

Cost Utility of Hub-and-Spoke Telestroke Networks From Societal Perspective

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Background: A hub-and-spoke telestroke network is an effective way to extend quality emergency stroke care to remote hospitals and improve patient outcomes.

Objectives: To evaluate the cost utility of a telestroke network in the management of acute ischemic stroke from the societal perspective.

Study Design and Methods: A lifetime Markov model was developed to compare the incremental costs and effectiveness of a telestroke network. One-year transition probabilities between the 3 health states based on the modified Rankin scale—minimal-to-no disability, moderate-to-severe disability, and death—were derived from literature. Costs included telemedicine setup and maintenance, initial and recurrent stroke treatment, rehabilitation, long-term care, and caregiver costs. Effectiveness was defined as quality-adjusted life-years (QALYs). Model inputs were obtained from the literature supplemented by data from Georgia Health Sciences University and Mayo Clinic. The base case network included 1 hub and 7 spokes, and assumed no survival benefits from acute treatment in a network. One-way sensitivity analyses were conducted.

Results: Compared with no network, patients treated in a telestroke network incurred \$1436 lower costs and gained 0.02 QALYs over a lifetime. Incremental costs decreased from \$444 for the first year to -\$1436 over a lifetime; incremental QALYs increased from 0.002 for the first year to 0.02 over a lifetime. Overall, results were robust in the 1-way sensitivity analyses. A telestroke network became less cost-effective with increasing spoke-to-hub transfer rates.

Conclusions: A telestroke network is cost saving and more effective compared with no network from the societal perspective in most modeled scenarios.

Am J Manag Care. 2013;19(12):976-985

For author information and disclosures,
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Stroke is a leading cause of severe disability, and the fourth-leading cause of death in the adult population in the United States.^{1,2} Acute ischemic stroke (AIS) accounts for more than 80% of all strokes.³ Administration of intravenous (IV) thrombolysis within a 3-hour window of the onset of AIS reduces disability.⁴ A recent clinical trial has demonstrated that IV thrombolysis administered between 3 and 4.5 hours after the onset of AIS could also significantly improve clinical outcome.⁵ Extending the 3-hour traditional time window by 1.5 hours is likely to increase the demand for IV thrombolysis because more AIS patients would present to the hospitals in time for treatment.

Despite the effectiveness of IV thrombolysis, fewer than 5% of patients who suffer AIS in the United States receive IV thrombolysis.⁶ One of the major barriers to IV thrombolysis administration is that most hospitals do not have the resources required to enable timely diagnosis and treatment of AIS patients. Hospitals with access to qualified personnel (eg, 24/7 on-call vascular neurologists) are most likely to provide care due to the time limitation. However, it is not feasible for every hospital to meet such resource and personnel requirements, especially those in remote rural areas. To serve communities without a stroke center, telestroke referral networks have been set up to connect a stroke center (the hub hospital) with local hospitals (spoke hospitals) and thus extend the reach of the acute stroke care team of the hub hospital to spoke hospitals. Through this establishment, AIS patients can receive more accurate diagnoses, more correct thrombolysis eligibility determination, and more appropriate emergency treatment, all resulting in potentially better prognoses. For instance, research studies revealed that telestroke results in correct diagnosis and thrombolysis decision making in 96% of instances.⁷

A hub-and-spoke telestroke network is an effective way to extend quality emergency stroke care to remote hospitals and improve patient outcomes. The costs associated with these networks, as well as the health-related outcomes, must be considered. We previously conducted a cost-effectiveness analysis (CEA) from the hospitals' perspective.⁸ Building on that model,⁸ the current study aimed to assess the cost utility of a hub-and-spoke telestroke network compared with no network (absence of regional

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stroke system of care and telemedicine) in the management of AIS from the societal perspective. Two such studies were published and subsequently independently appraised and scored by the Tufts Medical Center Cost Effectiveness Analysis Registry.^{9,10} However, our study was the first to develop a cost decision model that included the possibility of endovascular therapy in addition to IV thrombolysis and the first to include an expanded array of cost inputs associated with dedicated network program managers and personnel, higher estimates of inpatient care, inter-hospital transfer, rehabilitation, long-term care, and caregiver costs, as well as a wider range of spoke-to-hub transfer rates, using 2 independent telestroke network data input sets.

METHODS

Model Overview

A Markov model was developed to estimate the incremental costs and effectiveness with and without a telestroke network for the management of AIS over a lifetime. The model had 3 health states defined by the modified Rankin scale (mRS)¹¹: (1) minimal-to-no disability (mRS 0-2); (2) moderate-to-severe disability (mRS 3-5); and (3) death (mRS 6). A hypothetical cohort of AIS patients with a mean age of 68 years were assumed to receive acute care in a telestroke network versus a no-network setting and to transition between these health states at the beginning of each cycle (1 year). The mean age of 68 years was obtained from a US epidemiology study of patients with first-time stroke.¹² **Figure 1** illustrates the decision and treatment process for AIS and subsequent transitions. Building on the previous model,⁸ the base case of this study modeled a network with 1 hub and 7 spokes, with a total of 1112 unique AIS patients presenting to emergency departments in the network hospitals per year. The number of spoke hospitals in the network was based on a recent survey of active telestroke networks by Silva and colleagues,¹³ and the average number of AIS patients for spoke hospitals was obtained from the Georgia Health Sciences University and the Mayo Clinic telestroke networks. The number of AIS patients for the hub hospital was assumed to be 400, based on the typical size of a hub hospital. Data on network characteristics were obtained from the Georgia Health Sciences University and the Mayo Clinic telestroke networks (see **eAppendix** available at www.ajmc.com); these data were described in a study based

Take-Away Points

- This health economic study demonstrated that compared with a rurally located patient receiving routine stroke care at a community hospital, a patient treated in a telestroke network incurred \$1436 lower costs and gained 0.02 quality-adjusted life-years over a lifetime.
- The telestroke network was economically dominant over routine care.
- The results serve to inform government organizations, insurers, healthcare institutions, practitioners, patients, and the general public that an up-front investment in telemedicine and stroke network personnel can be justified in our health system.
- Insurance plans should reimburse telestroke consultations in the same fashion as face-to-face clinical encounters.

on the same network.⁸ The following assumptions were made in the model estimation:

- Acute ischemic stroke patients could only transition from a less severe to a more severe health state or remain in the same health state at each cycle.
- Stroke treatments between a telestroke network and no network differed only during the initial hospitalization for AIS, not after discharge from acute care.
- Incremental effectiveness associated with treatments in a telestroke network only resulted from IV thrombolysis or endovascular stroke therapy during the initial hospitalization for the first-time AIS.
- There was no difference in stroke-related mortality between patients with and without IV thrombolysis, and between patients with and without endovascular stroke therapy during hospitalization. We made these assumptions because clinical trials on IV thrombolysis did not show a significant difference in mortality between patients who received IV thrombolysis and patients who did not, though the former group had a numerically lower rate.^{4,14} In addition, there was also a lack of randomized controlled trial data comparing the efficacy of endovascular stroke therapy with no such therapy.^{15,16} Therefore, we assumed no mortality difference in mortality in the base case, which could be a conservative assumption.
- Rate of recurrent stroke was the same regardless of the treatment received during the initial hospitalization for AIS.

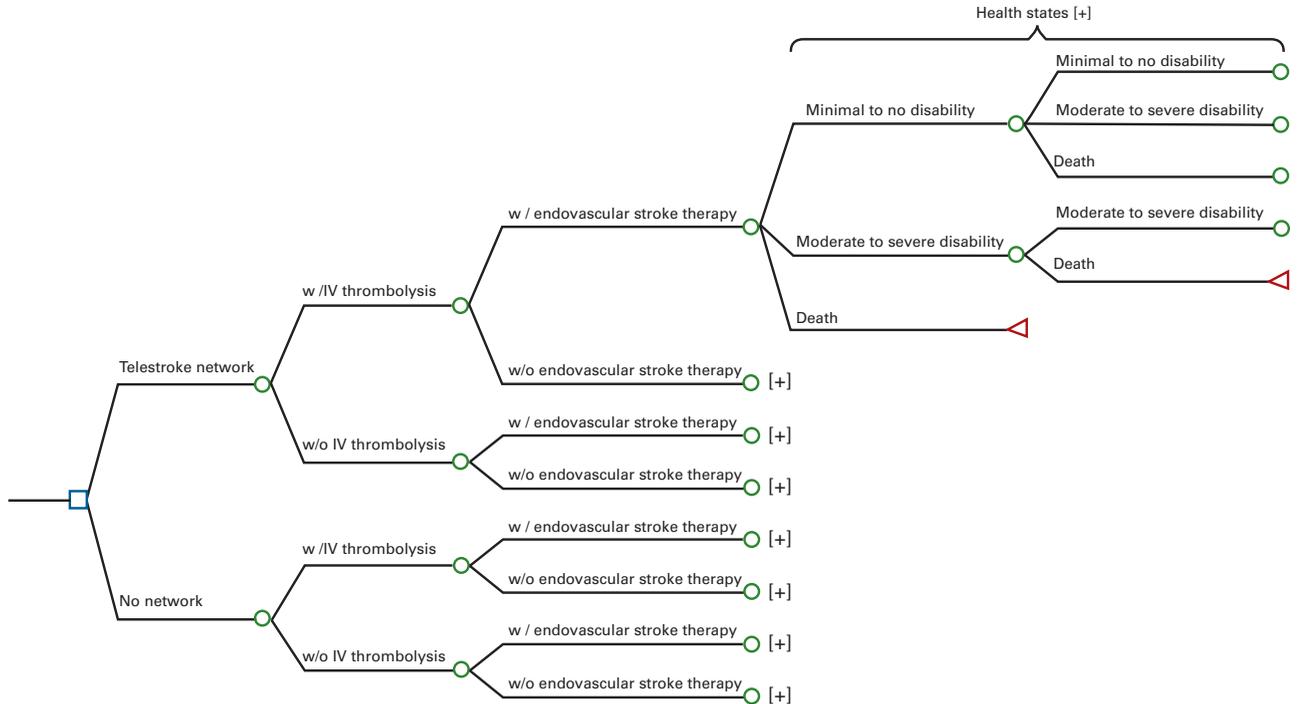
Model Inputs

Model inputs included 3 major groups: health state distributions, costs, and utilities.

Health State Distributions

Health state distributions at the end of each cycle were decided by the initial health state distribution and transition probabilities per cycle. The initial health state distribution was based on mRS at 3 months, which was determined by the type of acute treatment for AIS (ie, IV thrombolysis, endovascular stroke therapy). Although mRS can change within the first year of AIS, it tends to stabilize after 3 months.¹⁷

■ **Figure 1.** Decision Model



IV indicates intravenous; w/, with; w/o, without.

Therefore, mRS at 3 months was a good proxy for the health state for the first year among AIS patients. Data on mRS at 3 months for IV thrombolysis with different onset-to-treatment times and endovascular stroke therapies were obtained from clinical trials,^{14,16} and were adjusted based on the assumption that mortality was the same for patients with versus without IV thrombolysis and for those with endovascular stroke therapy versus without endovascular stroke therapy (see eAppendix).

Transition probabilities (Table 1¹⁸⁻²⁹) were estimated based on recurrent stroke rate and mRS after recurrent strokes. Recurrent stroke rate was different for the first year after stroke and subsequent years.²⁴ Modified Rankin scale distribution after recurrent strokes for patients with minimal to no disability was assumed to be the same as that among first-time AIS patients without IV thrombolysis and endovascular stroke therapy.^{14,30} Recurrent stroke increased the mortality rate among patients with moderate-to-severe disability compared with those with minimal to no disability.³⁰ Because the post acute stroke treatments did not differ between a telestroke network and no network, the transition probabilities after first-time AIS were the same for the 2 settings. In addition, all patients transitioned to death based on the age-specific natural death rate reported for the US general population.³¹

Cost Inputs

Costs included the following components: (1) telestroke setup and maintenance costs, (2) initial hospitalization costs, (3) post acute stroke care costs (including rehabilitation and nursing home costs), and (4) caregiver costs, which were obtained from the literature and publicly available data (Table 1). Rehabilitation costs (both inpatient and others) were onetime costs assumed to occur after each episode of stroke. Nursing home costs and caregiver costs were incurred as long as patients were alive. All cost inputs were inflated to 2011 US dollars using the medical care services component of the Consumer Price Index.²⁹

Utility Inputs

Utility values associated with minimal to no disability and moderate to severe disability among stroke patients, as measured by the EuroQol, were obtained from the literature.²³ Death was assumed to have a utility of 0.

Model Outputs

Model outputs included total incremental costs, incremental effectiveness outcomes, and incremental cost-effectiveness ratios (ICERs) comparing an AIS patient treated within a telestroke network with an AIS patient treated outside a telestroke network. Total incremental costs included all com-

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■ Table 1. Model Inputs

Model Inputs	Value	
Additional patients in each health state after initial hospitalization in telestroke network vs no network		
Minimal to no disability	6.34 ^a	
Moderate to severe disability	-6.34 ^a	
Death	0.00 ^a	
Transition probabilities^b	First Year	Subsequent Years
Minimal to no disability:		
To minimal to no disability	0.9066 ^b	0.9825 ^b
To moderate to severe disability	0.0686 ^b	0.0129 ^b
To AIS-related death	0.0249 ^b	0.0047 ^b
Moderate to severe disability:		
To moderate to severe disability	0.9445 ^b	0.9896 ^b
To AIS-related death	0.0555 ^b	0.0104 ^b
Network setup and maintenance (one-time costs for the initial hospitalization)	Costs	
Hub hospital		
Network program manager	\$54,671 ^{8,18}	
Personnel	\$91,615 ^{8,18}	
Videoconferencing system	\$831 ^{8,18}	
Other	\$4257 ^{8,18}	
Spoke hospital		
Telemedicine system	\$28,252 ^{8,18}	
Maintenance fee	\$5193 ^{8,18}	
Treatment costs per patient		
Inpatient costs (per event)		
No IV thrombolysis	\$9847 ^c	
IV thrombolysis	\$17,684 ^c	
Endovascular stroke therapy	\$44,934 ^c	
Outpatient costs (per event)		
Inter-hospital transfer	\$5182 ^d	
Drug cost (WAC) (per event)		
Alteplase 90 mg	\$3779 ^{8,19}	
Post acute stroke care costs per patient		
Rehabilitation cost (per event)		
Inpatient	\$21,688 ²⁰	
Other rehabilitations	\$10,941 ²⁰	
Long-term care cost (annual)		
Nursing home	\$77,745 ²¹	
Caregiver cost (hourly)		
Wage	\$23 ^e	

(Continued)

■ **Table 1. Model Inputs (Continued)**

Model Inputs	Value
Resource utilization for post acute stroke care	
Percent	
Inpatient rehabilitation	
Patients with moderate to severe disability	49% ^{11,17}
Patients with minimal to no disability	0% ^{11,17}
Other rehabilitation	
Patients with moderate to severe disability	33% ^{11,17}
Patients with minimal to no disability	100% ^{11,17}
Nursing home	
Patients with moderate to severe disability	60% ^{11,17}
Patients with minimal to no disability	5% ^{11,17}
Caregiver time	
Hours/week	
Patients with moderate to severe disability	18.6 ²²
Patients with minimal to no disability	8.6 ²²
Utility associated with modified Rankin scale	
Minimal to no disability	0.74 ²³
Moderate to severe disability	0.38 ²³
Death	0.00 ²³

AIS indicates acute ischemic stroke; IV, intravenous; MS-DRG, Medicare Severity Diagnosis-Related Group; WAC, wholesale acquisition cost.

^a Number of patients based on modified Rankin scale at 3 months, which was determined by the type of acute treatment received (see eAppendix, Supplemental Methods: Network Characteristics and Supplemental Methods: Effectiveness Input Estimation).

^b Based on stroke recurrence rate and outcomes.^{14,24}

^c Based on MS-DRG^{8,19,25,26}:

- Hospitalization for AIS with IV thrombolysis: MS-DRG codes 61-63.
- Hospitalization for AIS without IV thrombolysis: MS-DRG codes 64 and 65.
- Hospitalization for endovascular stroke therapy: *International Classification of Diseases, Ninth Revision, Clinical Modification* procedure code of 39.74 and MS-DRG codes 23 and 24.

^d Based on weighted average of air and ground transportation costs.^{8,27,28}

^e Average hourly wage among the US adult population.²⁹

ponents described above and were summed across all model cycles. Incremental effectiveness was measured as quality-adjusted life-years (QALYs), calculated as life years spent in each health state weighted by the utility of that health state. Cost and effectiveness outcomes were discounted at 3% per year in the base case.

Sensitivity Analysis

To determine whether the results were sensitive to certain parameters in the model, 1-way sensitivity analyses were performed by varying 1 model input at a time while holding other model inputs at the base case values. Parameters included in the sensitivity analyses were (1) annual recurrent stroke rate in the first year and subsequent years; (2) transition probability of disability or death after recurrent strokes; (3) utility inputs; (4) inpatient rehabilitation costs, other rehabilitation costs, and nursing home costs; (5) caregiver costs; (6) setup and maintenance costs of telestroke systems; and (7) network characteristics (eg, number of spoke hospitals, spoke-to-hub transfer rate, IV thrombolysis rate, endovascular stroke ther-

apy rate among transferred patients). The majority of inputs were varied within plus or minus 25% of the base case values, except for inpatient rehabilitation costs among stroke patients with minimal-to-no disability, in which case 5% and 10% utilization rates were assumed. A 2-way sensitivity analysis was also performed by varying both spoke-to-hub transfer rate (from 0% to 100%) and endovascular stroke therapy rate among transferred patients (with 25% and 50% of the base case value).

RESULTS

The base case model demonstrated that over a lifetime the telestroke network was both cost saving and more effective, and was therefore a dominant strategy compared with no network, though in the short term (eg, 1 year) the network was more costly than no network (Table 2). Specifically, the telestroke network resulted in incremental cost savings of \$1436 per patient over a lifetime horizon, with the greatest cost savings attributable to decreased nursing home care. The

■ **Table 2.** Base Case Cost-Effectiveness Results

Variable	One Year	Lifetime
Incremental costs (discounted, 2011 US dollars)		
Stroke network	\$444	-\$1436
Initial hospitalization	\$297	\$297
Hospitalization for recurrent stroke	\$396	\$396
Inpatient rehabilitation	\$0	\$1
Other rehabilitation	-\$59	-\$48
Nursing home	\$41	\$55
Loss of productivity	-\$236	-\$2227
Loss of productivity	\$5	\$89
Incremental effectiveness (discounted)		
Incremental QALYs	0.0020	0.0220
ICER (discounted)		
Cost per QALY	\$223,182	Dominant

ICER indicates incremental cost-effectiveness ratio; QALY, quality-adjusted life-year.

incremental effectiveness in terms of QALYs was minimal (0.002 per patient) in the 1-year time horizon, but increased to 0.02 per patient in the lifetime scenario (Table 2).

The changes in costs and QALYs over time are illustrated in **Figure 2**, with incremental costs associated with a telestroke network decreasing and incremental QALYs increasing over time. Both the costs and effectiveness start to level out at about 20 years.

The 1-way sensitivity analyses showed that the results were robust, with a telestroke network being the dominant strategy in all scenarios except when the spoke-to-hub transfer rate was varied (**Figure 3**). The discounted cost savings for the network compared with no network ranged from about \$1000 to \$1900 per patient over a lifetime. The incremental effectiveness ranged from an incremental 0.01 to 0.03 QALYs per patient (Figure 3). When varying the transfer rate from 0% to 100%, the model showed that the network remained a dominant strategy when the transfer rate increased to 60% and remained cost-effective with a willingness-to-pay threshold of \$50,000 per QALY when the transfer rate increased to 90%. The 2-way sensitivity analysis showed that the ICER was not sensitive to changes in the endovascular stroke therapy rate. When the rate was reduced to 25% and 50% of the base case value, the network remained cost-effective with a willingness-to-pay threshold of \$50,000 per QALY, with transfer rates of 83% and 80%, respectively.

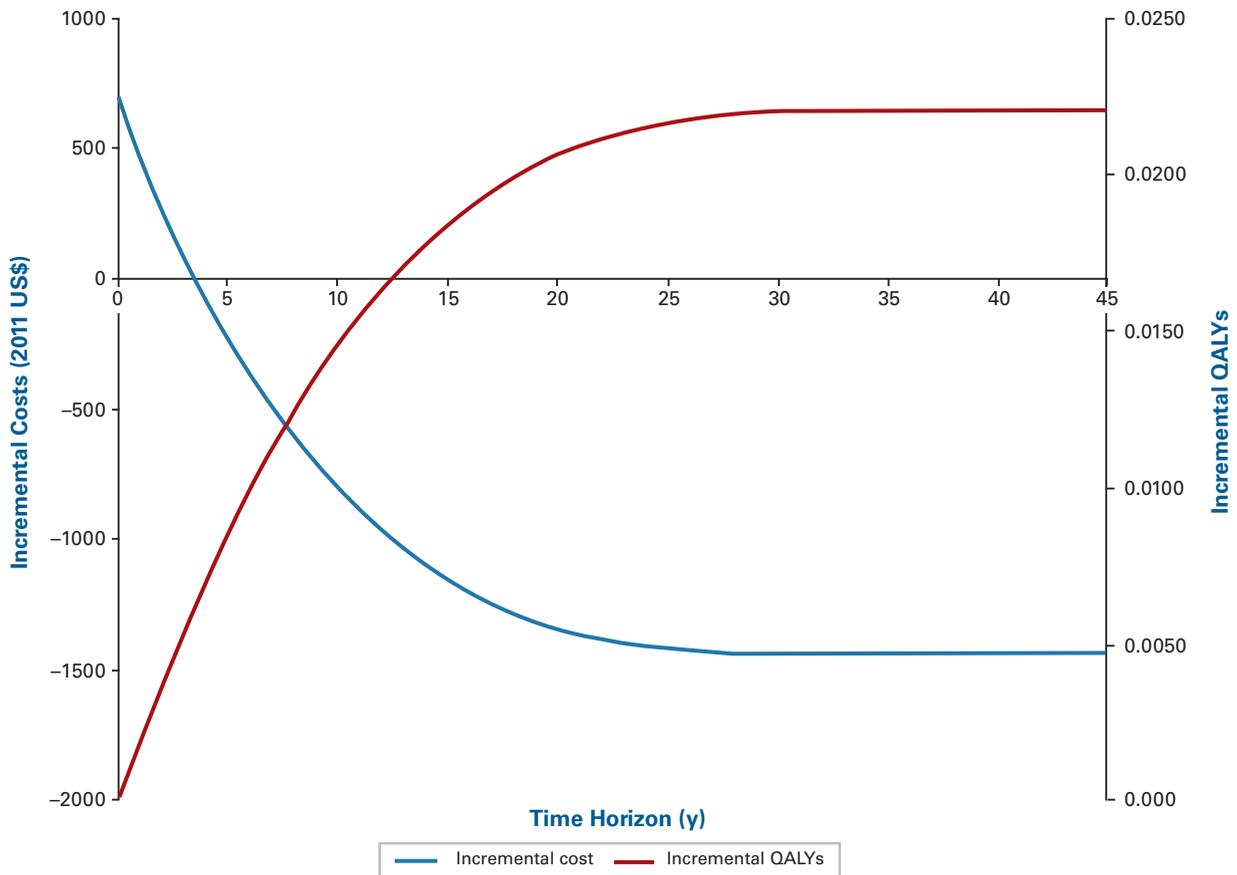
DISCUSSION

This cost utility analysis of hub-and-spoke telestroke networks examined the incremental costs and effectiveness of a

telestroke network compared with no network for the management of AIS from a societal perspective. Building on our previous work on the CEA of a telestroke network from hospitals' perspective,⁸ the current CEA took the societal perspective, which considered not only costs and outcomes up to the point of hospital discharge, but also all subsequent costs and outcomes following the initial hospitalizations. The costs included the proportion borne by hospitals as well as other components borne by society. Stroke is a leading cause of severe disability in the United States and poses substantial economic and quality-of-life burdens to patients, families, healthcare systems, and society as a whole. A societal perspective allows a more comprehensive assessment of the cost-effectiveness of a telestroke network.

In the base case, the model estimated that treating an AIS patient in the telestroke referral network was cost saving over a lifetime horizon, with approximately the same effectiveness as no network. The results were robust in the 1-way sensitivity analysis that varied most of the model inputs within the plus or minus 25% range of the base case values. In all these scenarios, the telestroke referral network was associated with less cost and more QALYs. When expanding the range of transfer rates from 0% to 100%, the analysis showed that a telestroke network remained cost-effective based on a willingness-to-pay threshold of \$50,000 per QALY up to a 90% transfer rate. An average spoke-to-hub transfer rate of more than 90% may happen in a network when all spoke hospitals are small hospitals (eg, <20 beds). However, this may be a rare setup for a telestroke network. In order to be financially sustainable, a telestroke network often is limited to small and medium-sized hospitals (about 100 beds) or medium-sized hospitals

■ **Figure 2.** Incremental Costs and QALYs per AIS Patient Over Time



AIS indicates acute ischemic stroke; QALY, quality-adjusted life-year; US\$, US dollars.

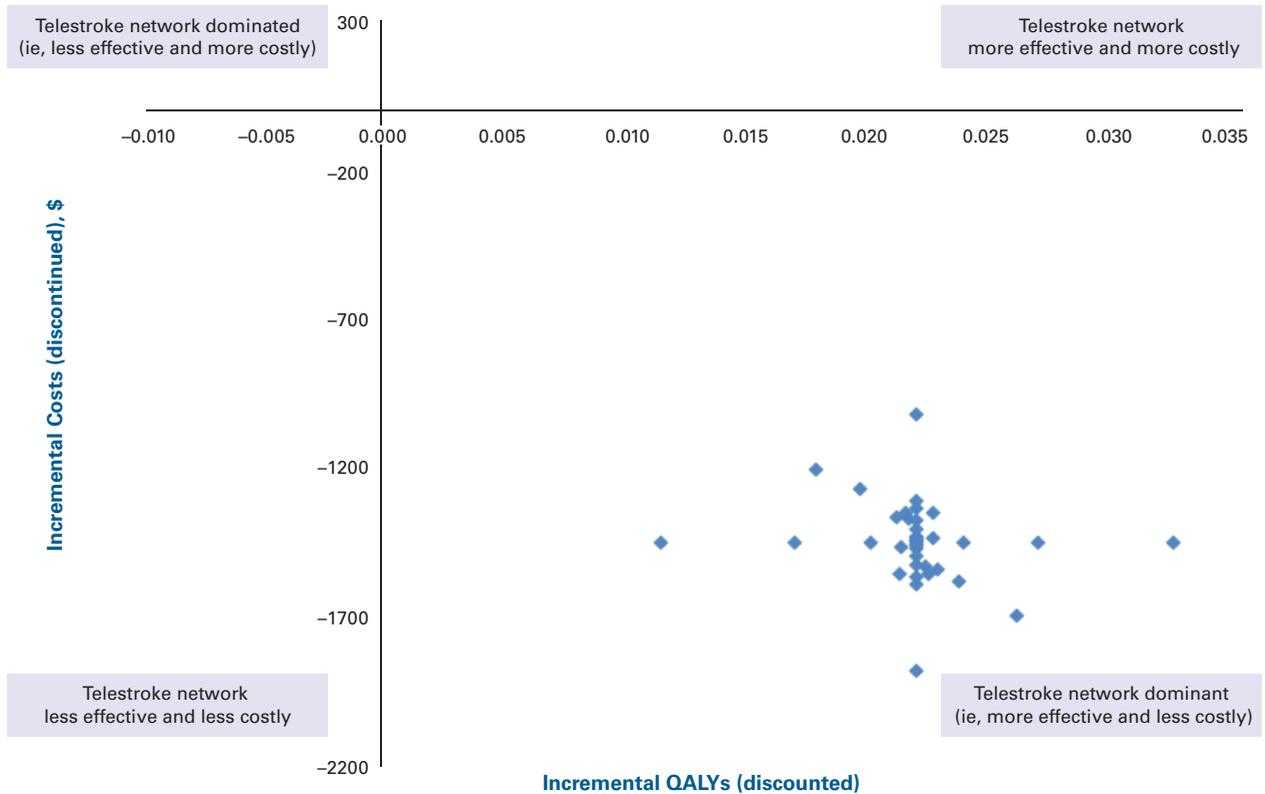
only. In such cases, the transfer rate is much lower than 90% because the medium-sized hospitals can frequently keep the majority of their stroke patients. Another implication of the result is that in order to be cost-effective, the transfer rate in a telestroke network should be kept low. If possible, spoke hospitals should only transfer highly selective patients—those who need higher levels of care in a hub hospital (eg, neurocritical care monitoring, endovascular therapy, hemicraniectomy). These findings are consistent with the CEA from the hospital perspective, which showed that a telestroke network is cost saving from the network perspective and a lower transfer rate is associated with better cost-effectiveness.⁸

Based on the results from this study, establishing a hub-and-spoke telestroke referral network seems to be a cost-effective strategy from the societal perspective in most network settings. With a telestroke referral network, more treatment-eligible AIS patients would receive IV thrombolysis and endovascular stroke therapy, which could substantially improve their outcomes. The improvement in the outcomes

is associated with reduced resource utilization (eg, inpatient rehabilitation, nursing homes, caregiver time). Therefore, although treating patients in a telestroke network is associated with higher up-front costs due to the setup of the telestroke network and more costly treatments (IV thrombolysis and endovascular stroke therapy) during the initial hospitalizations, it can potentially lead to cost savings over a lifetime.

As in most CEAs, one of the major limitations of the study is that the results are valid only if the assumptions hold. The CEA is limited by the data that can be obtained in the existing literature, in the public domain, and from clinical experience within our own telestroke referral networks. We maximized our efforts to obtain the best data available and relied on experts' opinions for those data not reported in the literature. Conservative assumptions were made under uncertainties. For example, the model assumed no mortality benefits from endovascular therapy during the initial hospitalization. Another example is that the study assumed that there were no differences in subsequent care and outcomes

Figure 3. Sensitivity Analysis of Cost and Effectiveness per AIS Patient Treated in a Telestroke Network Versus No Network (Lifetime)



AIS indicates acute ischemic stroke; QALY, quality-adjusted life-year.

following the initial hospitalizations. In reality, patients receiving initial acute treatment in a telestroke network may also receive better quality of acute care (beyond the use of IV thrombolysis and endovascular stroke therapy) and post acute stroke care,³² which may affect their final outcomes. However, the conservative approach improved the reliability of our analysis with imperfect data. Second, when estimating the setup and maintenance costs of a telestroke network, the first-year costs instead of prorated costs were used. As the costs of a telestroke network are highest in the first year, using the first-year costs is a conservative approach. Third, the model inputs used in the current CEA represented the national average values or the average values from 2 existing networks. In reality, there was substantial variation across different networks or different hospitals. Although the results from the 1-way sensitivity analysis could, to some extent, address how such variation may impact the cost-effectiveness of a telestroke referral network, the sensitivity analyses could not represent the full range of possible network settings. Fourth, the current CEA assumed identical accuracy of diagnosis for a telestroke network versus no network. Incorporat-

ing accuracy of telestroke diagnosis would be an interesting topic for future research. Finally, telestroke can also benefit other conditions such as hemorrhagic stroke and other neurologic emergencies, but our study only considered AIS. Using telestroke systems, telemedicine could be extended to other disease areas and thus improve outcomes among patients with other acute or chronic diseases.

As the science of healthcare delivery continues to develop and test new technologies and care paradigms, it is critical that health economic evaluations assess their costs and health consequences compared with standard practice. In this study, we have demonstrated that compared with a patient receiving routine stroke care at a community hospital without a regional stroke system of care and telemedicine, a patient treated in a telestroke network incurred \$1436 lower costs and gained 0.02 QALYs over a lifetime. The cost difference accounts for the investment in setting up the telestroke network from both hub and spoke hospitals. The telestroke network was economically dominant over routine care. The results serve to inform government, ministries of health, politicians, legislators, health policy makers, insurers, health-

care institutions, practitioners, patients, and members of the general public that an up-front investment in telemedicine technology, connectivity, infrastructure, and stroke network personnel can be justified in our health system. Government and nongovernment insurance plans should reimburse telestroke consultations in the same fashion as face-to-face clinical encounters.

Two other telestroke CEAs have already been published and revealed similar results. A Danish study determined that telestroke became more cost-effective as the time horizon increased, with an ICER of \$50,100 per QALY using a 1-year horizon comparing telestroke with standard care and telestroke being dominant with a 30-year time horizon.⁹ A US telestroke cost utility analysis by Nelson and colleagues¹⁰ revealed that compared with usual care, telestroke resulted in an ICER of \$108,363 per QALY with a 3-month horizon and \$2449 per QALY with the lifetime horizon. Under some circumstances in that published study, sensitivity analyses adjusting for numbers of stroke patients per spoke hospital and cost of spoke-to-hub transfers resulted in telestroke dominance (less costly and more effective).

Our study and the study by Nelson and colleagues¹⁰ share some similarities. Both were decision-analytic models of hub-and-spoke telestroke systems versus routine care that examined costs and health consequences for patients with AIS presenting to emergency departments. Both were conducted from societal perspectives in the United States and examined results for both short and lifetime time frames. Both utilized data inputs from Arizona telestroke networks. Nelson and colleagues combined data from Stroke Telemedicine for Arizona Rural Residents network with data from the University of Utah network. Our study combined data from the Mayo Clinic Telestroke network in Arizona (independent of Stroke Telemedicine for Arizona Rural Residents) with data from the University of Georgia network. The number of hospitals in the telestroke system base case scenario was also similar: 1 hub and 8 spokes in the study by Nelson and colleagues and 1 hub and 7 spokes in the current study. However, the 2 studies differed in the following ways: 1) Our decision model included the possibility of endovascular therapy in addition to IV thrombolysis. 2) Our cost inputs included those associated with dedicated network program managers and personnel, higher estimates of inpatient care, inter-hospital transfer, rehabilitation, long-term care, and caregiver costs, and a wider range of spoke-to-hub transfer rates. 3) The costs in the study by Nelson and colleagues were converted to 2008 US dollars, while ours were converted to 2011 US dollars. Despite these differences, it is reassuring that across several analyses designed to address this question, the answer is approximately

the same: compared with no network, telestroke networks are cost-effective.

CONCLUSION

A telestroke network is cost saving and more effective compared with no network from the societal perspective in most scenarios. Results may be sensitive to specific network features.

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Funding Source: This study received funding from Genentech, Inc.

Author Disclosures: Dr Demaerschalk reports employment with the Mayo Clinic, has received consulting fees from Genentech, Inc, and has received grants from Arizona State, the National Stroke Association, and Genentech, Inc. Dr Switzer has received consulting fees from Genentech, Inc. Drs Xie and Wu and Mr Fan report employment with Analysis Group, Inc, which received funding from Genentech, Inc, for this project. Ms Villa reports employment with Genentech, Inc, as well as stock options in the company.

Authorship Information: Concept and design (JX, LF, KFV, EQW); acquisition of data (BMD, JAS, JX, LF); analysis and interpretation of data (BMD, JAS, JX, LF, KFV, EQW); drafting of the manuscript (BMD, JAS, JX, LF, KFV); critical revision of the manuscript for important intellectual content (BMD, JAS, JX, LF, KFV, EQW); statistical analysis (JX, LF); provision of study materials or patients (BMD, JAS); obtaining funding (KFV); administrative, technical, or logistic support (JX, LF); and supervision (JX, KFV, EQW).

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■ eAppendix

Supplemental Methods: Network Characteristics

In the base case, the network was assumed to consist of 1 hub hospital and 7 spoke hospitals, the average number of hospitals in the US telestroke networks.¹ Other network parameters, including number of acute ischemic stroke (AIS) patients, rates of teleconsultations, spoke-to-hub transfers, intravenous (IV) thrombolysis, endovascular stroke therapies, and so forth were obtained from unpublished data from the Georgia Health Sciences University and the Mayo Clinic telestroke networks. The mean values were used in the base case (**Supplemental Table 1**).

Supplemental Table 1. Network Characteristics

Model Input	Value
Network	
Number of hub hospitals	1 ^a
Number of spoke hospitals	7 ¹
Hub hospital	
AIS patients per year	400 ^a
Spoke hospitals	
<i>No network</i>	
AIS patients per year	118 ^a
AIS patients receiving teleconsultations	0% ^a
AIS patients receiving IV thrombolysis	0.4% ^a
Patients receiving endovascular stroke therapy at the hub	0.0% ^a
Transfer rate among patients not receiving endovascular stroke therapy at the hub	75% ^a

AIS patients not receiving IV thrombolysis	99.6% ^a
Patients receiving endovascular stroke therapy at the hub	0.2% ^a
Transfer rate among patients not receiving endovascular stroke therapy at the hub	38% ^a
<i>Network with telemedicine</i>	
AIS patients per year	118 ^a
AIS patients receiving teleconsultations	35% ^a
AIS patients receiving IV thrombolysis	5.8% ^a
Patients receiving endovascular stroke therapy at the hub	15.8% ^a
Transfer rate among patients not receiving endovascular stroke therapy at the hub	56% ^a
AIS patients not receiving IV thrombolysis	94.2% ^a
Patients receiving endovascular stroke therapy at the hub	1.9% ^a
Transfer rate among patients not receiving endovascular stroke therapy at the hub	20% ^a

AIS indicates acute ischemic stroke; IV, intravenous.

^aBased on unpublished data from Georgia Health Sciences University and the Mayo Clinic telestroke networks.

Supplemental Methods: Effectiveness Input Estimation

Disability Status for Patients With and Without IV Thrombolysis

Disability associated with IV thrombolysis treatment was defined by modified Rankin Scale (mRS) at 3 months and obtained from a meta-analysis² (**Supplemental Table 2**). Because the model assumed no difference in mortality between patients with and without IV thrombolysis, an average mortality rate was used for both groups, and the rates of minimal to no disability and moderate to severe disability were then redistributed based on this mortality rate. This adjustment was done separately for each onset to treatment time category.

The timing of IV thrombolysis treatment among patients treated in a spoke hospital was obtained from the Georgia Health Sciences University and Mayo Clinic telestroke networks (**Supplemental Table 3**).

Supplemental Table 2. Modified Rankin Scale at 3 Months by IV Thrombolysis

Variable	IV Thrombolysis			No IV Thrombolysis		
	mRS			mRS		
	0-2	3-5	6	0-2	3-5	6
Meta-analysis² (3-month mRS by OTT), min						
0-90	50%	31%	19%	41%	38%	21%
91-180	49%	34%	17%	39%	45%	16%
181-270	58%	31%	11%	51%	39%	10%
Derived (equal mortality), min						
0-90	49%	31%	20%	42%	38%	20%
91-180	49%	34%	17%	39%	45%	17%
181-270	58%	31%	11%	51%	39%	11%

IV indicates intravenous; mRS, modified Rankin scale; OTT, onset to treatment time.

Supplemental Table 3. Onset to Treatment Time for Telestroke Network Versus No Network

OTT	Telestroke Network	No Network
0-90 min	9%	0%
91-180 min	71%	100%
181-270 min	20%	0%

OTT indicates onset to treatment time.

Disability Status for Patients With and Without Endovascular Stroke Therapy

Disability status associated with endovascular stroke therapy was defined by mRS at 3 months and obtained from the Mechanical Embolus Removal in Cerebral Ischemia (Multi-MERCI) trial³ (**Supplemental Table 4**). The model assumed no mortality benefit in the base case; thus, the same rate was used for patients without endovascular stroke therapy. Because there are no randomized, controlled clinical trials on mechanical embolectomy and thrombectomy, the ratio of mRS 0-2 at 3 months between patients with and without endovascular stroke therapy was assumed to be the same as the ratio between the active and control arms in the Prolyse in Acute Cerebral Thromboembolism II (PROACT II) trial,⁴ the only trial that compared outcomes between intra-arterial intervention and no intra-arterial intervention, in the base case (Supplemental Table 4). Using this ratio, the proportion of patients with MRS 0-2 at 3 months was estimated for patients without endovascular stroke therapy.

It should be noted that in PROACT II, the intervention in the active arm was intra-arterial recombinant prourokinase (r-proUK), which was different from the type of endovascular stroke therapy defined in this cost-effectiveness analysis. However, this was the only randomized controlled trial comparing an intra-arterial intervention with placebo among AIS patients, and it provided the best available estimate for patients without endovascular stroke therapy. The underlying assumption was that the efficacy of intra-arterial r-

proUK was the same as mechanical embolectomy and thrombectomy. This would be a conservative assumption if the former intervention is generally less effective than the latter.

Supplemental Table 4. Modified Rankin Scale at 3 Months by Endovascular Stroke Therapy and Previous IV Thrombolysis

Previous IV Thrombolysis	Endovascular Stroke Therapy			No Endovascular Stroke Therapy		
	mRS			mRS		
	0-2	3-5	6	0-2	3-5	6
Yes	38% ³	49% ³	13% ³	24% ^{3,4}	63% ^{3,4}	13% ^{3,4}
No	35% ³	49% ³	16% ³	22% ^{3,4}	62% ^{3,4}	16% ^{3,4}

IV indicates intravenous; mRS, modified Rankin scale.

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