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Telemedicine to Treat Rural Stroke Patients via a Hub-and-Spoke Model

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Telemedicine to Treat Rural Stroke Patients via a Hub-and-Spoke Model

Abstract

Background: Telemedicine is a model of care that is becoming known for its patient-centric and environmentally friendly applications. Combining telemedicine with a hub-and-spoke model is a method being used more frequently to disseminate vascular expertise and optimize recombinant tissue plasminogen activator (rt-PA) use. Approximately 45% of Americans do not have immediate access to acute stroke centers within 60 minutes. Due to this distance and time between onset and arrival, patients presenting to rural emergency departments are 10 times less likely to receive rt-PA than those same patients in urban settings. Telemedicine is one method that can be used to provide more accurate decisions regarding rt-PA, while a hub-and-spoke model can be used to reduce hospital and societal costs, along with the time between onset and presentation.

Methods: An exhaustive literature search using MEDLINE-PubMed, CINAHL, Google Scholar, and Web of Science using the search words telestroke, rural patients, and hub-and-spoke. Inclusion criteria were restricted to rural patients who received stroke care via telemedicine and a hub-and-spoke model. Selected studies were restricted to English only. Utilizing the GRADE criteria, all relevant articles were assessed for quality.

Results: 3 articles met inclusion criteria for this systemic review. Two articles focused solely on cost effectiveness. Significant network cost savings of $358,435 annually over a 5-year time horizon were observed, while patients incurred lifetime savings of $1436. The third study demonstrated significantly improved data collection, decision making, and increased rt-PA administration rates when comparing telemedicine and telephone consults.

Conclusion: Combining telemedicine technologies with a hub-and-spoke model results in cost savings for both the institution and patient. In addition, patients experience a slight improvement in overall QALY (quality adjusted life years). Secondly, utilizing telemedicine resulted in more complete data collection, more accurate decision making regarding administration of rt-PA, and higher administration rates. Despite the significant results in decision making and data collection, insignificant findings regarding select secondary outcomes warrant a larger study to better assess differences in 90-day patient outcomes.

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Keywords
Telestroke, rural patients, hub-and-spoke

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Telemedicine to Treat Rural Stroke Patients via a Hub-and-Spoke Model

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Biography

[redacted]
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To my family and friends who have supported me through the ups and downs associated with a career change and the rigors of PA school. I am forever grateful for you all.

To my classmates, faculty, and staff; without you this would not have been possible. Thank you for sharing your knowledge and support.
Abstract

Background: Telemedicine is a model of care that is becoming known for its patient-centric and environmentally friendly applications.\textsuperscript{1} Combining telemedicine with a hub-and-spoke model is a method being used more frequently to disseminate vascular expertise and optimize recombinant tissue plasminogen activator (rt-PA) use.\textsuperscript{2} Approximately 45% of Americans do not have immediate access to acute stroke centers within 60 minutes.\textsuperscript{4} Due to this distance and time between onset and arrival, patients presenting to rural emergency departments are 10 times less likely to receive rt-PA than those same patients in urban settings. Telemedicine is one method that can be used to provide more accurate decisions regarding rt-PA, while a hub-and-spoke model can be used to reduce hospital and societal costs, along with the time between onset and presentation.

Methods: An exhaustive literature search using MEDLINE-PubMed, CINAHL, Google Scholar, and Web of Science using the search words telestroke, rural patients, and hub-and-spoke. Inclusion criteria were restricted to rural patients who received stroke care via telemedicine and a hub-and-spoke model. Selected studies were restricted to English only. Utilizing the GRADE criteria, all relevant articles were assessed for quality.\textsuperscript{8}

Results: 3 articles met inclusion criteria for this systemic review. Two articles focused solely on cost effectiveness. Significant network cost savings of $358,435 annually over a 5-year time horizon were observed, while patients incurred lifetime savings of $1436. The third study\textsuperscript{2} demonstrated significantly improved data collection, decision making, and increased rt-PA administration rates when comparing telemedicine and telephone consults.

Conclusion: Combining telemedicine technologies with a hub-and-spoke model results in cost savings for both the institution and patient. In addition, patients experience a slight improvement in overall QALY (quality adjusted life years). Secondly, utilizing telemedicine resulted in more complete data collection, more accurate decision making regarding administration of rt-PA, and higher administration rates. Despite the significant results in decision making and data collection, insignificant findings regarding select secondary outcomes warrant a larger study to better assess differences in 90-day patient outcomes.

Keywords: Telestroke, rural patients, hub-and-spoke
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Table 1: Quality Assessment of Reviewed Articles
Telemedicine to Treat Rural Stroke Patients via a Hub-and-Spoke Model

Background
Telemedicine is a model of care that is becoming known for its patient-centric and environmentally friendly applications.¹ It can be defined as a way to provide real time assessments and care using digital and telecommunication platforms facilitating communication between a patient and a provider. Many studies look at these aspects, but could telemedicine be evaluated in a different manner? Combining telemedicine with a hub-and-spoke model is a method being used more frequently to disseminate vascular expertise and optimize recombinant tissue plasminogen activator (rt-PA) use.² A hub-and-spoke model consists of one hub or a major hospital where a specialist practices, is accompanied by a team, and has all the necessary resources to provide appropriate endovascular therapies. A spoke is typically a rural hospital that does not have the resources or specialists necessary to perform advanced stroke care beyond administering rt-PA. For example, if a patient in rural Oregon has a stroke, they can be rushed to a hospital and stabilized in an ER while conferring with a specialist via video conferencing. The specialist can then observe, help orchestrate an exam, and make a final decision on when and if rt-PA administration will benefit the patient.

The history of telemedicine dates to the late 1800’s after the development of the telephone. The telephone was used to reduce the amount of office visits and continues to be a method used today. In the 1950’s closed circuit television was used for psychiatric evaluations.
However, today we have the ability to communicate cheaply and effectively via video conferencing. Scott Rupp of NeuMD.com states that in 2014 the push for video forms of telemedicine began to take shape with the government providing $16 million in 2016 to improve telemedicine in rural areas. This funding is expected to help continue the evolution of telemedicine as virtual medical facilities continue to take shape, ultimately creating more accessible and convenient healthcare.

Based on current data approximately 45% of Americans do not have immediate access to acute stroke centers within 60 minutes. Due to this distance and time between onset and arrival, patients presenting to rural emergency departments are 10 times less likely to receive rt-PA than those same patients in urban settings. Telemedicine is one method that can be used to provide more accurate decisions regarding rt-PA, while a hub-and-spoke model can be used to reduce hospital and societal costs, along with, the time between onset and presentation.

Rt-PA is a cost effective and excellent tool to reduce long-term disability in acute ischemic stroke (AIS) patients. Overall the use of rt-PA is underused (less than 5% of stroke patients) which is attributed to the lack of stroke specialists. In a rural setting, this number is further diminished, again due to the lack of stroke specialists, lack of access to endovascular revascularization therapies, and geographic barriers. Hub-and-spoke medical models along with telemedicine have been developed to combat these barriers by providing quicker response times, which are aimed at enhancing stroke diagnosis, increasing rt-PA administration rates, and...
improving long term outcomes. Therefore, the goal of this review is to evaluate studies that assess the effectiveness of the hub-and-spoke model via telemedicine in patients suffering from stroke.

**Methods**

An exhaustive literature search using MEDLINE-PubMed, CINAHL, Google Scholar, and Web of Science using the search words telestroke, rural patients, and hub-and-spoke. Inclusion criteria were restricted to rural patients who received stroke care via telemedicine and a hub-and-spoke model. Selected studies were restricted to English only. Utilizing the GRADE criteria, all relevant articles were assessed for quality. ⁸

**Results**

A total of 8 articles were screened for relevance. Of the 8 articles reviewed, 3 met inclusion criteria for this systemic review. Two articles focused solely on cost effectiveness (1 study ⁹ looks at hospital-related costs while the other evaluates societal costs ¹⁰). The third study ² focuses primarily on accuracy of decision making in regard to combining the hub-and-spoke model with telemedicine. See Table 1.

**Switzer et al**

Cost effectiveness of hub-and-spoke model from a hospitals perspective conducted a 1-way sensitivity analysis. ⁹ A 1-way sensitivity analysis varies 1 model input while keeping all others constant. Doing so will show which input has the greatest impact on overall costs and helps guide future decision making in terms of allocating resources. The 4 manipulated model inputs were 1) network characteristics, including increasing the number of spoke hospitals up to 40; 2) setup and maintenance costs of...
telestroke systems; 3) marginal costs for treating AIS at the hub or spoke; and 4) discharge dispositions associated with endovascular stroke therapy. In addition, 2-way sensitivity analyses were performed, varying both spoke to hub transfer rates and endovascular stroke therapy rate among transferred patients.⁹

The base-case analysis represented a network, which included 1 hub and 7 spoke hospitals. The hub was where specialists were located while each spoke had trained professionals skilled in administering the required physical exams. From a network perspective, estimated cost savings are expected to be $358,435 per year over the first 5 years when compared to a non-network stroke medicine model. Broken down, the hub would incur costs of $405,121 annually, while each of the 7 spokes would incur savings of $109,080 annually. Furthermore, the financial models assume cost-sharing arrangements between the hub and spokes. Annual cost savings of $44,804 were distributed to each hospital (1 hub and 7 spokes) resulting in the aforementioned annual total network savings of $358,435 over a 5-year time horizon⁹.

When the number of spokes are manipulated, profits are projected to be incurred in all models except for networks consisting of 1 or 0 spokes. Manipulating the number of spokes produced network costs of $87,974 (0 spokes) to network cost savings of $2,400,000 (40 spokes).

Manipulating transfer rates from 0% to 100%, resulted in annual cost savings ranging from $555,818 to $5,588 respectively. The decline of cost savings was due to costs associated with transferring patients from spoke
hospitals to the hub hospital which resulted in increased spoke costs that were unable to be fully recovered by reimbursements incurred by the hub hospital. The hub did experience substantial decreases in incremental costs but ultimately the network, as a whole, suffered due to the substantial costs incurred at the spoke hospitals.\textsuperscript{9}

\textbf{Demaerschalk et al (2013)}

Cost effectiveness of hub-and-spoke model from a societal perspective\textsuperscript{10} discusses similar cost benefits as in the previous study; however, instead of focusing on institutional profits the focus is from a societal perspective. A Markov model was instituted to help determine if telestroke services via a hub-and-spoke model provided patients with a positive economical outcome. Inputs for the model included 3 major groups: health state distributions (utilizing a modified Rankin model), costs, and utilities. The modified Rankin scale (mRS) has 3 health states: 1) minimal-to-no disability, 2) moderate-to-severe disability, and 3) death. The Rankin scale can vary for each patient over the course of a year, but typically stabilizes after 3 months. Therefore, the state of the patient was determined after 3 months post-treatment. Cost inputs revolved around the overall cost to the patients from pretreatment to recovery. Utility inputs were gathered from literature with death having a utility of 0.\textsuperscript{10}

To implement the model a hypothetical cohort of AIS patients with a mean age of 68 were assumed to receive acute care via telestroke services. The model used the manipulated inputs, discussed above, to compare the results of services provided by traditional medical models to services
provided via a hub-and-spoke medical model (1 hub and 7 spokes). The cohort consisted of 1112 unique AIS patients.\textsuperscript{10}

To best determine the efficacy of utilizing a hub-and-spoke model in conjunction with telesstroke technology a 1 way-sensitivity analysis was conducted. Parameters used in the analysis were: 1) recurrent stroke rates, 2) transition probability of disability or death after recurrent strokes, 3) utility inputs, 4) rehabilitation costs, 5) caregiver costs, 6) setup and maintenance costs of telesstroke systems, 7) network characteristics. Furthermore a 2-way sensitivity analysis was performed which included variations to both spoke to hub transfers and endovascular stroke therapy rates among transferred patients.\textsuperscript{10}

Results from the models resulted in a lifetime savings with greater effectiveness if a hub-and-spoke model was used as opposed to a non-network model. Per patient lifetime cost savings were $1436 with the greatest benefit experienced due to a decreased need for nursing home care. Quality adjusted life-years (QALY) also improved. Over the lifetime of a patient QALY increased to 0.02 compared to a 1-year time horizon of 0.002.\textsuperscript{10}

\textbf{Demaerschalk et al (2012)}

“The Efficacy of Telemedicine for Stroke: Pooled Analysis of the Stroke Team Remote Evaluation Using a Digital Observation Camera and STROKE DOC Arizona Telestroke Trials”\textsuperscript{2} assessed the efficacy of digital technology in terms of making the correct decision regarding administration of rt-PA. The STROKE DOC AZ\textsuperscript{2} was a secondary study based on the results and
methodology of the initial STRoke DOC study\textsuperscript{11} conducted in California. STRoke DOC\textsuperscript{11} used digital observation cameras to assess stroke patients and saw higher use of rt-PA as well as higher incidence of correct decision making compared to telephone consults. The primary purpose of the STRoke DOC study\textsuperscript{11} was to determine if a “de novo” hub and spoke model could be used similarly in Arizona.

The STRoke DOC AZ trial\textsuperscript{2} was a single-hub, multi-spoke, randomized, blinded outcome trial. The purpose of STRoke DOC AZ was to build on and replace the first STRoke DOC trial of 2010 and to determine whether telemedicine or telephone consults were superior when compared to each other. Secondary outcomes included rt-PA use rate, 90-day functional outcome, and data completeness. Analysis for these studies were pre-specified and based on intent-to-treat population. The results from this study are based on 2 spoke centers of an Arizona hub-and-spoke model. A Fisher’s exact test was used to compare the other correct decision rates, rates of thrombolytic use, the rate of intracranial hemorrhage (ICH), mortality rates, and 90-day modified Rankin Scale (mRS) score. Statistical software R version 2.7.0 was utilized to conduct statistical analysis.\textsuperscript{2}

From the 2 spokes, 276 patients were prospectively evaluated with a mean age of 69 (±14.5 years. Fifty-one of these patients were female. Over all telemedicine consults took 8 minutes longer, on average, compared to telephone consults (35.4 minutes vs. 27.1 minutes). Despite the difference in time the correct decision to administer rt-PA significantly favored the use of telemedicine (96%) compared to telephone consults.
(83%); p-value = 0.002. However, most secondary outcomes were not statistically significant. The rate of IV rt-PA administration is 29% of patients in the telemedicine group and 24% in the telephone group; p-value = 0.41. The percentage of patients with a 90-day Barthel Index of 95-100, which measures ability to complete activities of daily living, were 46% of patients in the telemedicine group and 55% for telephone consults; p-value = 0.17. The percentage of patients with low level of disability (an mRS of 0-1) were 36% in the telemedicine group and 45% in the telephone group (p-value = 0.2). Mortality rates were 16% in the telemedicine group and 12% in the telephone group (p-value = 0.49). Lastly a significant difference in incomplete data was noted with the telemedicine consults compared to telephone consults (3% via telemedicine and 11% via telephone consults with a p-value of 0.004). As mentioned earlier, rt-PA has been widely underused at less than 5%. When utilizing the hub-and-spoke model rural stroke patient were determined to be candidates for rt-PA administration 29% of the time, resulting in more than a 24% increase in traditional medical settings.

**Discussion**

**Clinical Relevance**

Stroke is a leading cause of severe disability in the United States and poses a substantial burden to patients and the healthcare system both economically and in terms of quality-of-life. Regarding hospitals and the healthcare system utilizing a hub-and-spoke model in conjunction with telemedicine there is significant opportunity for long term cost savings.

Based on the models, a network of 1 hub and at least 2 spokes can incur cost
Despite large upfront costs to the hub, the more spokes that are included in the network generally correlate with greater cost savings. Both the 1-way and 2-way sensitivity analysis produced good results and revealed that hospital costs were particularly sensitive to transfer rates. Transferring patients adds additional network costs. Conversely, there is financial benefit if the patient is discharged from the hospital. For example, if a spoke hospital discharges a patient without out transferring them to the hub they will incur greater reimbursements for services provided. However, if the hub receives a transfer patient they receive greater inpatient reimbursements for providing additional endovascular stroke therapies; but may be difficult to overcome cost associated with transferring patients. The models ultimately concluded that in order to maximize cost savings transferring patients should be limited to those who are candidates for endovascular stroke therapy, hemicraniectomy, or other surgical or endovascular surgical interventions. Furthermore, improvement in patient outcomes corresponded with reduced resource utilization (e.g. inpatient rehabilitation, nursing homes, caregiver time). A reduction of resource utilization is best realized when an accurate assessment of stroke patients is completed. Lastly, while the data from the models is very attractive they are prospective models based on historical data. Further analysis and data collection should be gathered in the years to come to either confirm or deny the efficacy of the models.

The STRoke DOC AZ showed a significant increase in accurate decision making when utilizing telesstroke video consultations compared to
telephone consultations. The STRoke DOC AZ study\textsuperscript{2} proved that telemedicine is superior to telephone-only consults when deciding who is eligible to receive rt-PA and establishing an accurate stroke diagnosis (29% deemed eligible and received rt-PA). Using this information and adding to the fact that there are increased costs with transferring patients, we can conclude, utilizing telemedicine technology can be used to reduce transfer costs and provide a more accurate diagnosis. Furthermore, this is extremely important as 40% of the population, in the U.S., reside in communities without a hospital actively engaged in acute stroke care.\textsuperscript{8} Knowing that telemedicine is an effective resource for accurate diagnosis of stroke patients, what if a community is unable to either afford or use telemedicine technology? An added benefit of the STRoke DOC studies\textsuperscript{2,11} demonstrated the utilization of telephone-only consults can serve as an adequate ancillary, adjunctive, supplemental, or emergency backup modality for a telestroke network, provided proper training is in place at the spoke hospitals. Given the information obtained from the studies mentioned above, is there opportunity for a hub-and-spoke model to be used in other areas of medicine? The short answer is yes.

In a study entitled, “Impact of a University-Based Outpatient Telemedicine Program on Time Savings, Travel Costs, and Environmental Pollutants” there were 11,281 unique patients which resulted in a total travel distance savings of approximately 5 million miles, travel time savings of approximately 4.7 million minutes, and direct travel cost savings of approximately $2.8 million.\textsuperscript{1} By combining the results of the telestroke hub-
and-spoke studies\textsuperscript{2,11} and the travel/environmental benefit of the University-
Based study, there may be a huge opportunity for telemedicine to be used in
multiple areas of medicine. When evaluating stroke patients, telemedicine
has been used to make more accurate diagnoses, thus one can assume that
this accuracy can transfer to other areas of outpatient medicine. Secondly,
the cost savings due to travel and environmental factors applies to all when
using telemedicine technology. These cost savings will, in theory, improve
patient satisfaction and should increase a patient’s willingness to seek health
care. Lastly, telemedicine increases the availability of health care but also
reduces the need for patients to change providers every time they move. As
the world becomes more globalized and people become more mobile, the
ability to converse and transmit data via telemedicine will reduce the need to
find new providers and will allow patients to receive more consistent health
care.

\textbf{Limitations}

Limitations with the Switzer et al\textsuperscript{9} and Demaerschalk et al (2013)\textsuperscript{10}
studies include the assumption that benefits of telestroke were limited to the
increased use of intravenous thrombolysis and endovascular stroke
therapies. Other benefits were not factored in and could have further
improved cost savings. Secondly, data is limited to what can be found in
existing literature and public domains. Next, most inputs were based on 2
telestroke networks and may not be representative of broader network
models. The Switzer et al\textsuperscript{3} study had additional limitations. Specifically, it
was assumed the hubs had adequate resources and personnel to adequately
serve patients transferred from spoke sites. Also, the cost-benefit from telephone-only consults was not factored in the calculations.

With the Demaerschalk et al (2012)\textsuperscript{2} pooled analysis and RCT, a potential type II or type I error exists between the two samples STROke DOC vs STROke DOC AZ because the design of the AZ study did not have sufficient power to reveal a significant difference between the two treatment arms should a true difference have existed. The underpowered study made it difficult to detect differences in 90-day functional outcomes.

To effectively reduce limitations of the studies, noted above, a few recommendations can be made. Larger sample sizes should be obtained as more information becomes available. Telestroke networks are becoming more popular and data supporting multiple networks can be used to confirm assumptions used in prospective models while assessing the accuracy of models previously used. Secondly, in order to reduce type I and type II errors between comparable studies, the studies should be designed and conducted in same manner. This will better allow the detection of significant differences in outcomes.

**Conclusion**

Combining telemedicine technologies with a hub-and-spoke model results in cost savings for both the institution and patient. In addition, patients experience a slight improvement in overall QALY. These results must be cautiously accepted, due to the fact, that many of the models were conducted utilizing projected data. As the hub-and-spoke networks become
more widely accepted, larger amounts of historical data can be used to compare projections with reality.

Secondly, utilizing telemedicine resulted in more complete data collection, more accurate decision making regarding administration of rt-PA, which resulted in higher administration rates. Despite the significant results in decision making, administration rates, and data collection, insignificant findings regarding select secondary outcomes (mortality, disability post stroke, etc.) warrant a larger study to better assess differences in 90-day patient outcomes.
References


### Table 1- Quality Assessment of Reviewed Articles

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Number of studies</th>
<th>Study Designs</th>
<th>Limitations</th>
<th>Indirectness</th>
<th>Inconsistency</th>
<th>Imprecision</th>
<th>Publication bias</th>
<th>Quality</th>
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<td>Costs</td>
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<td>Cost-based analysis</td>
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<td>Not Serious</td>
<td>Not Serious</td>
<td>Not Serious</td>
<td>Likely&lt;sup&gt;a&lt;/sup&gt;</td>
<td>None</td>
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<td>Accuracy of Decision Making</td>
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<td>RCT</td>
<td>Serious&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Not Serious</td>
<td>Not Serious</td>
<td>Not Serious</td>
<td>Likely&lt;sup&gt;a&lt;/sup&gt;</td>
<td>None</td>
</tr>
</tbody>
</table>

<sup>a</sup> All 3 studies were conducted by the same group of researchers.

<sup>b</sup>This study only analyzed data from 2 spokes.