Published in final edited form as:
Curr Treat Options Cardiovasc Med. 2011 June ; 13(3): 215–224. doi:10.1007/s11936-011-0124-y.

Use of Telemedicine and Helicopter Transport to Improve Stroke Care in Remote Locations

Mihaela Saler, MD, **Jeffrey A. Switzer, DO**, and **David C. Hess, MD***
Department of Neurology, Georgia Health Sciences University, 1122 15th Street, Augusta, GA 30912, USA

Opinion statement

Intravenous recombinant tissue plasminogen activator is the only medication approved by the US Food and Drug Administration for treatment of acute stoke. Despite established efficacy, less than 3% of stroke patients receive treatment, and that number is even smaller for patients living in remote locations. This is in part due to a lack of neurologists and stroke specialists in these rural communities. The traditional model of "ship and drip" wastes crucial time, resulting in delays or loss of treatment. In this review, we discuss strategies to overcome geographic disparities in stroke care and improve acute treatment in remote locations. Helicopter transport from field to stroke center is one option to rapidly deliver patients to stroke centers. However, geography, weather, and unnecessary transport are potential drawbacks. Alternatively, "telestroke" facilitates remote evaluation of acute stroke patients via an audiovisual link and transmission of computerized tomography images. Despite the physical separation, stroke specialists are able to examine patients, review brain imaging and make correct treatment decisions; transfer to a stroke center can then be performed as appropriate. A cost-benefit analysis of telestroke is needed, although the recent proliferation of telestroke networks suggests an economic asset to some hospital systems.

Introduction

Stroke is a common, disabling, and often fatal disease. A stroke occurs every 40 s in the United States (US), and every 3.3 min someone dies from a stroke [1]. It is the number three cause of death in US, surpassed only by cardiovascular disease and cancer [1]. Stroke is the leading cause of long-term adult disability [2]. Among survivors, 15% to 30% will be permanently disabled and 20% will still require institutional care 3 months after a stroke [3]. Together, the direct and indirect costs of stroke in the US are estimated to be $53 billion annually and are expected to rise to over $2 trillion by 2050, with Hispanics and African-Americans disproportionately affected [4].

Management of stroke was significantly altered in 1996 when the US Food and Drug Administration approved intravenous (IV) tissue plasminogen activator (tPA) for use within 3 h of symptoms onset [5]. A subsequent 2008 European study showed that the administration of tPA may be beneficial up to 4.5 h after onset of symptoms, and the American Heart Association (AHA)/American Stroke Association (ASA) have issued a scientific advisory supporting treatment in selected candidates [6, 7]. In spite of established

*dhess@mcg.edu.

Disclosure
Mihaela Saler and Jeffrey A. Switzer and have no potential conflicts of interest relevant to this article. David C. Hess is a cofounder of REACH CALL, Inc, has founder's equity in REACH CALL, Inc, and is on the Board of Directors of REACH CALL, Inc.

efficacy its administration is still very limited, with only 2% to 3% of ischemic stroke patients receiving tPA [8].

Multiple factors account for the low rate of IV tPA use [9]. The most common reason for non-treatment is delay in hospital presentation [10]. However, for patients who arrive within a therapeutic window, fear of hemorrhagic complications and misunderstanding of the benefit to risk ratio prevents some emergency physicians from initiating treatment. Having stroke experts available for consultation in the emergency setting can overcome these hurdles.

Unfortunately, there is a significant shortage of physicians with expertise in acute stroke treatment. In the US, there are four neurologists per 100,000 persons, responsible for the care of approximately 800,000 acute stroke cases per year [3, 11]. In addition, there is an uneven geographical distribution of neurologists, with some states, such as Mississippi, having only 2 per 100,000 persons [11]. This creates a vacuum of neurologic expertise, particularly within rural areas. Compounding this shortage, many neurologists have discontinued their hospital privileges, prompting a crisis in call coverage [12]. The timeliness of treatment requires the availability of neurologists or other stroke specialists 24 h a day, 7 days a week.

Approximately 21% of the US population lives in rural areas [13]. This population has a higher risk for cardiovascular disease, including stroke, due in part to a higher incidence of obesity, hypertension, diabetes mellitus, and smoking [14]. In addition, as a result of the shortage of available medical personnel, treatment and follow-up for vascular risk factors is often incomplete. These inequalities in health care extend to the emergency stroke setting and make delivery of IV tPA unlikely. In rural areas there are fewer hospitals, requiring a longer distance to drive for emergency care. These hospitals are often small, with less than 100 beds, and some lack 24-hour CT capabilities or have no qualified personnel to interpret the CT. In addition, rural emergency departments (EDs) are often manned by local community or family medicine physicians without emergency medicine residency training. Neurologists and other stroke experts are concentrated in metropolitan areas and therefore unavailable for emergent in-person consultation. Finally, as a result of lower ED stroke volumes in these hospitals, staff may be less prepared to handle acute strokes when they present within a therapeutic window [15, 16].

To evaluate regional and geographic disparities in stroke care, Kleindorfer et al. [8] reviewed tPA treatment rates for ischemic stroke at the 4750 hospitals registered by Medicare Provider Analysis and Review (MEDPAR). Among 495,186 ischemic strokes over a 2-year interval in the Medicare dataset, only 11,884 were treated with tPA, representing 2.4% of the total. Sixty percent of the hospitals (representing roughly 40% of the US population) reported no tPA treatment. Hospitals without tPA use tended to be smaller (less than 100 beds in size) and located in less densely populated areas in the South and Midwest.

To increase rates of IV tPA administration and to assure a better quality of care for stroke, the Brain Attack Coalition (BAC) laid out the recommendations for the establishment of primary stroke centers (PSCs) [17]. In 2004, the Joint Commission started the certification of PSCs. As of October 1, 2009, there are more than 600 PSCs across the US [18]. However, most PSCs are located in metropolitan areas, and it has been difficult to extend the benefits of stroke certification to rural communities. In fact, less than 25% of the US population lives within 30 min of a PSC, and only half would be able to access a PSC within 1 h if state boundaries are respected by ground ambulance [19].

To improve rural stroke care and amplify rates of tPA administration, stroke systems of care must be designed to overcome distance and bring stroke specialists and patients together, either virtually or in person, while minimizing delays to treatment.

Treatment

- Different models of community stroke care have been implemented to deliver quality care to people living in underserved areas [20]. The traditional model of acute stroke management at underserved hospitals is often referred to as “ship and drip.” In addition, helicopter transport and “telestroke” are more commonly being integrated into systems of care to overcome geographic barriers to acute stoke treatment.

Ship and drip

- “Ship and drip” refers to the transportation of acute stroke patients from small hospitals that lack the expertise to administer and manage acute stroke, to larger hospitals that have the personnel to provide IV tPA and intensive care post-tPA management [21]. Transfer between centers may be by ground or air depending on time and distance.
- A prospective observational study using this approach was conducted from 1998 to 2000 in London, Ontario [22]. Patients with acute stroke who were first evaluated in a rural ED and then transferred to an academic medical center were compared with patients who presented directly to a London ED or were inpatients at the time of their stroke. For patients initially assessed at a community hospital, only patients who were capable of arriving within 3 h from onset of symptoms were transferred. A total of 82 patients were treated with IV tPA, 23 (28%) were transferred from a community hospital, 49 (60%) presented to the stroke center ED directly, and 10 (12%) were inpatients at the time of their stroke. The transfer was by ground with the average transfer time 89 min (46 to 138 min) over a mean distance 49 miles (11 to 80 miles). The mean time from onset of symptoms to arrival to stroke center was 123 min (76 to 168 min). A larger proportion of transferred patients (26%) were treated beyond 3 h (189 to 203 min). Patients transferred from outside hospitals had a significant shorter door to needle time within the London ED, 49 (21 to 81) compared to 95 min (42 to 174) for patients who presented directly to the stroke center ED; however this did not completely overcome the delays due to patient transport. The rate of symptomatic hemorrhages was similar. This study showed that it is feasible to transfer patients to facilities that are capable of administrating IV tPA located within 80 miles. However, because delays inherent in transport of patients decrease both the likelihood of treatment and the likelihood of a favorable outcome from IV tPA if treatment is administered, alternative strategies for rural stroke care are desirable [23].
- For patients ineligible for IV tPA or those that arrive at a PSC beyond the IV tPA window, endovascular clot retrieval may also be feasible. Nedeltchev et al. [24] described successful intra-arterial (IA) thrombolysis of patients initially evaluated at community hospitals. However, not surprisingly, evaluation and initial imaging at the outside facility resulted in delays to time of treatment [24].

Helicopter transfer

- One strategy to overcome delays in the “ship and drip” approach is to bypass the rural hospital altogether and have emergency medical services (EMS) deliver the patient directly to a stroke center. Because patients in rural communities may be

over a hundred miles from a PSC, helicopter transfer is necessary to cover large distances in a relatively short time. This model may be practical in areas that lack technological infrastructure required by telemedicine, or do not have a local hospital with a CT scanner, a requirement for tPA administration.

- As noted in the introduction, almost half of the US population resides more than 60 min from the nearest PSC. Even if ambulances cross state lines, 135.7 million Americans will still be more than 60 min away from a primary stroke center. By using air transportation, Albright et al. [19] estimate that this number could be reduced by more than half, to 62.9 million.
- Silliman et al. [25] analyzed a field to stroke center helicopter transfer approach to remote stroke care. The helicopter was available 24 h per day and the staff was composed of a pilot, nurse, and paramedic. The staff required significant training to recognize potential stroke patients. After identification of thrombolytic candidates, helicopter transport was activated and the patients were transported directly to the stroke center. Over a 3-year period, 111 field to stroke center air transports were performed; 85 patients (76%) were diagnosed with a cerebrovascular event, and 18 patients received tPA (15 IV and 3 IA). The flight radius was between 11 and 90 miles, with an average of 29.4 miles. This study confirmed good recognition of stroke by EMS and that helicopter transportation for acute thrombolysis in stroke is feasible. Bypassing small, rural EDs prevented further delays from initial triage and then transfer (“ship and drip”). However, patients with smaller deficits and those who did not receive tPA may have been manageable closer to home. Not all patients transported require thrombolysis or other acute treatment, and these patients may be appropriately managed at a local, rural hospital. Bypassing the rural hospital deprives these small hospitals of a potential revenue source from hospitalization of transient ischemic attacks to minor strokes and requires families to travel potential long distances to be close to their loved ones. A well-trained EMS staff able to accurately diagnose acute stroke patients is a necessity to minimize unnecessary air transportation. The authors noted the cost of a flight to be $3300 plus an additional fee of $45 per mile.
- Silbergleit et al. [26] performed a cost analysis of helicopter transport as a tool to facilitate stroke treatment. Parameters considered were the costs per additional good outcome (minimal or no disability defined as a modified Rankin score of 0 or 1 at 90 days) and per quality-adjusted life-year (QALY). When compared to other procedures for stroke care such as carotid endarterectomy (CEA), helicopter transport for stroke thrombolysis appeared cost-effective ($6100 per QALY for helicopter transfer and thrombolysis versus $4000 to $50,000 per QALY for carotid endarterectomy). The cost per flight was $3749 and was obtained by dividing the total cost for air medical service for 1 year by the number of flights performed at University of Michigan.
- Leira et al. [27, 28] investigated the possibility of early recruitment into acute stroke trials during inter-hospital helicopter transfer from remote areas. Their studies proved that it is a feasible alternative that requires minimal research-related training of medical staff [27, 28].
- Helicopter transport may be limited by geography and weather. The helicopter requires a clear area, free of obstructions of 60 ft by 60 ft during daytime and 100 ft by 100 ft at night for landing [25]. In addition, austere environmental conditions, including rain and snowfall, may delay or prevent air travel altogether. Also, a second method of transportation by air or ground must be available in case the stroke center is contacted for another possible acute stroke.

Telemedicine drip and ship

- Initial emergency assessment of stroke patients at rural hospitals including administration of IV tPA and subsequent transfer to stroke centers has been referred to as “drip and ship” [21]. This strategy is inherently attractive in that it avoids the delays in IV tPA that occur during transport of a patient from a rural emergency department to a PSC, delays which may result in loss of treatment or mitigate the benefit of thrombolysis.
- Some centers have successfully implemented telephone-only consultation to advise tPA administration. Frey et al. [21] demonstrated the safety of “tPA by telephone.” From 1998 to 2002, 53 patients from community hospitals were treated by IV tPA after phone consultation with a stroke specialist compared with 73 patients who were treated in-person by a neurologist. The inclusion and exclusion criteria were reviewed and recommendations for blood pressure treatment and fluid management were done by phone. Head CT was reviewed by radiologists and not by the consulting neurologist. Patients were transported to a stroke center from 43 “spoke” hospitals, covering a distance of up to 277 miles from the “hub.” tPA treatment was initiated at outside hospital and continued during flight. No complications related to flight were encountered. Many neurologists use this approach at their own institution, and when done together with CT interpretation by a radiologist may be satisfactory. However, some neurologists may not feel comfortable in administering a drug that has a small chance of a potentially fatal consequence without first being able to examine the patient or review the CT images themselves. In addition, telephone-only consultation makes distinguishing between a conversion disorder and stroke or encephalopathy and aphasia impossible. The safety and efficacy of tPA administration using a telephone system alone, without the ability to review a head CT, is not established [29].
- To circumvent the obstacles of telephone-only consultation, Levine and Gorman [30] described implementation of telemedicine for acute stroke care, which they termed “telestroke.” The goal was to facilitate correct medical decision making, in particular whether or not to administer IV tPA, despite the physical separation between neurologist and patient. In most telestroke networks, an ED physician initiates a call to the stroke specialist when a potential tPA candidate presents. Using an audio-video telecommunications link, the consultant can speak with patient and family to determine symptom onset, past history and potential contraindications, and perform a remote neurologic examination, such as the National Institutes of Health Stroke Scale (NIHSS). Vital signs, glucose level, other pertinent laboratory results can be reviewed and a CT head can be assessed for early infarct signs and hemorrhage. The risks and benefits of thrombolysis can be discussed with the ED physician, patient, and family, and transfer to a tertiary center facilitated following initiation of tPA. In addition, telemedicine allows for realtime evaluation of the patient, so alterations in management can be made in the case of worsening of symptoms, fluctuating blood pressure, or avoidance of unnecessary administration in patients with rapidly resolving symptoms.
- Although disparate technologies have been used for telestroke, the core requirement is a high-definition audiovisual system with pan, tilt, and zoom camera controls. Audio may be synched with the video display or performed separately via telephone. In addition, a CT scanner must be available at the remote site whereby Digital Imaging and Communications in Medicine (DICOM) images can be transferred to the consultant.

- Studies have demonstrated that an NIHSS done during a telestroke consultation is reproducible and accurate [31-34]. A remote NIHSS examination can be performed with minimal assistance locally from a nurse or physician. The AHA/ASA concluded that a remote NIHSS examination using telemedicine is comparable to an in-person assessment [29].
- Telestroke has become increasingly adopted by tertiary stroke centers to provide acute stroke care to patients in remote and underserved areas. The common paradigm of telestroke is a network of hospitals with a “hub” hospital (typically a PSC) and satellite hospitals or “spokes” that are small in size (under 100 beds), located remotely, and lack in-house neurology consultants.
- Multiple systems in the US and worldwide have demonstrated the feasibility of telemedicine for acute stroke assessment and treatment [35-38]. At the Medical College of Georgia (MCG), we initiated a rural telestroke hub and spoke network in 2003 [39, 40]. The network covers 10 small (less than 100 bed) rural hospitals between 37 and 127 miles, and an additional 7 larger (more than 100 bed), underserved suburban hospitals between 10 and 209 miles away from MCG. Onset to treatment time appears to be as fast as or faster than can be achieved in person at tertiary medical centers [41]. Because the smaller spokes lack intensive care units and post-tPA care requires at least 24 h of intensive monitoring, patients are typically transferred to the hub for further management (“drip and ship”). Alternatively, larger community hospitals may have the resources to admit and manage some post-tPA patients (“drip and keep”), requiring remote follow-up neurologic consultation.
- The Telemedical Pilot Project for Integrative Stroke Care (TEMPiS) in southern Bavaria compared five community hospitals with telemedical consultation for stroke with five community hospitals with no telemedicine support and no local stroke specialist. Remote consultation included both the acute presentation and inpatient management of stroke patients. The in-hospital mortality and symptomatic hemorrhage were not significantly different. Importantly, 44% of patients at hospitals with telemedicine support had a poor outcome at 3 months compared with 54% of patients at non-telemedicine hospitals ($P<0.0001$), suggesting that early, remote involvement of a stroke specialist has a significant benefit on long-term outcome [42].
- Moskowitz et al. [43] conducted a survey of 382 stroke specialists and 226 ED physicians regarding the implementation of telestroke for acute care of stroke. More than 90% of both stroke specialists and ED physicians agreed or strongly agreed with the statements that telestroke improves diagnosis and treatment, is superior to telephone consult, and will reduce regional disparities in stroke treatment. The biggest concern among ED physicians was regarding the complications of IV tPA and their management; however, they felt secure to administer tPA under the remote supervision of a stroke specialist.
- Patients who do not improve with IV tPA could be considered for IA tPA or mechanical clot extraction following interhospital transfer. Pfefferkorn et al. [44] described “drip, ship and retrieve” for patients with basilar artery occlusion and compared this to transfer of patients for IA therapy without preceding IV tPA administration. Treatment with IV tPA was initiated at the community hospitals under remote guidance with immediate transfer to the stroke center. Using “drip, ship and retrieve,” 92% of basilar artery occlusions were successfully recanalized and there was a significant increase in the proportion of independent patients when compared to IA therapy alone.

- Stroke trials suffer from protracted enrollment [45]. When compared with cardiology and oncology, there are far fewer investigators and enrolling centers. Patients living in remote locations are often not eligible for study participation for the same reasons that they are unlikely to receive standard of care thrombolysis, and when transported to enrolling centers they often arrive after the window for participation has closed. Telestroke may be able to overcome some of these hurdles by early identification of study participants, and possibly remote enrollment and administration of an investigational agent. For example, telestroke was successfully used to facilitate recruitment into time-sensitive acute stroke trials, including the Minocycline to Improve Neurological Outcome in Stroke and Factor Seven for Acute Hemorrhagic Stroke trials [46].
- Meyer et al. [47] analyzed the accuracy of telemedicine for acute stoke treatment. Two hundred and thirty-four patients with acute stroke were randomly assigned to a remote telemedicine or telephone consultation. The correct treatment decision was made more frequently in the telemedicine group (98% vs. 82%; P=0.0009). The telemedicine NIHSS was higher, a fact that may be explained by the ability of vascular consultant to directly exam the patient. No significant difference was found between the two groups regarding post-treatment intracerebral hemorrhages or mortality.
- Given the expanding evidence for acute stroke treatment using telemedicine, in 2009 the AHA/ASA laid out guidelines for the use of telestroke [29]. They recommended stroke expert consultation via telemedicine whenever local or onsite stroke expertise is insufficient to provide round the clock coverage.
- Despite established feasibility and effectiveness, and support from both emergency physicians and stroke specialists, many barriers to wider dissemination persist. Licensure limits telemedicine consultations across state lines, and hospital credentialing requires replication of paperwork. Nevertheless, teleradiology has successful overcome the hurdles to fill a void in radiology coverage. In addition, medicolegal concerns regarding telestroke persist among some practitioners. Most tPA-related malpractice cases result from non-treatment [48]. By increasing the odds of treatment, the extension of stroke expertise via telestroke to underserved hospitals likely reduces the overall liability to the health care system, hospital, and local physician.
- Financial sustainability is probably the biggest hurdle for telestroke. Telemedicine systems require onsite training, technical infrastructure, and support, and consultants may request on-call pay for coverage of a remote hospital. In addition, although hospital reimbursement for stroke care is augmented by the Centers for Medicare and Medicaid Services (CMS) when IV tPA is administered (to reflect the greater resource allocation and hospital costs associated with management of these patients), if the tPA is initiated at an outside facility (“drip and ship”) then the higher codes are not permissible. However, under the “drip, ship and retrieve” paradigm, hubs may profit from the higher reimbursement allocated to endovascular stroke treatment if patients arrive within a therapeutic window for an intervention. A comprehensive cost-benefit analysis of telestroke is needed.

References and Recommended Reading

1. Thom T, Haase N, Rosamond W, et al. American heart association statistics committee and stroke statistics subcommittee. Heart disease and stroke statistics-2006 update; a report from the American heart association statistics committee to stroke statistics subcommittee. Circulation. 2006; 113(6):e85–151. [PubMed: 16407573]

2. Prevalence of disabilities and associated health conditions among adults—United States. MMWR Morb Mortal Wkly Rep. 1999; 50(7):120–125.
3. 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; 40:2635–60. [PubMed: 19423851]
4. Brown DL, Boden-Albala B, Langa KM, et al. Projected costs of ischemic stroke in the United States. Neurology. 2006; 67:1390–5. [PubMed: 16914694]
5. NINDS rt-PA Stroke Study Group. Tissue plasminogen activator for acute ischemic stroke. N Engl J Med. 1995; 333:1581–7. [PubMed: 7477192]
6. Hacke W, Kaste M, Bluhmki E, et al. ECASS investigators. Thrombolysis with alteplase 3 to 4.5 hours after acute ischemic stroke. N Engl J Med. 2008; 359(13):1317–29. [PubMed: 18815396]
7. Del Zoppo GJ, Saver JL, Jauch EC, et al. Expansion of the time window for treatment of acute ischemic stroke with intravenous tissue plasminogen activator: a science advisory from the American heart association/American stroke Association. Stroke. 2009; 40(8):2945–8. [PubMed: 19478221]
8. Kleindofer D, Xu Y, Moomav CJ. US geographic distribution of rt-PA utilization by hospital for acute ischemic stroke. Stroke. 2009; 40:3580–4. [PubMed: 19797701]
9. Bambauer KZ, Johnston SC, Bambauer DE, et al. Reasons why few patients with acute stroke receive tissue plasminogen activator. Arch Neurol. 2006; 63(5):661–4. [PubMed: 16682535]
10. CASPR. Prioritizing interventions to improve rates of thrombolysis for ischemic stroke. Neurology. 2005; 64:654–9. [PubMed: 15728287]
11. Bradley WG. Neurology in the next two decades: report of the workforce task force of the American academy of neurology. Neurology. 2000; 54(4):787. [PubMed: 10690963]
12. Switzer JA, Levine SR, Hess DC. Telestroke 10 years later-'telestroke 2.0'. Cerebrovasc Dis. 2009; 28:323–30. [PubMed: 19628933]
13. Census 2000 Population statistics. Available at http://www.fhwa.dot.gov/planning/census [Accessed November 2010]
14. Eberhardt MS, Pamuk ER. The importance of place of residence: examining health in rural and non-rural areas. Am J Public Health. 2004; 94(10):1682–6. [PubMed: 15451731]
15. Leira EC, Pary JK, Davis PH, et al. Slow progressive acceptance of intravenous thrombolysis for patients with stroke by rural primary care physicians. Arch Neurol. 2007; 64:518–21. [PubMed: 17420312]
16. Leira EC, Hess DC, Torner JC, et al. Rural-urban differences in acute stroke management practices. A modifiable disparity. Arch Neurol. 2008; 56(7):887–91. [PubMed: 18625855]
17. Alberts MJ, Hademenos G, et al. Recommendations for the establishment of primary stroke centers. Brain attack coallition. JAMA. 2000; 283(23):3102–9. [PubMed: 10865305]
18. Facts about Primary Stroke Center Certification. Available at http://www.jointcommission.org/assets/1/18Primary_Stroke_Certification.Pdf [Accessed November 2010]
19. Albright KC, Branas CC, Meyer BC, et al. Acute cerebrovascular care in emergency stroke systems. Arch Neurol. 2010; 67(10):1210–8. [PubMed: 20937948]
20. Switzer JA, Hess DC. Development of regional programs to speed treatment of stroke. Curr Neurol Neurosci Rep. 2008; 8:35–42. [PubMed: 18367037]
21. Frey JL, Jahnke HK, Goslar PW, et al. tPA by telephone: extending the benefits of a comprehensive stroke center. Neurology. 2005; 64:154–6. [PubMed: 15642925]
22. Merino JG, Silver B, Wong E, et al. Extending tissue plasminogen activator use to community and rural stroke patients. Stroke. 2002; 33:141–6. [PubMed: 11779903]
23. Lees KR, Bluhmki E, von Kummer R, et al. Time to treatment with intravenous alteplase and outcome in stroke: an update pooled analysis of ECASS, ATLANTIS, NINDS and EPITHET trials. Lancet. 2010; 375(9727):1695–703. [PubMed: 20472172]
24. Nedeltchev K, Arnold M, Brekenfeld C, et al. Pre- and in-hospital delays from stroke onset to intra-arterial thrombolysis. Stroke. 2003; 34:1230–4. [PubMed: 12702836]

25. Silliman SL, Quinn B, Huggett V, et al. Use of a field- to stroke center helicopter transport program to extend thrombolytic therapy to rural residents. Stroke. 2003; 34:729–33. [PubMed: 12624299]
26. Silbergleit R, Scott PA, Lowell MJ, et al. Cost-effectiveness of helicopter transport of stroke patients for thrombolysis. Acad Emerg Med. 2003; 10:966–72. [PubMed: 12957981]
27. Leira EC, Lamb DL, Nugent AS, et al. Feasibility of acute clinical trials during aerial interhospital transfer. Stroke. 2006; 37:2504–7. [PubMed: 16946166]
28. Leira EC, Ahmed A, Lamb DL, et al. Extending acute trials to remote populations. A pilot study during interhospital helicopter transfer. Stroke. 2009; 40:895–90. [PubMed: 19131655]
29. Schwamm LH, Holloway RG, Amarenco P, 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; 40:2616–34. [PubMed: 19423852]
30. Levine SR, Gorman M. "Telestroke": the application of telemedicine for stroke. Stroke. 1999; 30:464–9. [PubMed: 9933289]
31. Shafqat S, Kvedar JC, Guanci M, et al. Role for telemedicine in acute stroke. Feasibility and reliability of remote administration of the NIH stroke scale. Stroke. 1999; 30(10):2141–5. [PubMed: 10512919]
32. 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. [PubMed: 14615620]
33. Wang S, Lee SB, Pardue C, et al. Reliability of national institutes of health stroke scale via telestroke. Stroke. 2003; 34:e188–92. [PubMed: 14500929]
34. Meyer BC, Lyden PD, Al-Khoury L, et al. Prospective reliability of the STRokE DOC wireless/site independent telemedicine system. Neurology. 2005; 64(6):1058–60. [PubMed: 15781827]
35. LaMonte MP, Bahouth MN, Hu P, et al. Telemedicine for acute stroke. Triumphs and pitfalls. Stroke. 2003; 34:725–8. [PubMed: 12624298]
36. Schwamm LH, Rosenthal ES, Hirshberg A, et al. Virtual TeleStroke support for the emergency department evaluation of acute stroke. Acad Emerg Med. 2004; 11(11):1193–7. [PubMed: 15528584]
37. Audebert HJ, Kukla C, von Claranau SC, et al. Telemedicine for safe and extended use of thrombolysis in stroke: the telemedic pilot project for integrative stroke care (TEMPiS) in Bavaria. Stroke. 2005; 36(2):287–91. [PubMed: 15625294]
38. Demaerschalk BM, Bobrow BJ, Raman R, et al. Stroke team remote evaluation using a digital observation camera in Arizona. The initial mayo clinic experience trial. Stroke. 2010; 41:1251–8. [PubMed: 20431081]
39. Hess DC, Wang S, Hamilton W, et al. REACH. Clinical feasibility of a rural telestroke network. Stroke. 2005; 36:2018–20. [PubMed: 16051892]
40. Wang S, Gross H, Lee SB, et al. Remote evaluation of acute stroke in rural community hospitals in Georgia. Stroke. 2004; 35:1763–8. [PubMed: 15166386]
41. Switzer JA, Hall C, Gross H, et al. A web-based telestroke system facilitates rapid treatment of acute ischemic stroke patients in rural emergency departments. J Emerg Med. 2009; 36(1):12–8. [PubMed: 18242925]
42. Audebert HJ, Schenkel J, Heuschmann PU, et al. 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. [PubMed: 16914402]
43. Moskowitz A, Chan YF, Bruns J, et al. Emergency physician and stroke specialist beliefs and expectations regarding telestroke. Stroke. 2010; 41:805–9. [PubMed: 20167910]
44. Pfefferkorn T, Holtmanssoptter M, Schmidt C, et al. Drips, ship and retrieve. Cooperative recanalization therapy in acute basilar artery occlusion. Stroke. 2010; 41:722–6. [PubMed: 20150550]
45. Elkins JS, Khatabi T, Fung L, et al. Recruiting subjects for acute stroke trials: a meta-analysis. Stroke. 2006; 37(1):123–8. [PubMed: 16322489]
46. Switzer JA, Hall CE, Close B, et al. A telestroke network enhances recruitment into acute stroke trials. Stroke. 2010; 41:566–9. [PubMed: 20056929]

47. Meyer BC, Raman R, Hemmen T, et al. Efficacy of site-independent telemedicine in the STRokE DOC trail: a randomized, blinded, prospective study. Lancet Neurol. 2008; 7(9):787–95. [PubMed: 18676180]

48. Weintraub MI. Thrombolysis (tissue plasminogen activator) in stroke: a medicolegal quagmire. Stroke. 2006; 37(7):1917–22. [PubMed: 16728683]