Chapter

Telestroke: A New Paradigm

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Abstract

Stroke is one of the leading causes of death and disability across the world. With the development of new modalities of treatment, including the use of intravenous tissue plasminogen activator and mechanical thrombectomy, clinical outcomes have improved in patients with acute ischemic strokes. However, these interventions are time dependent, and there exists a great disparity between the rural and urban parts of the world in terms of the availability of neurologists and these lifesaving treatment options. Telestroke networks utilize digital technology for two-way, high-resolution video teleconferencing to help abate these disparities by bringing safe, efficient, and cost-effective care to underserved communities in the United States and around the world.

Keywords: telestroke, acute ischemic stroke, tPA, teleconference, quality measures

1. Introduction

In the United States (US), stroke is the fifth leading cause of mortality with a stroke occurring approximately every 40 seconds and stroke-related death approximately every 4 minutes [1, 2]. In 2011, stroke was found to be the leading cause of disability in the US, with around 7 million stroke survivors [3]. In 2016, the World Health Organization designated stroke as the second leading cause of mortality worldwide. Acute ischemic strokes account for about 80% of all stroke-related deaths [4]. Intravenous tissue plasminogen activator (tPA) has been shown to improve outcomes in acute ischemic stroke [5, 6]. In patients who receive tPA, early administration has been shown to reduce morbidity, mortality, and adverse events such as intracranial hemorrhages, promoting early discharges and higher rates of independent ambulation at discharge [5, 7]. Mechanical thrombectomies performed by neuro-interventionists have shown to improve outcomes for patients with proximal intracranial arterial occlusion [8–11] and have become the standard of care for patients who qualify for intervention. However, this procedure is performed only at tertiary care centers and is not available at smaller hospitals around the country.

Despite the obvious benefits of tPA administration, only a small percentage of patients presenting with acute ischemic strokes are eligible to receive it [12–15]. The most common reason attributed to this is a delay between the development of stroke symptoms and the patient seeking treatment at a hospital [16, 17]. There are also marked rural–urban disparities in stroke care [18–20]. These disparities are, in part, a result of the scarcity of neurologists [21–24]. Studies have shown better outcomes in stroke patients under the care of neurologists as compared to physicians of other specialties, such as Internal Medicine or Family Medicine [22, 25, 26]. Telestroke aims to bridge this gap by providing neurology expertise in remote areas around the world through high-quality audio-video conferencing and digital image sharing.

2. Historical perspective

Communication of medical information across long distances has occurred throughout history. It is well documented that bonfires and heliographs were used to send communications about the bubonic plague in Europe [27]. Telegraph communication was used in the civil war and radio communication was used in World War I, and wars thereafter, to send information about casualties and to request medical dispatches and transport for wounded soldiers [28]. Telemedicine in its current form was developed by NASA to monitor the physiologic states of astronauts during manned space missions [29]. The first interactive video telemedicine systems were established for psychiatry [30] and radiology [31] but later expanded to critical care [32] and oncology [33] to bridge the shortage of specialists in these fields. In 1999, the term *telestroke* was first coined by Levine and Gorman, who described the use of video telecommunications as a means to facilitate cerebrovascular consults to remote areas adding great expertise to the care of stroke patients [34]. Since then the number of telestroke networks around the world has expanded significantly [35–38].

3. Telestroke models

Before discussing telestroke models, it is important to understand the terminology used to describe telestroke systems, as described by the American Telemedicine Association [39].

1. Distant site: the distant telestroke provider location.

2. Originating site: the site where the patient is initially located.

3. Telestroke network: a group of primary, secondary, and tertiary care settings that provide acute stroke care to patient populations. Telestroke networks consist of originating sites where the patients are located and distant sites where the telestroke provider is located.

4. Spoke: the affiliate or partner site in a telestroke network that is underserviced or under-supported by neurologists where patient services are delivered.

5. Hub: a comprehensive tertiary care center where vascular neurologists and other acute stroke specialists compose a call panel delivering telestroke services to network partner sites (i.e., spoke sites). This is also the center where the patient may be transferred if a higher level of care is needed.

Several different telestroke models have been described and are listed below [38, 39].

1. Hub and spoke within a single healthcare system.

2. Hub and spoke with external sites.

3. Horizontal hubless network: interconnected sites within a large hospital system for on-call clinical coverage.

4. Third-party distribution model: telestroke services are provided to multiple originating sites through arrangements with an independent corporation or an affiliated network of telestroke providers.

5. Supervisory training model: academic teleneurology programs to assist trainees within the hospital system.

Hub and Spoke with external sites and third-party distribution models are the most commonly used models within telestroke [35]. In telestroke networks, the majority of spoke sites are small hospitals (i.e., 0–99 beds) [37], but the spoke hospital size may vary from 25 to 500 beds in different telestroke networks [17]. A telestroke consult typically starts with a patient presenting to a spoke site with a suspected stroke. After an initial assessment by the physician at the spoke site, a triage process is conducted through telephone operators, followed by a video teleconferencing call with the neurologist at the distant site [see flow diagram of a telestroke system]. After reviewing the National Institute of Health Stroke Scale (NIHSS) and brain imaging (typically a non-contrasted CT scan of the head) and reviewing the patient's history for indications/contraindications for tPA, a decision is made for administration of tPA. After this initial process, the decision of transferring the patient to the hub site is made, depending upon the need for further investigation, possible thrombectomy/neurosurgical intervention, or requirement of a higher level of care as compared to the spoke site. The term "Drip and Ship" is often used to describe transfer from spoke to hub sites, where after receiving the bolus dose of tPA, the patient is started on tPA drip and transferred emergently for further management [40].

The majority of the hospitals in telestroke systems have formal written contracts between the hub and the spoke site with a closed-loop communication system in place [37]. A vast array of Food and Drug Administration (FDA) approved two-way video-conferencing modalities with picture archiving and communication system are available for use by these networks that provide Health Insurance Portability and Accountability Act (HIPPA) compliant, secure, encrypted multipoint data sharing with evolving functionality through the use of desktops, robotic carts, laptops, tablets, and even mobile phones with provider-to-provider interfaces [37, 38].

More recent advancements in telestroke systems include an ambulance-based telemedicine system that provides a feasible tool for prehospital stroke assessment [41–44]. Early attempts at prehospital telestroke consults were limited due to technical difficulties [44]. Newer studies have shown a high level of agreement in evaluation and treatment by mobile stroke units with a vascular neurologist on board compared to telestroke consults by a vascular neurologist [45] at a distant site who guides immediate treatment [46]. The data, however, is still limited and requires further investigation before the utility and efficacy of telestroke programs can be ascertained.

4. Effectiveness and utility of telestroke in management of acute ischemic stroke

The primary goal of telestroke models is to establish a network of neurology consults across underserved areas that do not have in-house neurology consultants available, thereby expediting the initial stroke exam and care. As the effective tPA window is time-sensitive, and early administration of tPA is known to improve outcomes [5, 6, 13, 47], delay in transport of patients to tertiary care centers can lead to loss of the crucial intervention time window in acute ischemic stroke patients. After adequate training, the use of telestroke systems to measure NIHSS scores is viable and scoring is reliable, with inter-rater reliability comparable to that of in-person measurements [48, 49] even in telemedicine-naïve stroke practitioners [50]. Such assessment has also been found to be reliable when performed by neurology trained nurse practitioners [51], on laptop-based workstations [52], or even mobile-based video telestroke consults [53, 54]. Also, the FDA has approved teleradiology systems that enable effective and rapid evaluation of images by stroke specialists [55]. Stroke specialist evaluation via teleradiology systems has been found to be comparable to assessment by a neuroradiologist in aiding the decision making for tPA administration [56, 57].

Studies have shown that telestroke facilitated administration of tPA to patients in community hospitals and rural hospitals (as small as 100 beds or less) has outcomes comparable to those of in-person treatment at comprehensive stroke care centers [58–61]. Even with in a stroke network, the performance of spoke sites is similar regardless of the bedsize [62]. Also, the use of telestroke at rural hospitals can provide patients with comparable or reduced time between symptom onset and tPA administration [door-to-needle time (DTN)] compared to those directly presenting to tertiary care centers [63]. A non-blinded randomized control trial in the Telemedic Pilot Project for Integrative Stroke Care (TEMPiS) network in Germany showed that patients treated in telestroke network hospitals had significantly fewer poor outcomes compared to patients treated in community hospitals without telestroke capabilities [64]. Telestroke consults are becoming exceedingly cost-effective in dealing with acute strokes in the community [65–69].

5. Telestroke for post-tPA care and work up

Telestroke consults also have utility beyond acute stroke. Patients receiving tPA or those with subacute strokes with milder symptoms not requiring emergent intravascular intervention can remain at the spoke site for further investigation. Telestroke follow-up consults can aid in guiding the physicians at the spoke sites to continue further stroke workup and discharge patients from the spoke site. This may also reduce the cost of transport and limit patients being transferred to hub sites to only those requiring urgent neurosurgical/intravascular intervention. A randomized control trial by Evans et al. showed that the management of stroke patients in dedicated stroke units showed better outcomes for large vessel infarcts but not for small lacunar infarcts when compared to those in general medical wards with stroke team support [70]. Based on this hypothesis, small lacunar strokes could potentially be managed by the medical team at spokes sites with telestroke consults and follow-ups. The Telemedicine in Stroke in Swabia Project and The Order of St. Francis Stroke Network study experience demonstrated the safety and reliability of such telestroke models [71, 72]. Even for patients requiring treatment in an intensive care unit, teleneurointensive care units are providing valuable support for prevention, diagnosis, and the timely management of cerebrovascular conditions induced secondary to neurologic injuries [73] and have shown improved outcomes [74].

Telestroke has also been studied in in-home and ambulatory post-stroke rehabilitation settings for serial neurologic assessments and timely adjustments of therapies. These studies have shown that telerehabilitation approaches are comparable to conventional rehabilitation in improving activities of daily living and motor function for stroke survivors [75, 76]. Virtual neurovascular clinics aimed at secondary stroke prevention are another evolving avenue for follow-up visits for stroke patients [77].

In the field of clinical research, telestroke consults may aid in identifying patients who are eligible for trials of therapies for ischemic or hemorrhagic strokes, neuroprotective agents, or innovative diagnostic tests, thereby facilitating expedited enrollment at the originating sites after transfer to stroke centers [78]. Telestroke models are being incorporated into the education and training of neurologists, emergency teams, and nursing staff [77, 79–82]. With the ever-expanding horizons of telestroke, training in telemedicine will likely become mainstream for all future physician and medical personnel training programs. However, the data regarding the use of telestroke beyond acute stroke care is still limited and needs further investigation.

6. Telestroke outcomes and cost-effectiveness

Zaidi et al. showed that outcomes at 90 days were no different between patients treated with tPA by telemedicine and patients treated by the same neurologists over the same time interval at the stroke center hub hospital [83]. They also found no difference in time from stroke onset to treatment. Switzer et al. found that the average time between symptom onset and treatment at the spoke sites in their telestroke system was lower than the emergency department at their hub site [63]. As previously mentioned, several studies have found post-tPA outcomes at spoke sites were comparable to those of in-person treatment at comprehensive stroke care centers [58–61]. Implementation of a standardized regional telestroke program in a community setting increased utilization of alteplase, improved DTN time, decreased length of stay, and significantly increased the chances of patients going home [84].

Establishing a telestroke network requires infrastructure and technology-related expenses along with the expenses of round-the-clock neurology coverage and the cost of transport. Initial projects around the country were supported by government funds and research grants, but to develop a self-sustaining model, telestroke networks need to be cost-effective. For a Danish telestroke system consisting of five hubs and five spokes, a 2008 study by Ehlers et al. calculated an incremental cost-effectiveness ratio (the cost of thrombolysis per quality-adjusted life year [QALY]) to be approximately US$50,000 after 1 year [69]. In 2011, Nelson et al. conducted cost data analyses of telestroke networks in rural Arizona and Utah and found the incremental cost-effectiveness ratio using a 90-day horizon of $108,363 per QALY and a lifetime horizon of $2449 per QALY [66], which reflected a high initial cost but overall long-term cost reduction, likely due to rehabilitation cost reduction from early tPA administration. Also, the highest cost-effectiveness was seen in the most severe stroke cases. In a 2013 study by Switzer et al., cost savings of $358,435 per year over 5 years were observed in a telestroke system consisting of one hub and seven spokes, as well as an improvement in patients' quality of life associated with increased numbers of individuals being discharged to home [67]. Growing evidence for the cost-effectiveness of telestroke networks and improved patient outcomes has spurred the growth of telestroke networks around the world.

7. Telestroke quality measures

Continuous quality improvement is a key element for any successful telestroke program. Several elements play a role in this improvement, including adaptation to local laws and statues, effective training programs, identification of competency issues, and overcoming challenges with technical and manpower issues at both provider and recipient sites. In 1988, Donebedian was the first to describe the model of structure, process, and outcomes measurements for assessing the quality of healthcare [85]. Systematic collection and analysis of quality data has been shown to improve the quality of stroke care that is delivered [86], and telestroke is no exception to this. Several quality measures help assess and quantify the overall function of telestroke systems. Most hub hospitals have stroke certification and emergency and ICU staff training through standards set by the Joint Commission on the Accreditation of Healthcare Organizations (JCAHO) process.

7.1 Structural measures

The capacity of the healthcare system, staffing ratios of specialists, availability of specialized units and equipment, and the organization structure with hospital networking should all be carefully studied and analyzed for any telehealth network systems. Defined protocols should be in place both at the originating and distant sites.

7.2 Process measures

Analogous to the traditional stroke pathway, the key global component of telestroke quality is still DTN time. Median DTN with telestroke varies from 106 to 121 minutes, even though the recommendation is less than 1 hour [58]. Several aspects of stroke chain-of-care that play an important role in DTN include Emergency Department (ED) door to CT scan (D-CT) time, ED door to teleneurologist consult time, teleneurologist to camera/phone time, and teleconsult duration (Con).

Clear definitions of these times are important as no uniform definitions currently exist. In some centers, a consult with teleneurologist occurs after CT scan results are obtained, while in other centers, a consult is initiated even before the CT scan is ordered. The time from ED to consult differs in these situations, which can affect these measures. Similarly, the definition of consult time varies between centers. At some centers, consult time is defined as the time spent on camera evaluating patients, and at other centers, it is defined as time spent on camera along with the time spent reviewing the images and other diagnostic results. Because of these variations, consult duration varied from 14 to 32 minutes in different studies [87, 88]. Studies showed that telestroke by itself might not decrease the DTN as there are variations in the subsects of stroke chain-of-care [89].

It has been shown that D-NC and Con play a major role in DTN [90]. Various factors including, when the consultant is notified, the time a consultant takes to interview the patient, and the experience level of the staff aiding with the examination will have to be considered while analyzing such data. The percentage of patients transferred after a telestroke consult to a destination hospital is also an important factor as it involves significant costs [67]. Data should be collected quantifying the rate of transfers after the consult and steps should be taken to minimize unnecessary transfers.

7.3 Outcome measures

The success of any program is ultimately decided by measuring outcomes, which could be patient related or system related. A modified Rankin scale, which is measured 90 days after a stroke, is the most commonly used measurement of

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stroke outcome [83]. Steps should be taken to ensure a 90-day follow-up on all the telestroke treated patients. No significant differences in mortality or morbidity were noted in patients in the hub and spoke hospitals of the TEMPiS network [91]. Even though 90-day outcomes after stroke are reported in most clinical trials, this data is not routinely collected by hospitals because of the cost and complexity involved. Data on stroke mimics that were treated by telestroke networks is an important factor as it plays a big role in minimizing costs, even though tPA administration might not increase the risk to these patients. Similarly, data on the percentage of patients receiving tPA through telestroke networks is very useful to compare with in-person stroke treatment numbers. In a study that examined several telestroke networks, the rate of tPA via telestroke was 18–36% compared to the national average tPA administration rate of 5–8% [91].

7.4 Patient/provider-related outcomes

Data collection regarding patient characteristics, NIHSS score pre/post-treatment and before discharge, length of hospital stay, discharge disposition (home vs. rehab vs. sub-acute rehab), readmission rate, complications including intracranial hemorrhage, other significant hemorrhages, mortality, and 90-day follow-up outcomes are recommended by the American Heart Association and the American Stroke Association [92]. One of the highest priorities for several healthcare systems is patient satisfaction. Attempts should be made to follow-up with the treated patients and family members about their satisfaction with the telestroke process. LaMonte et al. found that the telestroke process enhanced patient satisfaction in their study [93]. Measuring provider satisfaction is equally important for improving telestroke service quality. Studies showed that patients are more enthusiastic about telemedicine compared to providers even though both of the groups were satisfied [94]. Providers having less of a personal benefit was one of the possible reasons behind this discrepancy [92].

7.5 Technological quality measures

In a good telestroke program, the technology involved is as important as the physicians' clinical expertise. Video and audio conferencing equipment quality, transmission clarity, internet speed, user-friendliness of the software, accessibility of personnel training modules, and encryption of patient information in transit to protect patient privacy all play a role for effective delivery of telestroke care. All technical difficulties, failures, and limitations should be continuously monitored, documented, and analyzed promptly to prevent repeated occurrences.

Lastly, apart from the issues unique to telestroke, data on regular measures as recommended by National Quality Forum for stroke patients, including use of tPA, anti-thrombolysis therapy by day 2, thromboembolism prophylaxis, lipid-lowering medications on discharge, anti-thrombotic therapy on discharge, anticoagulation in the setting of atrial fibrillation, rehabilitation evaluation, and stroke education should be collected and evaluated regularly [95].

7.6 Quality measures: final thoughts

There are still challenges with current models. In the last 15 years, there has been a substantial improvement in stroke quality measures. Most of the measures are already being performed with a high compliance rate and innovation. They should be expanded to pre-hospitalization and post-hospitalization settings as well as to telestroke for further improvement of stroke care [62, 96–99]. Universal guidelines about definitions of times in stroke chain-of-care, protocols for consultant notification, and specific standard stepwise processes that can be applied universally for telestroke networks will be useful in standardizing telestroke models. As telestroke is becoming more popular in delivering care for acute stroke patients, there is a need for strict quality metrics to ensure safe and effective care for the patients. Even though in several aspects telestroke is as effective as in-person stroke care, there are several issues pertinent to telestroke like technology, policies, and challenges with data collection due to distant participating sites that need to be refined for effective and timely management of stroke patients.

8. Telestroke across the world

Lack of neurology coverage is not unique to the US; it is a problem worldwide [100]. Several countries in Europe have developed efficient telestroke networks [59, 64, 69, 101–103], with the TEMPiS network in Germany showing remarkable results [64, 104, 105]. The Telestroke Committee of the European Stroke Organization has recently published recommendations regarding telestroke networks in Europe concerning infrastructure, teleconsultation service, transfer options, standard operating procedures, professional training, and quality monitoring and improvement. They have also made recommendations about the technical and ethical aspects of telemedicine [106], which are similar to ones in the US.

Asia is quite heterogeneous in terms of variability in language, governments, culture, historical links, socioeconomic development, and organization of health services. In China, the National Telestroke Center, established in 2014, was designed to provide neurological coverage to 300 rural hospitals throughout the country through the telestroke network [107]. This was also the first platform where Google Glasses were used for real-time telestroke consults. The system is still evolving and data from China is still limited. In India, telestroke systems are still uncommon, but they show prospects for expansion, aiming to provide care to rural communities that are limited in their resources [108, 109]. Japan, Singapore, and South Korea have rather advanced nationwide medical systems, but telemedicine experience in these countries is still limited [110–112]. Teleneurology and telestroke have great potential to extend neurology expertise to underserved populations in the world; however, further investment in creating infrastructure and technology is needed before their impact on healthcare is realized.

9. Telestroke in the new era of novel coronavirus (COVID-19)

In December 2019, the first case of the novel coronavirus COVID-19 was identified in China [113]. Since then, the rapid spread of the virus has led to a worldwide pandemic [114]. The US has become the epicenter of this pandemic with the largest number of reported cases worldwide. Of all COVID-19 cases, an estimated 19% are healthcare personnel [115]. The COVID-19 pandemic has put a significant strain on healthcare personnel in providing in-person care, especially in an acute setting. Several States in the US and countries around the world have implemented stay-at-home orders. Hospitals have canceled elective procedures and outpatient in-person clinic visits to minimize the exposure risk to patients and healthcare workers. Additionally, COVID-19 is associated with an increased risk of thromboembolic complications [116]. This puts neurologists at risk of exposure while assessing patients with acute neurological deficits. Screening for symptoms of COVID-19 has also become difficult in the setting of neurological deficits, especially aphasia and encephalopathy. Most countries around the world, including the US, already suffer from a lack of adequate neurology coverage [100] and COVID-19 exposure not only puts neurologists' wellbeing and life at risk but also exacerbates this deficiency. This pandemic has brought the need and utility of telemedicine, teleneurology, and telestroke into the limelight [117–120]. Teleconsults are an effective way of providing outpatient care as well was acute care inside the hospitals, limiting the exposure risk to physicians and patients, as well as limiting the use of personal protective equipment which is in short supply. The pandemic may change the paradigm of teleneurology and telestroke permanently and force the system to adapt to its growing need at a much faster pace.

10. Hurdles and barriers

Despite the utility and efficacy of telestroke networks, there exist significant hurdles in establishing and efficiently sustaining a viable telestroke program.

10.1 Issues regarding reimbursement

The most important hurdle is third party reimbursement. It took decades for the concept of telemedicine to come to fruition, and pay parity kept telemedicine programs across the country from flourishing, sustaining, and expanding [121–126]. Without appropriate reimbursement, the burden of financial overhead in maintaining the high-quality video interface, teleneurology and teleradiology coverage, and costs of emergent care including imaging, tPA, and transportation to hub hospitals would make telestroke network unsustainable. The Centers for Medicare and Medicaid Services (CMS) has addressed the need for reimbursement for telemedicine services and third-party payers have followed suit [37, 121]. Appropriate reimbursement for teleservices remains a concern among providers [127] and continues to be a barrier for the expansion of telestroke networks to underserved areas of the country.

10.2 Licensure and credentialing constraints

Licensure and hospital credentialing, often across state lines, further burdens physicians and hospitals to spend resources, thus putting additional constraints on the expansion of these services. Physicians are required to maintain a license in the state where the spoke site is located in addition to the hub site where they usually work. This requires unrestricted licensure to be maintained in every state where the teleconsult is requested. A national or multistate license for telemedicine would reduce the necessity for a consultant to be licensed in multiple individual states, but this kind of license does not currently exist [128]. In 2011, CMS began allowing credentialing and privileging by proxy at small and critical-access hospitals, which has allowed these hospitals to rely on the credentialing and privileging process performed at the hub site [92, 129]. However, this policy needs to be adopted by all 50 states to mitigate the onus of licensing and credentialing on physicians and small hospitals. Also, reimbursement in cases where the patient receives tPA at the spoke site and is transferred to the hub hospital remains an issue, as neither the spoke nor hub facility is eligible to bill the higher Medicare diagnosis-related group codes that are associated with thrombolytic administration [128].

10.3 Infrastructure and technological challenges

Establishing and maintaining the infrastructure for high-quality video conferencing in small rural hospitals also adds to the financial burden on these hospitals. There is also marked heterogeneity in the platforms available, which spoke sites need to take into account before joining a telestroke model [37, 128]. Platform differences also limit the flexibility of these rural hospitals in terms of associating with more than one network or transitioning to a different network as the platforms utilized by these networks may be incompatible. Additionally, to comply with CMS billing requirements, a high-quality, two-way video connection is recommended and a minimum frame rate of at least 20 frames per second has been suggested [130]. Thus, high-speed internet is an essential component of telestroke networks. The availability of high-speed internet connections in rural parts of the country is limited and is a separate problem limiting the implementation of telestroke networks. These issues become exceedingly challenging in resource-limited countries around the world.

10.4 Physician buy-in and telestroke staff training

Convincing the leadership of potential spoke sites of the cost-effectiveness of joining a telestroke system requires time and effort on the part of the hub telestroke providers. Joining a telestroke system not only requires investment in infrastructure but also requires extensive training and development of protocols for teleconsults and transfers. These requirements may appear daunting to the leadership and hospital staff, especially at small rural hospitals with limited resources. However, the literature supporting the safety, cost-effectiveness, and improved patient outcomes related to telestroke networks may help encourage their buy-in to such programs. Joining such a system implies a long-term partnership between the hub and the spoke sites. Trust also needs to be established between the spoke site ED staff and consulting neurologists. Endorsements and testimony from the leadership of existing spoke sites in similar settings, hearing patient experiences from those who benefitted from these networks, and meeting with the team of consulting neurologists may prove useful in building this trust.

Along with the establishment of infrastructure for telestroke, medical staff at spokes sites need to be trained for ever-evolving telestroke protocols and joint commission requirements. They need to be able to recognize the early signs and symptoms of acute stroke, perform NIHSS exams, screen for eligibility for tPA, and to be proficient at using the teleconsult interface to facilitate the process efficiently. Telestroke systems can include stroke patient management training to spoke medical staff on education NIHSS exam demonstrations, reviews of alteplase reconstitution, administration and considerations, alteplase dosage calculations and telemedicine cart demonstration and review. Other patient management training can be provided to paramedics local to the spoke sites, these sessions typically include; impact of and time sensitivity of strokes, what is a stroke, types of stroke, stroke mimics, EMS neurological assessments, stroke management/prehospital guidelines and telemedicine and alteplase through an organizational system of care.

Given the wide variability of telestroke systems based on AHA/ASA guidelines and local governing factors, each network should develop an standard operating protocol (SOP) that suits their needs (**Tables 1**–**3**) [131]. The volume of teleconsults can vary greatly between the spoke hospitals, thus training needs to be reinforced at specified intervals to ensure efficient and seamless consults and to maintain high-quality patient care. This may lead to telemedicine fatigue in the staff at low-volume hospitals that needs to be mitigated during the training by emphasizing the importance of their work in the teleconsult system in their community at improving

American College of Cardiology/American Heart Association class of recommendation and level of evidence to clinical strategies, interventions, treatments, or diagnostic testing in patient care[*]

Class (strength) of recommendation

Class I (strong)—benefit >>> risk

Suggested phrases for writing recommendations:

- Is recommended
- Is indicated/useful/effective/beneficial
- Should be performed/administered/others
- Comparative-effectiveness phrases[†]:
  - Treatment/strategy A is recommended/indicated in preference to treatment B
  - Treatment A should be chosen over treatment B

Class IIa (moderate)—benefit >> risk

Suggested phrases for writing recommendations:

- Is reasonable
- Can be useful/effective/beneficial
- Comparative-effectiveness phrases[†]:
  - Treatment/strategy A is probably recommended/indicated in preference to treatment B
  - It is reasonable to choose treatment A over treatment B

Class IIb (weak)—benefit ≥ risk

Suggested phrases for writing recommendations:

- May/might be reasonable
- May/might be considered
- Usefulness/effectiveness is unknown/unclear/uncertain or not well established

Class III: no benefit (moderate) (generally, LOE A or B use only)—benefit = risk

Suggested phrases for writing recommendations:

- Is not recommended
- Is not indicated/useful/effective/beneficial
- Should not be performed/administered/others

Class III: harm (strong)—risk > benefit

Suggested phrases for writing recommendations:

- Potentially harmful
- Causes harm
- Associated with excess morbidity/mortality
- Should not be performed/administered/others

[*]*The outcome or result of the intervention should be specified (an improved clinical outcome or increased diagnostic accuracy or incremental prognostic information).*
[†]*For comparative-effectiveness recommendations (COR I and IIa; LOE A and B only), studies that support the use of comparator verbs should involve direct comparisons of the treatments or strategies being evaluated.*

Table 1.
American Heart Association summary of recommendations for telestrokes [131].

outcomes in patients who may have otherwise not had an opportunity for timely stroke intervention due to time lost in transportation to larger centers.

10.5 Data security and sharing

Telestroke networks, like traditional practices, are required to be compliant with HIPAA, which governs protected health information in the US. Given that telestroke

Level A
• High-quality evidence‡ from more than one randomized controlled trial (RCT) • Meta-analyses of high-quality RCTs • One or more RCTs corroborated by high-quality registry studies
Level B-R (randomized)
• Moderate-quality evidence‡ from one or more RCTs • Meta-analyses of moderate-quality RCTs
Level B-NR (nonrandomized)
• Moderate-quality evidence‡ from one or more well-designed, well-executed nonrandomized studies, observational studies, or registry studies • Meta-analyses of such studies
Level C-LD (limited data)
• Randomized or nonrandomized observational or registry studies with limitations of design or execution • Meta-analyses of such studies • Physiological or mechanistic studies in human subjects
Level C-EO (expert opinion)
• The consensus of expert opinion based on clinical experience

Class of recommendation (COR) and level of evidence (LOE) are determined independently (any COR may be paired with any LOE). A recommendation with LOE C does not imply that the recommendation is weak. Many important clinical questions addressed in guidelines do not lend themselves to clinical trials. Although RCTs are unavailable, there may be a very clear clinical consensus that a specific test or therapy is useful or effective.
‡The method of assessing quality is evolving, including the application of standardized, widely used, and preferably validated evidence grading tools; and for systematic reviews, the incorporation of an Evidence Review Committee.
COR, class of recommendation; EO, expert opinion; LD, limited data; LOE, level of evidence; NR, nonrandomized; R, randomized; and RCT, randomized controlled trial.

Table 2.
Level (quality) of evidence‡ [131].

Telemedicine	COR	LOE
1. For sites without in-house imaging interpretation expertise, teleradiology systems approved by the US Food and Drug Administration are recommended for timely review of brain imaging in patients with suspected acute stroke.	I	A
2. When implemented within a telestroke network, teleradiology systems approved by the US Food and Drug Administration are useful in supporting rapid imaging interpretation in time for IV alteplase administration decision making.	I	A
3. Telestroke/teleradiology evaluations of acute ischemic stroke (AIS) patients can be effective for correct IV alteplase eligibility decision making.	IIa	B-R
4. Administration of IV alteplase guided by telestroke consultation for patients with AIS may be as safe and as beneficial as that of stroke centers.	IIb	B-NR
5. Providing alteplase decision-making support via telephone consultation to community physicians is feasible and safe and may be considered when a hospital has access to neither an in-person stroke team nor a telestroke system.	IIb	C-LD
6. Telestroke networks may be reasonable for triaging patients with AIS who may be eligible for interfacility transfer to be considered for acute mechanical thrombectomy.	IIb	B-NR

Table 3.
American Heart Association/American Stroke Association guidelines for telemedicine [131].

networks rely on real-time data sharing between the spoke and the hub, data security becomes a concern. Data security requires end-to-end encryption on the sharing platform, reliable documentation and storage, strict control of access to users within the network, and cooperation between the information technology staff at both sites. To ensure 24-hour coverage, consulting physicians often use a mobile device for such calls and must be cognizant of their surroundings while consulting remotely. For example, most telestroke systems provide home accessibility for physician consults. Currently due to HIPPA rules the use of hand held mobile phones remains limited for detection of stroke. Given the renewed interest in telehealth with the COVID-19 pandemic, there is a potential for use of mobile phone application technology.

Healthcare data breaches have been on the rise with larger and teaching hospitals being at a greater risk [132, 133]. Given multiple points of entry and the potential for data breaches in telestroke networks, extra care is needed at the hub and spokes sites to ensure data safety. Despite these challenges, telestroke networks have shown to provide safe, efficient, and cost-effective stroke care to underserved communities. There is still enormous potential for telestroke networks to expand into rural areas of the country as well as around the world.

11. Conclusion

Since its conception, telestroke has expanded greatly in its scope and utility in bridging the gap in stroke care between the rural and urban communities, in both acute and continued care. Despite the challenges faced in establishing and sustaining telestroke networks, these networks are flourishing and expanding, creating an ever-evolving paradigm for stroke care throughout the country and around the world.

Conflict of interest

The authors have no conflicts of interest to disclose.

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