Safe and Effective Implementation of Telestroke in a US Community Hospital Setting

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ABSTRACT

Context: There is substantial hospital-level variation in use of tissue plasminogen activator (tPA) for treatment of acute ischemic stroke. Telestroke services can bring neurologic expertise to hospitals with fewer resources.

Objective: To determine whether implementation of a telestroke intervention in a large integrated health system would lead to increased tPA utilization and would change rates of hemorrhagic complications.

Design: A stepped-wedge cluster randomized trial of 11 community hospitals connected to 2 tertiary care centers via telestroke, implemented at each hospital incrementally during a 1-year period. We examined pre- and postimplementation data from July 2013 through January 2015. A 2-level mixed-effects logistic regression model accounted for the staggered rollout.

Main Outcome Measures: Receipt of tPA. Secondary outcome was the rate of significant hemorrhagic complications.

Results: Of the 2657 patients, demographic and clinical characteristics were similar in pre- and postintervention cohorts. Utilization of tPA increased from 6.3% before the intervention to 10.9% after the intervention, without a significant change in complication rates. Postintervention patients were more likely to receive tPA than were preintervention patients (odds ratio = 2.0; 95% confidence interval = 1.2-3.4). Before implementation, 8 of the 10 community hospitals were significantly less likely to administer tPA than the highest-volume tertiary care center; however, after implementation, 9 of the 10 were at least as likely to administer tPA as the highest-volume center.

Conclusion: Telestroke implementation in a regional integrated health system was safe and effective. Community hospitals' rates of tPA utilization quickly increased and were similar to the largest-volume tertiary care center.

INTRODUCTION

Tissue plasminogen activator (tPA) is the only treatment approved by the US Food and Drug Administration for acute ischemic stroke, but tPA continues to be underutilized.[1-3] There are many reasons for this underutilization, including patient factors as well as physician and hospital factors. Among the patient factors that exclude patients from receiving tPA are that patients present outside the treatment window or otherwise fail to meet inclusion criteria for the treatment. Physician and hospital-level factors contributing to less-than-ideal tPA utilization include emergency physicians' discomfort with the medication and its risk profile, and varying levels of hospital resources and support. Indeed, in a previous analysis of our 14-hospital regional integrated health care system, we found considerable hospital-level variation in tPA utilization.[4]

Because of this substantial variation between hospitals' tPA utilization in our health care system, a systemwide telestroke project was implemented. Telestroke refers to the use of telecommunication technologies to provide medical information and services for stroke care, and it is a valuable tool to fill gaps in access to acute stroke services.[5,6] In the provision of emergent neurologic expertise, telestroke may enable Medical Centers to overcome major barriers to tPA utilization[6,7] and has a Class I recommendation based on Level A evidence supporting this application.[8]

Kaiser Permanente Southern California (KPSC) is ideally organized for implementation of telestroke. The system includes 2 tertiary Medical Centers with in-house stroke neurology and neurologic intensive care units, as well as 12 community Medical Centers that lack such resources. By connecting the resources of the tertiary centers with the needs at the other hospitals, implementation of telestroke could improve the care of all patients with ischemic stroke in the system.

METHODS

We performed a stepped-wedge cluster randomized trial; this design has advantage over a simple pre-post analysis in that it allows for modeling the effect of time on the effectiveness of the intervention. The telestroke intervention was implemented in 11 Medical Centers and incrementally rolled out over the study period. Each Medical Center's Emergency Department (ED) was connected to an on-call stroke neurologist through telemedicine technology. Emergency physicians were encouraged to consult the on-call stroke neurologist via telestroke on any patient presenting with signs and symptoms

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suggestive of stroke such as sudden difficulty with speech, strength, sensation, balance, or vision, and arriving within 6 hours of onset. Our primary objective was to determine the effectiveness of the intervention as indicated by increased tPA utilization after implementation. Our secondary objective was to assess for safety of the intervention by examining whether there were changes in rates of tPA-related bleeding complications.

Data Source and Populations

Structured data from electronic health and administrative records identified all patients presenting to 1 of 11 participating EDs in our health care system between July 1, 2013, and January 15, 2015, with a primary diagnosis of ischemic stroke using International Classification of Diseases, Ninth Revision (ICD-9) Codes 433.xx, 434.xx, and 436. Because 2 of the community-based sites had previously implemented telestroke through outside vendors, and 1 hospital has 24-hour inhospital neurologist availability because of a neurology residency, we excluded patients from those sites. Instead, we focused our analysis on the 11 community-based sites in which telestroke was a new intervention. These Medical Centers had a staggered implementation of the telestroke intervention. Medical Center 1 began implementation on August 15, 2013, and the other centers began on the following dates in 2014: Medical Center 2 on January 20, Medical Centers 3 and 4 on May 19, Medical Center 5 on June 11, Medical Center 6 on July 2, Medical Centers 7 and 8 on July 28, Medical Center 9 on August 25, Medical Center 10 on September 2, and Medical Center 11 on December 16.

Demographic and clinical details were extracted for each patient, as well as tPA utilization and an indicator of whether telestroke was used for each visit. We excluded patients younger than age 18 years, those with a previous stroke within 90 days, and those with missing or implausible brain imaging or tPA administration times. The data were combined with predefined rollout dates to create indicators of intervention status by Medical Center per rollout month. Each patient was categorized as preintervention or postintervention on the basis of whether telestroke had been implemented at the presenting hospital by the date of patient presentation. Human subjects approval was obtained through the KPSC institutional review board.

Outcome Measures

The primary outcome was tPA receipt, identified by pharmacy code. Our secondary safety outcome was intracranial or gastrointestinal bleeding, identified by ICD-9 codes (432.xx, 430, 431, and 578.xx). One of the authors (AS) reviewed all charts of patients with questions of the outcome variables.

Statistical Analysis

Patient characteristics were described using medians and quartiles or means with standard deviations for all continuous variables, and frequencies and percentages for all categorical variables. All analyses were 2-tailed and were performed at a significance level of 0.05. For continuous variables with missing values, we used mean imputation and constructed indicator variables for missingness. For categorical variables, an "unknown" category was created, along with the same missing indicators. This ensured that study group comparisons could be constructed for all observations.

The outcome of interest was defined as tPA receipt at a given encounter. It was operationalized both at the patient level to assess patient characteristics and at the medical-center level to assess variability in rates between centers and more appropriately account for effects of the study design. For the former, we used logistic regression to assess the intervention effects on tPA utilization at individual encounters. For the latter, we used negative binomial regression to assess whether the telestroke intervention effect varied

Table 1. Patient demographics

Demographic	Preintervention (n = 1613)[a]	Postintervention (n = 1044)[a]	Total (N = 2657)[a]	p value
Age, years, mean (SD)	70.7 (13.6)	71.3 (13.7)	71.0 (13.6)	0.1617
Diagnosis year				
2013	768 (47.6)	46 (4.4)	814 (30.6)	< 0.001
2014	845 (52.4)	915 (87.6)	1760 (66.2)	
2015	0 (0.0)	83 (8.0)	83 (3.1)	
Sex				
Women	779 (48.3)	510 (48.9)	1289 (48.5)	0.7796
Men	834 (51.7)	534 (51.1)	1368 (51.5)	
Race				
White	704 (43.6)	412 (39.5)	1116 (42.0)	0.0003
Black	279 (17.3)	258 (24.7)	537 (20.2)	
Hispanic	464 (28.8)	278 (26.6)	742 (27.9)	
Asian/Pacific Islander	157 (9.7)	88 (8.4)	245 (9.2)	
Other	4 (0.2)	5 (0.5)	9 (0.3)	
Unknown	5 (0.3)	3 (0.3)	8 (0.3)	
Comorbidities				
Previous stroke	98 (6.1)	60 (5.7)	158 (5.9)	0.7266
Diabetes	600 (37.2)	374 (35.8)	974 (36.7)	0.4729
Hypertension	1113 (69.0)	708 (67.8)	1821 (68.5)	0.5203
Atrial fibrillation	280 (17.4)	157 (15.0)	437 (16.4)	0.1150
CHF	212 (13.1)	134 (12.8)	346 (13.0)	0.8178
COPD	100 (6.2)	68 (6.5)	168 (6.3)	0.7455
Valvular heart disease	132 (8.2)	91 (8.7)	223 (8.4)	0.6285
Other characteristics				
Elixhauser index, mean (SD)	3.4 (2.4)	3.4 (2.5)	3.4 (2.4)	0.8471
Use of anticoagulant	306 (19.0)	196 (18.8)	502 (18.9)	0.8992

[a] Data are no. (%) unless indicated otherwise.
CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; SD = standard deviation.

by Medical Center. This approach also allowed us to include an offset term (log stroke volume) to scale each Medical Center's monthly rate relative to its monthly stroke volume.

The model included indicators for Medical Centers to account for baseline variability between centers, indicators for exposure and length of exposure to the telestroke intervention, and Medical Center by intervention interactions to assess the heterogeneity in treatment effects. The model adjusted for patient-level demographic and clinical characteristics. We also assessed time-by-intervention interactions but found that the intervention effect did not appear to vary by length of exposure to the telestroke intervention. We also tested for interactions with patient race, ambulance arrival, and patient sex. Where necessary, forest plots were used to assess the interactions between the telestroke intervention and the relevant variables. All analyses were conducted using SAS 9.3 software (SAS Institute Inc, Cary, NC).

RESULTS

Of the 2657 patients included in our analysis, 1613 presented in the preintervention period (before implementation of telestroke), and 1044 presented in the postintervention period. The pre- and postintervention cohorts were similar in demographic characteristics and medical history (Table 1).

As detailed in Table 2, tPA utilization increased from 6.3% to 10.9% from the pre- to postintervention period, with no meaningful change in rates of bleeding complications. Telestroke was engaged in 24% of patient encounters in the postintervention period.

Primary Outcome

Patients treated in the postintervention period were more likely to receive tPA than those treated before the intervention (odds ratio = 2.0, 95% confidence interval = 1.17-3.4).

Before telestroke implementation, 8 of the 10 community Medical Centers were significantly less likely to administer tPA to patients with ischemic stroke compared with the largest-volume stroke center. After the telestroke implementation, however, 9 of the 10 community Medical Centers were at least as likely to administer tPA to ischemic stroke patients as that highest-volume stroke center (Figure 1). The effect of the intervention did not vary significantly by patient race, ambulance arrival, or arrival off-hours (5 pm-8 am Monday to Friday, or anytime Saturday or Sunday).

Secondary Outcomes

There were no meaningful differences in intracranial or gastrointestinal bleeding complications from the pre- to postintervention periods, and overall bleeding complications was slightly lower after the intervention (5.1% vs 4.9%; Table 2).

Table 2. Details of patient encounters

Patient encounter	Preintervention (n = 1613)[a]	Postintervention (n = 1044)[a]	Total (N = 2657)[a]	p value
Transferred from a skilled nursing facility	10 (0.6)	8 (0.8)	18 (0.7)	0.6534
Transported via ambulance	520 (32.2)	307 (29.4)	827 (31.1)	0.1236
Admitted during off-hours[b]	424 (26.3)	283 (27.1)	707 (26.6)	0.6400
Door-to-imaging time, minutes				
Mean (SD)	61.8 (42.3)	55.3 (37.7)	59.2 (40.7)	< 0.001
Median (IQR)	56 (29-89)	44 (25-79)	51 (26-85)	
Door-to-imaging time categories, minutes				
Preregistration[c]	44 (2.7)	6 (0.6)	50 (1.9)	< 0.001
< 30	379 (23.5)	349 (33.4)	728 (27.4)	
31-60	454 (28.1)	307 (29.4)	761 (28.6)	
61-90	356 (22.1)	186 (17.8)	542 (20.4)	
91-120	200 (12.4)	119 (11.4)	319 (12.0)	
> 120	180 (11.2)	77 (7.4)	257 (9.7)	
Door-to-needle time, minutes				
Mean (SD)	75.4 (41.3)	62.6 (28.4)	68.6 (35.5)	0.019
Median (IQR)	66 (46-96)	55 (47-69)	58 (46-82)	
Door-to-needle time categories, minutes				
≤ 30	8 (7.9)	2 (1.8)	10 (0.4)	0.001
31-60	36 (35.6)	73 (64.0)	109 (4.1)	
61-90	28 (27.7)	27 (23.7)	55 (2.1)	
91-120	19 (18.8)	7 (6.1)	26 (1.0)	
121-150	3 (3.0)	2 (1.8)	5 (0.2)	
151-180	3 (3.0)	2 (1.8)	5 (0.2)	
181-210	3 (3.0)	0 (0.0)	3 (0.1)	
211-240	1 (1.0)	1 (0.9)	2 (0.1)	
Bleeding complications				
Any	83 (5.1)	51 (4.9)	134 (5.0)	0.7643
Intracranial	17 (1.1)	15 (1.4)	32 (1.2)	0.3769
Subarachnoid	6 (0.4)	4 (0.4)	10 (0.4)	0.9634
Intracerebral	38 (2.4)	20 (1.9)	58 (2.2)	0.4483
Gastrointestinal	22 (1.4)	12 (1.1)	34 (1.3)	0.6309
Discharge disposition				
Home	1186 (73.5)	775 (74.2)	1961 (73.8)	0.4834
Skilled nursing facility	150 (9.3)	106 (10.2)	256 (9.6)	
Other	277 (17.2)	163 (15.6)	440 (16.6)	
Other clinical factors				
Use of telestroke	—	251 (24.0)	—	< 0.001
Received tPA	101 (6.3)	114 (10.9)	215 (8.1)	< 0.001

[a] Data are no. (%) unless indicated otherwise.
[b] Off-hours defined as encounters between 5 pm and 8 am weekdays and anytime Saturday or Sunday.
[c] Preregistration refers to patients who received brain imaging within 60 minutes before official Emergency Department admission time.
IQR = interquartile range; SD = standard deviation; tPA = tissue plasminogen activator.

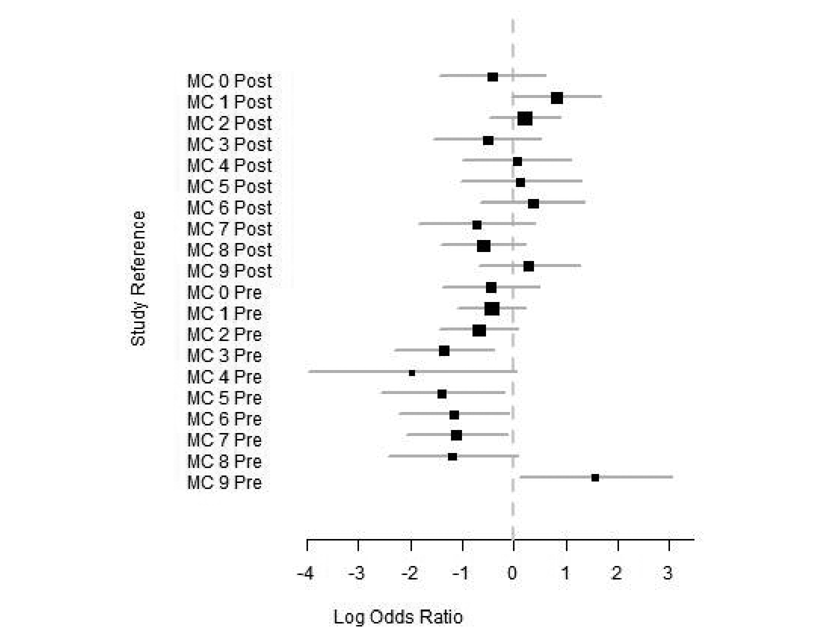

Figure 1. Likelihood of tissue plasminogen activator (tPA) treatment by Medical Center.

Adjusted odds of tPA receipt for each community Medical Center (MC) relative to odds at largest-volume stroke center. Bottom half of forest plot (MC 0 Pre to MC 9 Pre) illustrates relative odds of each MC in preintervention period (Pre). With the exception of MC 0 and MC 9, each MC has lower odds of tPA administration. Top half of forest plot (MC 0 Post to MC 9 Post) illustrates relative odds of each MC in postintervention period (Post). With the exception of MC 8, each MC has similar or higher odds of tPA administration relative to highest-volume academic center.

There were also improvements in median time from door to imaging (preintervention = 56 minutes vs postintervention = 44 minutes) and door to needle (66 minutes vs 55 minutes).

We also assessed the same Medical Center-by-intervention interaction for the patient-level data. This additional analysis revealed a similar pattern as in Figure 1, suggesting that further adjusting for patient characteristics did not change our conclusions. Furthermore, we believe the Medical Center-level analysis provides the added benefit of scaling the monthly rates for each Medical Center by its monthly stroke volumes, and thus provides a clearer interpretation of the findings.

DISCUSSION

In this stepped-wedge cluster randomized trial, we found that implementation of a telestroke intervention in our integrated health system improved rates of tPA administration for patients with ischemic stroke presenting to the community Medical Centers in the postintervention period. Rates of bleeding complications remained acceptably low and did not rise with the increased rate of tPA administration. Our results reinforce the utility of telestroke as previously reported. Many studies have demonstrated the utility of telestroke for assessing stroke severity[9-12] and for increasing the use of tPA among eligible patients.[13-17] Our findings add to this body of literature supporting the value of telestroke for improving tPA administration rates among patients with ischemic stroke presenting to community hospitals. We found that telestroke can be implemented safely and effectively in community hospitals, and that the beneficial effects (increased tPA utilization) occurred quickly after implementation without a significant lag period and without any corresponding change in complications.

These findings have important implications for future delivery of stroke care. Particularly in hospitals with limited local resources and/or limited access to neurologic expertise, telestroke is an important tool to aid in the evaluation and treatment of potential stroke. We specifically found that unwarranted hospital variability in stroke care could be eliminated through a standardized telestroke program. Additionally, telestroke may aid in triage and transfer decisions and in identifying patients potentially eligible for endovascular intervention or patients who might otherwise benefit from transfer to a stroke center. Future work may help to clarify the role for telestroke in such decisions.

Our study does have limitations. Our study design does not allow for a calculation of statistical power. We were unable to define the population of patients eligible for tPA; our finding of increased tPA utilization reflects an increased rate of tPA use among *all* patients with ischemic stroke. However, it is unlikely that our findings reflect a simple increase in the proportion of tPA-eligible patients because the study was conducted over a short period and without any corresponding public health messaging. Secondly, telestroke was utilized in 24% of cases after the intervention, and we do not know what distinguished these cases from those that did not engage telestroke. The seemingly low utilization rate may suggest that most patients with stroke arrived beyond the therapeutic time window. Additional patients may have been excluded if the ED physician noted obvious contraindications to thrombolytic therapy such as recent surgery or anticoagulant use, or if symptoms completely resolved before the telestroke call. Furthermore, we cannot confirm that the 24% of cases in which telestroke was utilized were the same cases in which the improved tPA rate was realized. Yet in the absence of other interventions or quality-improvement initiatives, it is reasonable to attribute the change in tPA utilization to the major systematic change that took place during this intervention period. Finally, we were unable to assess physician satisfaction with telestroke. Future work in our system should examine whether telestroke remains a frequently used tool, clarify the reasons

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for physicians' activation or deferral of telestroke, and confirm physician comfort and satisfaction with the use of telestroke for patients with ischemic stroke.

CONCLUSION

In our regional integrated health system, we found that implementation of a telestroke intervention eliminated unwarranted hospital variation in care and led to increased rates of tPA utilization among patients with acute ischemic stroke, with consistently low rates of hemorrhagic complications. Telestroke was implemented safely and effectively in this US community hospital setting. ❖

Disclosure Statement

The author(s) have no conflicts of interest to disclose.

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Health

The aim of the art of medicine is health, but its end is the possession of health. Doctors have to know by which means to bring about health, when it is absent, and by which means to preserve it, when it is present.

— Galen of Pergamon, 129 AD - c200 AD, Roman physician and philosopher of Greek origin