National Trends in Telestroke Utilization in a US Commercial Platform Prior to the COVID-19 Pandemic

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Objectives: Most data on telestroke utilization come from single academic hub-and-spoke telestroke networks. Our objective was to describe characteristics of telestroke consultations among a national sample of telestroke sites on one of the most commonly used common vendor platforms, prior to the COVID-19 public health emergency. *Materials and methods:* A commercial telestroke vendor provided data on all telestroke consultations by two specialist provider groups from 2013-2019. Kendall's τ β nonparametric test was utilized to assess time trends. Generalized linear models were used to assess the association between hospital consult utilization and alteplase use adjusting for hospital characteristics. *Results:* Among 67,736 telestroke consultations to 132 spoke sites over the study period, most occurred in the emergency department (90%) and for stroke indications (final clinical diagnoses: TIA 13%, ischemic stroke 39%, hemorrhagic stroke 2%, stroke mimics 46%). Stroke severity was low (median NIHSS 2, IQR 0−6). Alteplase was recommended for 23% of ischemic stroke patients. From 2013 to 2019, times from ED arrival to NIHSS, CT scan, imaging review, consult, and alteplase administration all decreased ($p<0.05$ for all), while times from consult start to alteplase recommendation and bolus increased ($p<0.01$ for both). Transfer was recommended for 8% of ischemic stroke patients. Number of patients treated with alteplase per hospital increased with increasing number of consults and hospital size and was also associated with US region in unadjusted and adjusted analyses. Longer duration of hospital participation in the network was associated with shorter hospital median door-to-needle time for alteplase delivery (39 min shorter per year, p=0.04). *Conclusions:* Among spoke sites using a commercial telestroke platform over a seven-year time horizon, times to consult start and alteplase bolus decreased over time. Similar to academic networks, duration of telestroke participation in this commercial network was associated with faster alteplase delivery, suggesting practice improves performance.
Key Words: Stroke—Telestroke—Alteplase—Acute stroke care—Emergency care

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Received April 16, 2021; revision received July 21, 2021; accepted August 1, 2021.

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1052-3057/$ - see front matter

https://doi.org/10.1016/j.jstrokecerebrovasdis.2021.106035

Introduction

Telemedicine can mitigate disparities in resource availability between emergency departments (EDs) in stroke care delivery, i.e., telestroke.[1−3] Availability of telestroke improves performance on stroke quality metrics, and in particular, to increase alteplase use.[4−10] Additionally, by providing 24/7 access to neurology consultation, telestroke has enabled many hospitals to meet stroke center certification requirements.

There are various models for telestroke delivery, including the hub-and-spoke model in which consultations are provided by an academic hub and the hub-less model where consultations are provided via a for-profit telemedicine company-based model or private practice consultants.[11] Most research on telestroke has come from single academic hub-and-spoke telestroke networks and therefore only captures one set of experiences.

To fill this gap in knowledge, we described trends in telestroke consultations from 2013 to 2019, among a national sample of 132 care locations using a commercial telestroke platform.

Methods

Data source and population

We used data from a large, commercial, telehealth company that provides the software and the platform for telestroke delivery to physician service organizations. These organizations then use the telestroke infrastructure provided by the vendor to connect centralized stroke experts with patients at spoke sites receiving the telestroke services. The telehealth company also provides a stroke data collection tool that collects encounter-level data on telestroke consultations.

Two sets of stroke experts are using the tool to provide care at 132 sites where the key data fields could be mapped to a common set of fields. One of these providers is a major physician services organization with a stroke team of about 15 specialists and serving many health systems at approximately 90 care locations (free-standing EDs and hospitals). The second provider is a major integrated delivery network in the western U.S. with a stroke team of about 30 specialists serving approximately 40 spokes (primarily hospitals, and 2 clinics). We included all telestroke encounters logged 2013-2019 by the two major providers.

All data are fully de-identified and reported at the encounter level. The study was approved by the local Institutional Review Board. Requests to access the dataset from qualified researchers trained in human subject confidentiality protocols may be sent to the corresponding author. The telehealth company provided the data but did not influence our analytic plan or presentation of results.

Variables of interest

The dataset included characteristics of telestroke consultations, including location of consultation, time metrics for consultation, National Institutes of Health Stroke Scale (NIHSS), alteplase eligibility, alteplase recommendation, alteplase receipt, final clinical impression, and patient disposition. Table 2

We also characterized sites receiving telestroke consultation by the number of consults per year, hospital size (see Supplemental Table 1 for definitions), rurality based on Rural Urban Commuting Area (RUCA) code,[12] and US geographic region (Northeast, Midwest, South, West). Site-level outcomes of interest were at the site level and included the number of patients treated with alteplase per year and hospital-level performance on door-to-needle time for alteplase delivery.

Analysis

We use descriptive statistics to characterize consultations. Longitudinal changes in time-metrics were examined using generalized estimating equations. We examined the bivariate relationship between receiving hospital characteristics and performance on alteplase delivery as measured by door-to-needle time and number of patients treated with alteplase. We then used generalized estimating equations to examine the independent relationship between receiving hospital characteristics and alteplase performance. Characteristics of receiving sites included number of consults performed per year, hospital size, rurality, and region. All analyses were performed in SAS 9.4 (Cary, NC).

Results

Telestroke encounters

The dataset included 67,736 telestroke encounters between 2013-2019 from 2 major specialist providers connected with 132 receiving sites (Table 1). The vast majority of consultations (nearly 90%) took place in the ED. The telestroke consultant's diagnosis was stroke in 53.0% of cases (transient ischemic attack [TIA], 12.8%; ischemic stroke, 38.8%; hemorrhagic stroke 2.4%). Other common diagnoses included encephalopathy (7.1%), seizure (6.5%), and altered mental status (3.0%). NIHSS was recorded in 47,009 cases (69.4%); median NIHSS was 2 (IQR 0−6).

Across all years (2013 to 2019), median time from ED arrival to consult request was 27 min (IQR 10.4−96.9), from consult request to call-back was 3.1 min (IQR 2.1−5.0), and from consult call-back to alteplase administration was 38 min (IQR 28−52 min). From 2013 to 2019, there were significant trends of decreasing times from the patient's arrival to: CT scan (median 15 min [IQR 7-32] in 2013 to 4 min [3-6] in 2019, $p<0.001$), teleconsultation (27 min [12-57] in 2013 to 23 min [8-61] in 2019, $p<0.001$), review of imaging (54 min [38-84] in 2013 to 48 min [27−96] in 2019, $p<0.001$), and alteplase administration (55 min [44−81] in 2013 to 40 min [27−53] in 2019, $p=0.02$). Time from consult request to callback by consultant did not significantly change over the study period (4 min [3−5] in 2013 to 3 min [2−5] in 2019, $p=0.06$), however time from consultant callback to alteplase recommendation (25 min [18−35] in 2013 to 20 min [14−32] in 2018, $p<0.01$) decreased over time. Time from consultant callback to alteplase administration (32 min [26−43] in 2013 to 46 min [22−80] in 2019, $p<0.001$) significantly increased with time (Fig. 1). To understand whether this increase may have been explained by changes in workflow, we examined change in time from CT to consult request time

Table 1. *Telestroke encounter characteristics.*

	N (%) unless otherwise specified N = 67,736
Age, mean (SD)	64.9 (17.0)
(N= 67325 encounters with age recorded)	
Sex, % Male	21,968 (45.4%)
(N=48,353 encounters with sex recorded)	
Consults per Year	
2013	1815 (2.7%)
2014	3485 (5.1%)
2015	6398 (9.5%)
2016	9577 (14.1%)
2017	20662 (30.5%)
2018	25564 (37.7%)
2019	235 (0.4)
Consults per year per spoke	
(median, IQR)	14.2 (14.0, 14.3)
2013	8.9 (8.8, 9.0)
2014	6.8 (6.6, 8.0)
2015	3.2 (3, 7.7)
2016	6.8 (1.9, 9.1)
2017	8.4 (1.8, 8.6)
2018	15.4 (3.4, 16.4)
2019	
Consult location	
Emergency Department	19664 (89.9%)
Inpatient	2208 (10.1%)
(N=21,872 encounters with location recorded)	
Consult type	
Curbside	594 (1.3%)
Cancelled	1033 (2.2%)
Phone	9248 (19.7%)
Telehealth video	23492 (49.6%)
(N=47,324 encounters with variable recorded)	
Final Clinical Impression	
Ischemic Stroke (IS)	8996 (38.8%)
Hemorrhagic Stroke	557 (2.4%)
TIA	2972 (12.8%)
Consult Cancelled	952 (4.1%)
Mimics:	9735 (41.9%)
Encephalopathy/altered mental	2338 (10.1%)
status	1518 (6.5%)
Seizure	494 (2.1%)
Complex Migraine	224 (1.0%)
Bell's Palsy	31 (0.1%)
EEG Study	5130 (22.1%)
Other	
(N=23,218 encounters with clinical impression recorded)	
NIHSS	
Mean (SD)	4.75 (6.48)
Median (IQR)	2 (0-6)
(N=47,009 encounters with NIHSS recorded)	

(*Continued*)

Table 1 (*Continued*)

	N (%) unless otherwise specified N = 67,736
Imaging reviewed, yes	37,523 (94.6%)
(N=39,659 encounters with variable recorded)	
Alteplase recommendation	
Yes	5,023 (10.1%)
No	37,106 (74.3%)
N/A	7,789 (15.6%)
(N=49,918 encounters with variable recorded)	
Alteplase administered in the full	
cohort, n (%)	128 (7.1%)
2013	169 (4.9%)
2014	193 (3.0%)
2015	284 (3.0%)
2016	686 (3.3%)
2017	411 (1.7%)
2018	1903 (2.8%)
overall	
Door-to-Needle Time, median (IQR)	53 min (42, 73)
(N=1152 encounters with alteplase)	
Disposition, transfer	3190 (8.4%)
(N=37,786 encounters with disposition recorded)	
Disposition of IS patients	
Recommend transfer	677 (10.2%)
(N=6,614 encounters with variable recorded)	
Endovascular treatment in IS	
patients, *n* (%)	0 (0%)
2013-2015	15 (10.9%)
2016	850 (25.2%)
2017	183 (24.8%)
2018	1048 (24.7%)
overall	
(N=4,242 with variable recorded)	

Legend. SD standard deviation; IS Ischemic stroke; IQR interquartile range

and found that this significantly decreased from 2013 to 2018 (p=0.006), with CT most often preceding consultation requests in 2013, and by 2018 consultation requests most often preceding CT.

There were significant increases over time in both the number and proportion of patient consults eligible for alteplase and in the number of patients treated with alteplase (eligible increased from 198 in 2013 to 1,759 in 2018, p=0.0001;treated increased from 128 in 2013 to 440 in 2018, $p<0.001$ [2019 not included as these data were not available for the full year]).

There were 12,247 patients deemed eligible for endovascular intervention (30% of the 40,907 for whom the field was completed). Among thrombectomy-eligible patients, timeliness of imaging, consultation, and

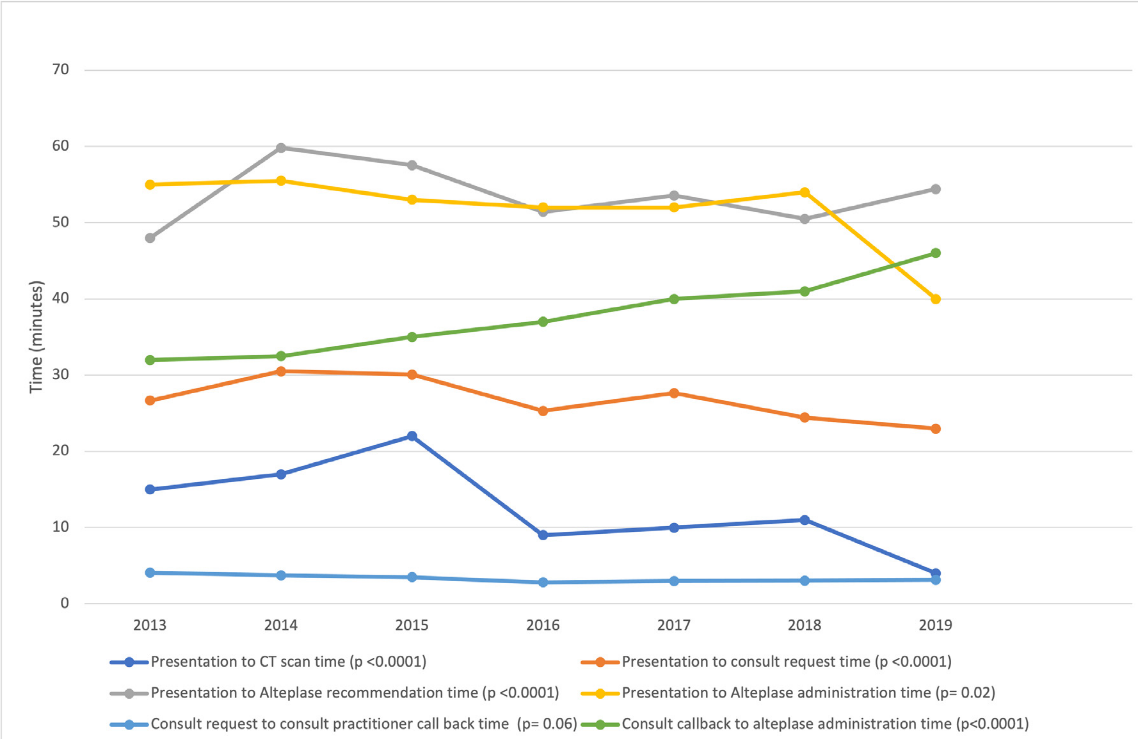

Fig. 1. *Trends in Telestroks Consultations Time Mertics 2013–2019.*

treatment metrics were relatively stable from 2015 to 2018 (Supplement). Of the 36,786 patients with disposition recorded, transfer was explicitly recommended for 3,190 of patients (8.4%).

Among all patients with disposition recorded, the percentage of patients for whom transfer was recommended decreased over time from 8.5% in 2013 to 4.0% in 2018 ($p<0.001$).

Receiving hospital characteristics associated with performance on alteplase delivery

Site characteristics are presented in Table 2. In bivariate analyses, larger hospitals, and those performing more consults per year had higher frequency of alteplase administration, while rural hospitals and those in the Northeast had lower frequency of alteplase

Table 2. *Characteristics of sites receiving telestroke consultations.*

Site Characteristic	*N* (%) *unless otherwise specified N* = 132
Consults per year, mean (SD)	110.2 (156.6)
Hospital size*	
Small	65 (52.9%)
Medium	27 (22.0%)
Large	31 (25.2%)
(N=121 sites with variable available)	
Rural	43 (33.9%)
(N=127 sites with variable available)	
U.S. Region	
Northeast	31 (24.2%)
South	49 (38.3%)
Midwest	3 (2.3%)
West	45 (35.2%)
Average of median door-to-needle times, minutes *(N=66 sites with variable available)*	72.9 (198.7)
Average of percentage of eligible patients treated with alteplase, (SD)	35.5% (27.3)

Legend: SD, standard deviation; RUCA, rural-urban commuting area
*See Supplemental Table 1 for Hospital Size categories.

Table 3. *Relationship between receiving hospital characteristics and performance on alteplase delivery: number of patients treated with alteplase per year.*

Variable	Unadjusted change in number of patients treated per change in variable unit	*p*-value	Adjusted change in number of patients treated per change in variable unit	*p*-value
Consults per year (unit=100 consults)	2.57	<0.0001	2.54	<0.0001
Hospital size				
Small	ref	0.09	ref	0.75
Medium	2.6	<0.001	0.4	0.03
Large	5.7		2.5	
Rurality	-0.6	0.03	-0.03	0.88
U.S. region				
West	ref	0.02	ref	0.07
Northeast	-4.7	0.57	-2.4	0.01
South	-0.8	0.16	2.58	0.86
Midwest	-5.3		-0.46	

administration. After accounting for other covariates, consult volume and hospital size remained significantly associated with alteplase administration frequency, and hospitals in the South were also more likely to have higher frequency of alteplase administration (Table 3).

Alteplase administration was administered to 1903 patients, and door-to-needle time was documented in 1152 (60.5%). Receiving hospital performance on door-to-needle time for alteplase delivery was not significantly associated with any spoke characteristics on bivariate or multivariable analysis (Table 4). Likewise, door-to-imaging time and door-to-consult time and consult callback-to-alteplase time were not significantly different by region, hospital size, rurality, or hospital consult volume, with the exception of longer times from arrival-to-consult request in the South. (354 min, *p*=0.03).

Finally, we examined the relationship between duration of participation in the telestroke network and alteplase delivery metrics. There was no significant association between duration of participation and proportion of eligible patients treated with alteplase (increase of 0.03% additional patients per additional year, *p*=0.07). However, we did find that sites with longer duration of participation had shorter door-to-needle times for patients treated with alteplase. In adjusted analyses accounting for hospital size, rurality, and U.S. region, the door-to-needle time significantly decreased by 39 min for every year of affiliation with the network (*p*=0.04).

Discussion

We report data from 132 spokes using a commercial telestroke platform from 2013 to 2019. This included nearly 68,000 telestroke consultations (at least 3-fold more telestroke consultations than published cumulatively in the medical literature to date). Consultation time metrics significantly improved over the duration of the study period, including time to NIHSS assessment, CT scan, imaging

Table 4. *Relationship between receiving hospital characteristics and performance on door-to-needle time for alteplase delivery.*

Variable	Unadjusted change in time (minutes) per change in variable unit	*p*-value	Adjusted change in time (minutes) per change in variable unit	*p*-value
Consults per year (units=100 consults)	-6.23	0.64	-11.39	0.47
Hospital size				
Small	ref	0.48	ref	0.47
Medium	-45.9	0.48	-48.9	0.34
Large	-44.5		-66.5	
Rurality	-4.9	0.64	-8.7	0.47
U.S. region				
West	ref	0.72	ref	0.20
Northeast	-81.0	0.44	-109.1	0.26
South	-54.9	Missing	-69.1	Missing
Midwest	Missing		Missing	

review, teleconsultation, and alteplase administration. However, we also found that time from *call back* to alteplase recommendation and administration significantly increased over time.

We were surprised to find increasing times from consult call back to alteplase recommendation and administration. However, given that time from ED arrival to alteplase administration improved over time, one possibility for the increased time from callback to administration is that with more rapid time from arrival to consultation, the telestroke consultant was involved in the patient care at an earlier point in the ED course and prior to collection of all relevant data necessary for recommendation. This possibility is supported by our finding of a decrease in time from CT performance to consultation request over the study period.

From 2013 to 2016, we found a declining trend in the number of consults conducted by each spoke per year, followed by an uptrend from 2016 to 2019. One possibility is that sites were responding to changes in clinical evidence. For example, the negative findings of the Interventional Management of Stroke (IMS) III trial in 2013[13] may have contributed to decreasing consultations related to patients potentially eligible for endovascular intervention until after 2015 when subsequent trials affirmed the benefit for eligible patients.[14–18] However any attempted explanation is purely speculative.

Similarly, we were surprised to find a decrease in the percentage of patients with transfer recommended and decreasing percentages of patients treated with alteplase from 2013 to 2018. This stands in contrast to the literature describing increasing transfers and increasing rates of alteplase treatment over time among stroke patients. However, this sample represents a unique subset of sites caring for acute stroke patients and the sample includes patients with telestroke consultations called *suspected* stroke regardless of final diagnosis. Thus, the declining proportions of transfer recommendations and alteplase administration may be reflective of changes in the population of patients for whom telestroke consultations were called, or even changes in the sites and resources of the sites participating in the telestroke networks.

We found that hospitals with higher frequency of consults also had more patients eligible for alteplase and a greater proportion of patients treated with alteplase. This may simply reflect a higher volume of eligible patients. However, when we limited to patients identified as eligible for alteplase, we also found that hospitals with increased consult frequency had higher rates of treatment among *eligible patients.* In addition, we found that sites with longer duration of participation had shorter door-to-needle times for patients treated with alteplase. These results are similar to previous work, finding that the *intensity* of a hospital's participation in a telestroke network is associated with improved performance on stroke care delivery.[10] These findings suggest that increased frequency of consultation has a direct benefit to performance on stroke care delivery. Potential mechanisms include improved performance through repeated practice and knowledge transmission during the telestroke interactions.

These results add to the existing telestroke literature, as most previous reports have been based on academic hub-and-spoke model systems.[4,6,8,10] We found a somewhat lower rate of alteplase delivery to stroke patients in our data relative to other academic hub-and-spoke networks. However only 54% of patients in our data had an ischemic stroke diagnosis at the conclusion of the telemedicine encounter. In contrast, other systems with reported rates of 15–20% have not included rate of stroke diagnosis or have explicitly focused on patients with acute ischemic

Table 5. *Comparison of telestroke consultations in commercial platform to published data from 3 academic hub-and-spoke telestroke networks.*

	Commercial Platform N=65,535	Georgia's REACH Program[18]	Kaiser Permanente Southern California[4]	Partners Telestroke network	TeleMedical Project for integrative Stroke Care (TEMPiS)[19]
	National	Georgia	Southern California	New England	Southeast Bavaria/Germany
Years reported	2013–2019	2003–2005	2013–2015	2003–2018	2003–2012
Number of spoke/ receiving hospitals	132	30	10	43	15
Rate of stroke diagnosis	54%	Not included	Not included	Not included	Not included
Proportion of patients receiving alteplase	10.1%	15.5%	10.9%	18.9%	15.5% in most recent year of data
Door-to-needle time, minutes Median (IQR)	53 (42–73)	Not included	55 (47–69)	73 (55–100)	40 (29–59) in most recent year of data

Legend. IQR Interquartile Range

stroke, making these rates difficult to truly compare (Table 5).[4,10]

Well-designed stroke systems of care are paramount to ensure access to high-quality care delivery for all patients with stroke.[19,20] Academic hub-and-spoke telestroke programs have an important role in the system of care, and an extensive body of literature affirms the value of the academic hub-and-spoke telestroke network.[1,5–7,9,10,21–23] Our findings suggest that commercial networks may also contribute to high-quality stroke care delivery, and fill gaps in access where academic hub-and-spoke programs have not emerged. Our results suggest that commercial platforms are able to provide a consistent benefit to patients with respect to alteplase delivery, and that receiving sites that are engaged in the process perform similarly to spoke hospitals in academic networks. It may be that the nature of the telestroke network is less important than the quality of the providers and of the connection.

Our study does have limitations. While one of the first descriptions of stroke care delivery via telestroke on a national scale, the data are based on hospitals connected with only 2 major providers and may not be reflective of patterns in other networks or with other hub providers. Due to limitations of our data we are unable to characterize some important components of stroke presentation and course (e.g., hemorrhagic transformation, endovascular procedure metrics). We also are not able to characterize details of the consulting telestroke providers (e.g., fellowship training completion) or of spoke hospitals (e.g., stroke center status). Additionally, there were missing data for some fields (e.g., NIHSS, clinical impression) however data appear to be missing at random and should not have biased our results. Finally, we were unable to characterize how telestroke consultation contributed to some components of the stroke system of care (e.g., transfer times) because our data were limited to the initial telestroke consultation.

Conclusions

Among 132 hospital sites receiving telestroke consultations via a commercial telestroke network, times to consult start and alteplase bolus decreased over time. However, performance varied by region and by telestroke consult volume. We found that duration of telestroke participation was associated with faster alteplase delivery, suggesting improved performance with increased practice opportunity. Overall, commercial telestroke networks appear to behave similarly to academic networks.

Declaration of Competing Interest

KSZ, RS, AM have no disclosures to report. YW reports being employed by TelaDoc Health. LHS reports being a consultant on user interface design and usability to LifeImage.

Funding: Agency for Healthcare Research and Quality (K08 HS024561, Zachrison); NIH/NINDS (R01 NS111952, Mehrotra)

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.jstrokecerebrovasdis.2021.106035.

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