual institutional basis.

Overall, the practice of teleneurology is alive, well, and rapidly expanding. The evidence base for its use as a boon to patients, providers, and society is strong and growing as well. Our laws have not kept pace with this growth and the state-specific governance impedes standardization, and this represents an impediment to further expansion of telestroke use. There are clear signs of improvement, however, as numerous states are taking steps to modernize their telemedicine provisions and encourage its use through reimbursement. For many reasons, however, any active teleneurology network will require dedicated legal assistance for the foreseeable future to navigate within the current climate of medicolegal and financial uncertainty.

References

1. Freeman WD, Vatz KA, Griggs RC, Pedley T. The workforce task force report: clinical implications for neurology. Neurology. 2013;81(5):479–86.
2. Rubin MN, Wellik KE, Channer DD, Demaerschalk BM. Role of telemedicine in providing tertiary neurological care. Curr Treat Options Neurol. 2013;15(5):567–82.
3. Federation of State Medical Boards. Telemedicine overview: board-by-board approach. http://www.fsmb.org/pdf/grpol_telemedicine_licensure.pdf (2013). Accessed 6 June 2014.
4. Kulcsar M, Gilchrist S, George MG. Improving stroke outcomes in rural areas through telestroke programs: an examination of barriers, facilitators, and state policies. Telemed J E Health. 2014;20(1):3–10.
5. Federation of State Medical Boards. Model policy for the appropriate use of telemedcine technologies in the practice of medicine. http://www.fsmb.org/pdf/FSMB_Telemedicine_Policy.pdf (2014). Accessed 6 June 2014.
6. American Telemedicine Association. 2014 state telemedicine legislation tracking. http://www.americantelemed.org/docs/default-source/policy/state-telemedicine-policy-matrix.pdf?sfvrsn=38. Accessed 6 June 2014.
7. American Telemedicine Association. States with parity laws for private insurance coverage of telemedicine. http://www.americantelemed.org/policy/state-telemedicine-policy/page/2/#.U5Iqm3JdXTp. Accessed 6 June 2014.

8. Thomas L, Viswanathan A, Cochrane TI, Johnson J, O'Brien J, McMahon M, et al. Variability in the perception of informed consent for IV-tPA during telestroke consultation. Front Neurol. 2012;3:128.
9. Kaspar BJ. Legislating for a New Age in medicine: defining the telemedicine state of care to improve healthcare in Iowa. Iowa Law Rev. 2014;99:839–66.
10. Bailey RA. The legal, financial, and ethical implications of online medical consultations. J Tech Pol. 2011;16(53):68–71.

Reimbursement in Teleneurology

Eric R. Anderson

One of the greatest barriers to the widespread adoption of telemedicine is the perceived difficulty of reimbursement. At the time of writing, there are several major payers that reimburse for telemedicine services, which include Medicare, Medicaid (variable from state to state), and private payers (variable from state to state). As the field of telemedicine continues to evolve at a rapid pace, coverage for telemedicine services should closely follow. Continuous monitoring of individual state policy and legislation on the subject will be necessary in order to remain up to date with the most recent changes.

Medicare

Medicare, the federal health insurance program intended for individuals 65 and older as well as those with specific chronic diseases, is uniform across the USA. Promoting the reimbursement for telemedicine services through Medicare is essential in advancing the practice of telemedicine and expanding utilization. In 1997, the Balanced Budget Act first mandated Medicare to reimburse for telemedicine services, although with limited scope. Since that time, there have been several legislative iterations that have broadened the scope of telemedicine, including where it can be delivered and by whom.

Despite the propitious progression of Medicare reimbursement, criteria that must be met in order to qualify remain largely limiting. Of note, the originating site typically must be in a health professional shortage area (HPSA) or outside of a metropolitan service area (MSA) to be considered reimbursable by Medicare. These qualifications are defined by the Health Resources and Services Administration

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(HRSA) and the US Census Bureau, respectively. Importantly, the patient's home is not considered an eligible site for reimbursement by Medicare. Unfortunately, several neurologic diseases such as stroke, multiple sclerosis, epilepsy, dementia, and amyotrophic lateral sclerosis, among others, leave our patients relatively immobile regardless of whether or not they reside in an urban or rural setting. Even with the largely acknowledged limitations of Medicare reimbursement, it remains the de facto standard for many state Medicaid and private insurance programs.

At the time of this writing, Medicare has strict regulations regarding the reimbursement of telemedicine services [1, 4, 6]. In order to be reimbursed by Medicare, the following criteria must be met:

Eligible Technology Medicare requires that two-way live audio and video must be utilized for the rendered services. Thus, both the remote physician and the patient at the originating site must be able to both see and hear one another in real time.

Eligible Patient The patient must be a Medicare beneficiary and must be present during the time that the service is provided. A family member, physician, or other party cannot substitute for the patient.

Originating Site The site where the patient is located during an encounter must be outside of a metropolitan area and be one of the approved sites (Table 1). Of note, HRSA maintains a website to determine or confirm eligibility for reimbursement of approved telemedicine services (http://datawarehouse.hrsa.gov/telemedicineAdvisor/telemedicineEligibility.aspx). One must simply enter in the address of the remote site that will be receiving services to determine if that site lies in an eligible geographic location.

Eligible Services The services rendered via telemedicine must be one of several approved services (Table 2) that are derived from a fraction of existing Medicare part B services. Note that Medicaid and private payers may provide reimbursement for services outside of this list, but those services are state specific.

Eligible Provider The practitioner providing the services must be an approved provider (Table 3). Of note, this list of providers applies to Medicare alone, and

Table 1 Eligible originating sites for medicare reimbursement

Eligible originating sites
Office of a physician or practitioner
Hospital
Critical access hospital
Rural health clinic
Federally qualified health center
Skilled nursing facility
Hospital-based dialysis center
Community mental health center

The patient must be located at one of these sites in order for the encounter to be reimbursed by Medicare

Table 2 Eligible service for medicare reimbursement

Eligible service	Code
Telemedicine consultations, emergency department, or initial inpatient	HCPCS G0425-G0427
Follow up inpatient telemedicine consultations	HCPCS G0406-G0408
Office or outpatient telemedicine visits	CPT 99201
Subsequent hospital-care services	CPT 99231-99233
Subsequent nursing facility care services	CPT 99307-99310
Neurobehavioral status examination	CPT 96116
Inpatient pharmacologic management	HCPCS G0459
Psychiatric diagnostic interview examination	CPT 90791, 90792
Individual psychotherapy	CPT 90832-90834 and 90836-90838
Individual and group health and behavior assessment and intervention	CPT 96150-96154
Individual and group medical nutrition therapy	CPT 97802-97804 and HCPCS G0270
Smoking cessation services	CPT 99406, 9407 and HCPCS G0436, G0437
Alcohol and/or substance abuse assessment and intervention services	HCPCS G0396, G0397
Annual alcohol misuse screening (per 15 min)	HCPCS G0442
Brief behavioral counseling for alcohol misuse (per 15 min)	HCPCS G0443
Behavioral counseling for obesity	HCPCS G0447
Family psychotherapy	CPT 90846, 90847
Prolonged service in the outpatient setting requiring direct patient contact beyond the usual service	CPT 99354, 99355
Annual wellness visit	HCPCS G0438, G0439

Table 3 Eligible originating sites for medicare reimbursement

Eligible providers
Physician
Physician assistant
Nurse midwife
Nurse practitioner
Clinical nurse specialist
Clinical psychologist[a]
Clinical social worker[a]
Registered dietician or nutritionist

[a] Clinical psychologists and social workers may not bill for psychotherapy services that include medical evaluation and management, and they may not bill or receive payment for CPT codes 90805, 90807, and 90809

Medicaid or private payers may not allow reimbursement for some of the providers listed.

Once all of the criteria above have been met, the provided telemedicine services may be submitted to Medicare for reimbursement. Services rendered by telemedicine are reimbursed at the same rate as the current fee schedule amount for the specified service. In order to appropriately bill, a GT modifier is attached to the current procedural terminology (CPT) code which indicates that the service was provided "via an interactive audio and video telecommunications system." This modifier certifies that the beneficiary was present at an eligible site when the approved service was provided.

Another important feature of Medicare reimbursement for telemedicine services is the ability to collect for a technical or facility fee at the originating site. These services are billed using the telemedicine-originating site fee which is coded with HCPCS Q3014. This authenticates that the originating site is located in an area that is eligible for Medicare reimbursement of telemedicine services. The reimbursement amount for HCPCS Q3014 is updated yearly and based upon the Medicare economic index.

Medicaid

Medicaid, the state-administered program for low-income individuals and families, varies from state to state in which telemedicine services may be covered. Each state has the authority to regulate the practice of medicine within its own borders, and, thus, has the authority to determine what telemedicine services it will cover, if any. The major impetus for state Medicaid to cover telemedicine services is to improve patient access, improve patient outcomes, and to ameliorate the enormous costs associated with patient transfers between emergency departments, nursing homes, prisons, and hospitals.

However, states largely have a choice to maintain the status quo and adopt Medicare's criteria for the reimbursement of telemedicine services or they can innovate. A handful of states now allow for the reimbursement of telemedicine services in the home through interactive video or remote monitoring. Additionally, many states have instituted parity laws or legislation that mandates private insurer coverage of telemedicine services equivalent to what is covered within that state.

Due to the dynamic nature of state policy and legislation across the USA, a static comprehensive compilation of current state policy is unattainable in a traditionally published format. However, there are several digital resources available at the time of this writing that have taken on the herculean task of keeping current and up-to-date state policies and legislation available to the public [2, 3, 5]. These resources outline Medicaid reimbursement for telemedicine as well as any parity legislation mandating reimbursement by private payers as well.

(http://www.ncsl.org/research/health/state-coverage-for-telehealth-services.aspx)

(http://www.americantelemed.org/about-telemedicine/policy/state-telemedicine-policy#.U5-D6pRdWe0).

Conclusion

The financial viability of the practice of telemedicine is intimately linked to the dynamic changes in reimbursement policy and legislation at the national and state levels. As telemedicine services increasingly become available for reimbursement, we expect that utilization of those services will also increase. It is important to keep abreast of the latest changes in state policy and legislation in order to continue to ensure financially viable telemedicine endeavors.

References

1. Center for Telehealth & e-Health Law. Reimbursement. http://ctel.org/expertise/reimbursement/. Accessed 10 March 2015.
2. State Coverage for Telehealth Services. http://www.ncsl.org/research/health/state-coverage-for-telehealth-services.aspx. Accessed 10 March 2015.
3. State Telemedicine Policy Center. http://www.americantelemed.org/policy/state-policy-resource-center#.VP8T1GTF9T4. Accessed 10 March 2015.
4. Telehealth Services—Rural Health Fact Sheet Series. http://www.cms.gov/Outreach-and-Education/Medicare-Learning-Network-MLN/MLNProducts/downloads/TelehealthSrvcsfctsht.pdf. Accessed 10 March 2015.
5. Telemedicine. http://www.medicaid.gov/Medicaid-CHIP-Program-Information/By-Topics/Delivery-Systems/Telemedicine.html. Accessed 10 March 2015.
6. Telemedicine and Telehealth Services. January 2013. http://www.americantelemed.org/docs/default-source/policy/medicare-payment-of-telemedicine-and-telehealth-services.pdf?sfvrsn=14. Accessed 10 March 2015.

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