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The role of stroke care infrastructure on the effectiveness of a hub-and-spoke telestroke model in South Carolina

Mithuna Srinivasan, PhD[a,*], **Amber Scott, MPH**[b,c], **Jackie Soo, ScD, MPH**[d], **Meera Sreedhara, PhD, MPH**[b,e], **Shena Popat, MHA**[a], **Kincaid Lowe Beasley, MPH**[b], **Tiara N. Jackson, PhD, MPH, CHES**[f], **Amena Abbas, MPH**[b,g], **W. Alexander Keaton, MPH**[b,c], **Christine Holmstedt, DO, FAHA**[h], **Jillian Harvey, PhD, MPH**[h], **Ryan Kruis, MSW, LISW-CP**[h], **Shay McLeod, MSN, RN**[h], **Roy Ahn, ScD**[d]

[a]NORC at the University of Chicago, 4350 East-West Hwy 8th Floor, Bethesda, MD 20814, United States

[b]Centers for Disease Control and Prevention, National Center for Chronic Disease Prevention and Health Promotion, Atlanta, GA, United States

[c]Oak Ridge Institute for Science and Education, Oak Ridge, TN, United States

[d]NORC at the University of Chicago, Chicago, IL, United States

[e]Cherokee Nation Operational Solutions, Tulsa, OK, United States

[f]Decision Information Resources, Inc., Houston, TX, United States

[g]ASRT, Inc., Atlanta, GA, United States

[h]Medical University of South Carolina, Charleston, SC, United States

Abstract

Objective: To examine the relationship between stroke care infrastructure and stroke quality-of-care outcomes at 29 spoke hospitals participating in the Medical University of South Carolina (MUSC) hub-and-spoke telestroke network.

Materials and methods: Encounter-level data from MUSC's telestroke patient registry were filtered to include encounters during 2015-2022 for patients aged 18 and above with a clinical

[*]Corresponding author. srinivasan-mithuna@norc.org (M. Srinivasan).

CRediT authorship contribution statement

Mithuna Srinivasan: Writing – review & editing, Writing – original draft, Supervision, Methodology, Formal analysis, Conceptualization. **Amber Scott:** Writing – review & editing, Conceptualization. **Jackie Soo:** Conceptualization, Data curation, Formal analysis, Methodology, Software, Writing – original draft, Writing – review & editing. **Meera Sreedhara:** Conceptualization, Writing – review & editing. **Shena Popat:** Writing – original draft, Project administration. **Kincaid Lowe Beasley:** Writing – review & editing, Project administration, Conceptualization. **Tiara N. Jackson:** Writing – original draft. **Amena Abbas:** Writing – review & editing. **W. Alexander Keaton:** Writing – review & editing. **Christine Holmstedt:** Writing – review & editing, Resources. **Jillian Harvey:** Writing – review & editing, Resources. **Ryan Kruis:** Writing – review & editing, Resources. **Shay McLeod:** Writing – review & editing, Resources. **Roy Ahn:** Supervision, Conceptualization, Writing – original draft, Writing – review & editing.

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We declare no competing interests.

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diagnosis of acute ischemic stroke, and who received intravenous tissue plasminogen activator. Unadjusted and adjusted generalized estimating equations assessed associations between time-related stroke quality-of-care metrics captured during the encounter and the existence of the two components of stroke care infrastructure—stroke coordinators and stroke center certifications—across all hospitals and within hospital subgroups defined by size and rurality.

Results: Telestroke encounters at spoke hospitals with stroke coordinators and stroke center certifications were associated with shorter door-to-needle (DTN) times (60.9 min for hospitals with both components and 57.3 min for hospitals with one, vs. 81.2 min for hospitals with neither component, p <.001). Similar patterns were observed for the percentage of encounters with DTN time of ≤60 min (63.8% and 68.9% vs. 32.0%, p <.001) and ≤45 min (34.0% and 38.4% vs. 8.42%, p <.001). Associations were similar for other metrics (e.g., door-to-registration time), and were stronger for smaller (vs. larger) hospitals and rural (vs. urban) hospitals.

Conclusions: Stroke coordinators or stroke center certifications may be important for stroke quality of care, especially at spoke hospitals with limited resources or in rural areas.

Keywords

Stroke; Quality of healthcare; Program evaluation; Telemedicine; Remote consultation

Introduction

In the United States, more than 795,000 people have a stroke each year, and it is a leading cause of death.[1] When stroke occurs, access to evidence-based, timely care is critical to reduce neurological damage and mortality. However, this access is not equally distributed across communities, with rural populations often needing to travel long distances to access stroke treatment, resulting in geographic disparities in outcomes.[2] Furthermore, patients admitted to hospitals with lower patient volumes may lack access to necessary specialist evaluation and care.

Telestroke is a promising approach to treat patients living in medically underserved communities by improving access to stroke specialists and timely stroke treatment.[3] Some telestroke programs operate as “hub-and-spoke” models where specialists based at a hub provide remote stroke consultation to hospitals that are smaller and have fewer resources.[4] By using synchronous audio and visual communication, health care professionals at originating spoke hospitals (where the patient presents) can communicate with hub-based specialists who assist in the diagnosis and treatment of acute stroke.[5,6] Telestroke has helped physicians in smaller community or rural hospitals reduce their times to stroke treatment and increase rates of appropriate treatment.[7,8]

While telestroke clinical teams comprise staff with specialized neurovascular care expertise (including neurologists, neurocritical care specialists, and neurosurgeons),[9,10] stroke coordinators at spoke hospitals are often considered an essential part of telestroke services.[11-13] Coordinators[1] develop hospital-specific protocols and best practices for stroke care,[2] implement stroke education programs (e.g., training on telepresentation education, medication use protocols, acute stroke education to patients and their families, and administering the National Institutes of Health Stroke Scale (NIHSS) to patients to assess stroke severity),[3] facilitate communication between the hub-and-spoke hospitals,[4] collect, analyze, and use performance data to improve care delivery, and[5] provide ongoing feedback to clinical staff at spoke hospitals.[14] This focus on processes and education may potentially be why the presence of stroke coordinators can lead to improved quality and timeliness of patient care.[15] Spoke hospitals that are certified stroke centers include acute stroke teams and units, standardized care protocols, and an integrated emergency response system.[16] A recent study compared concordance to ischemic stroke treatment guidelines across hospitals with and without stroke center certification; results showed that stroke center certification was associated with increased adherence to stroke care guidelines.[17] Both stroke center certifications and stroke coordinators are key components of a spoke hospital's stroke care infrastructure; they also may be essential to the hospital's ability to effectively interact with an interdisciplinary hub team to manage and monitor patients with acute ischemic strokes under a telestroke model.[10,18]

While data in the literature describe the effectiveness of telestroke models on patient outcomes, less is known about how stroke care infrastructure—such as stroke coordinators and stroke center certifications as described above—relate to stroke quality-of-care outcomes. Studies that examine the effectiveness of telestroke models are important for understanding which models work, but evaluations that delve deeper into the facilitators of successful models can generate important, practice-based evidence to support a broader adaptation of such facilitators. In 2023, the Centers for Disease Control and Prevention's Division for Heart Disease and Stroke Prevention and NORC at the University of Chicago (NORC) conducted an outcomes evaluation of MUSC's telestroke network. This study examined whether such stroke care infrastructure components affected stroke quality-of-care time metrics for MUSC's 29 spoke hospitals participating in telestroke. Furthermore, this study assessed whether those associations between stroke care infrastructure and quality-of-care metrics differed by the type of spoke hospital based on location (rural or urban) and size (large or small/medium).

Methods

Description of the telestroke network

The MUSC hub-and-spoke telestroke network, launched in 2008, comprises rural and community spoke hospitals across South Carolina. Fig. A1 in the Online Appendix shows the statewide reach of the MUSC network. Because of this program, all residents of the state now live within 60 min of expert stroke care.

All telestroke encounters are completed on 2-way audio video. When a patient presents with stroke-like symptoms at a spoke hospital, staff can call MUSC's admit transfer center (ATC), and the center then pages the MUSC telestroke physician on call on their phone. Telestroke providers immediately log on to the telestroke platform at MUSC and work with the spoke hospital's health care team to quickly gather information about the patient, examine and diagnose the patient, review computed tomography (CT) scans, and make treatment recommendations. The nurses assist the telestroke providers in completing a NIHSS on the suspected stroke patient. Telestroke providers have immediate access to patient's brain imaging. At many of the spoke hospitals, the stroke coordinator is also at the bedside assisting the nurse and care team. Each hospital has its own coordinator, and coordinators are not a shared resource.

The telestroke encounters at different spoke hospitals are very similar even though hospitals have different resources. All hospitals have the basic necessary resources to complete a rapid stroke assessment and can at least provide thrombolytic therapy. Hospitals that do not have the resources to admit patients that received thrombolytic therapy may need to transfer to primary or comprehensive centers closest to them.

In addition to the provision of clinical care, hub consultations also offer education and mentorship to spoke hospital physicians, nurses, and emergency medical technicians. To aid in this, MUSC maintains a registry of all patients in the telestroke network, and each month MUSC reviews patterns and trends in time-related stroke quality-of-care outcomes such as door-to-registration (DTR) time and door-to-needle (DTN) time, among others.

Data Source and Study Population

We conducted a retrospective analysis of de-identified telestroke encounter-level data, from 29 spoke hospitals, available through MUSC's telestroke patient registry. The dataset included basic patient demographics, stroke severity, and the stroke quality-of-care measures used in this analysis (measures are described in more detail below). Our unit of analysis was the telestroke encounter because a lack of unique patient identifiers in the registry data precluded analyses at the patient level. MUSC confirmed that repeat encounters make up roughly 18% of all telestroke encounters.

We filtered the dataset to include telestroke encounters between January 1, 2015, and December 31, 2022, for patients at least 18 years of age who had a clinical diagnosis of acute ischemic stroke, and who received intravenous tissue plasminogen activator (tPA). Only observations with non-missing data on all variables of interest were retained for analyses (Table A1 in the Online Appendix). Even though MUSC's telestroke model began in 2008, we began our observation period in 2015 because it was not until then that spoke hospitals started to have stroke coordinators or stroke-focused certifications, and to implement systematic and evidence-based stroke care processes. Furthermore, although MUSC had 37 participating spoke hospitals as of 2022, hospitals were excluded from analysis if they reported having a coordinator but were missing the coordinator start date, or if they reported having certification but were missing the certification effective date, thereby restricting the final sample to observations from 29 spoke hospitals.

We supplemented the encounter-level registry data with spoke hospital-level data also provided by MUSC, including hospital location, hospital size, and whether, in a given year, a hospital had a stroke coordinator or a stroke center certification (granted by the Joint Commission). Using the hospital's location, we classified hospitals as urban or rural, based on the Health Resources and Services Administration (HRSA) Federal Office of Rural Health Policy data files. Hospital size was classified by MUSC as small (1-25,000 annual emergency department [ED] visits), medium (25,001-50,000 annual ED visits), and large

(50,001-90,000 annual ED visits). Table A2 in the Online Appendix shows the distribution of the 29 spoke hospitals by rurality and size.

Measures

Our primary outcome of interest was DTN time, which is one of the main stroke-related quality metrics.[19] DTN time represents the overall duration of stroke care, from patient presentation at the spoke hospital with stroke-like symptoms to administration of tPA. We analyzed continuous and dichotomous variables that considered the actual DTN time in minutes, as well as whether DTN time was ≤45 min and ≤60 min.[20] We also considered a range of more intermediate time metrics as secondary stroke quality-of-care outcomes including: DTR time, registration to ATC call time, ATC call to physician logon time, consult start to tPA decision time, and tPA decision to administration time.

Our main explanatory variable was a categorical indicator for whether, at the time of a telestroke encounter, the spoke hospital had key components of stroke care infrastructure—a stroke coordinator and/or a stroke center certification. Tables A3 and A4 in the Online Appendix show how the presence of stroke coordinators and/or stroke center certifications were distributed among spoke hospitals and telestroke encounters, respectively. Since these components were not distributed equally and there were very few encounters at hospitals with only certifications, we grouped spoke hospitals into three categories: had both components of stroke care infrastructure, had one component, or had neither component.

Multivariable models controlled for an array of predictors of stroke quality-of-care outcomes that were available in the MUSC provided data. Encounter-level demographic characteristics of patients receiving a telestroke service included sex (male or female), age (in years), and race (White vs. racial minority groups). Nearly all encounters in the racial minority group were associated with Black or African American patients; we were unable to disaggregate race into more granular categories due to small numbers. We also controlled for the patient's initial NIHSS score recorded during the encounter. Hospital-level covariates included indicators for the hospital's location (urban or rural) and size (large or small/medium). Small and medium-sized spoke hospitals were combined into one category owing to small cell sizes. Finally, we controlled for the year of the telestroke encounter to account for non-linear time trends.

Analysis

We used generalized estimating equations with robust standard errors clustered by hospital. Continuous outcomes used the linear regression function (identity link and Gaussian family), while categorical outcomes used the binomial family and logit link. First, we conducted analyses to examine the distribution of encounters by patients' demographic characteristics, and hospital-level factors, across the 29 participating spoke hospitals. We also examined rates in the outcome variables. Then, we used multivariable regression models to assess the relationship between stroke quality-of-care outcomes and the stroke care infrastructure explanatory variable, controlling for the covariates described above. We also estimated hospital type-specific regression models (with the same covariates) to separately assess the association between stroke quality-of-care outcomes and stroke care infrastructure for each hospital location category (urban or rural) and size category (large or small/medium). All analyses were conducted in 2023 using Stata, version 16 (StataCorp LLC, College Station, Texas). We used an α level of 0.05 or less to denote statistical significance. Our study was approved by the Institutional Review Boards at both MUSC and NORC.

Results

The telestroke registry comprised 26,651 encounters that occurred between January 1, 2015, and December 31, 2022. Of these, 12,048 encounters involved acute ischemic stroke patients aged 18 and above. We further limited the sample to encounters wherein patients had received tPA, since DTN time was our primary outcome. The tPA administration rate in our sample was approximately 25%, which is higher than tPA rates noted in studies using nationally representative samples.[21-23] After imposing all restrictions, 1,974 telestroke encounters from 29 spoke hospitals met eligibility criteria and were included in the analysis (Table A1 in the Online Appendix).

A large proportion (60.6%) of the included encounters occurred at spoke hospitals with both infrastructure components, stroke coordinators and certifications; 25.3% of encounters occurred at hospitals with only one component; and 14.0% occurred at hospitals with neither component. Regarding the type of stroke center certification, the vast majority (96.2%) of encounters in certified sites were in Primary Stroke Centers (PSCs), while 3.6% were in Acute Stroke Ready hospitals, and 0.2% were in Thrombectomy-Capable Stroke Centers.

Table 1 shows that across included telestroke encounters, on average, patients were aged 66.2 years and had an initial NIHSS score of 8.73, indicating moderate stroke severity. Telestroke encounters were evenly distributed by patient sex. Approximately two-thirds of encounters involved White patients, although the proportion was higher at hospitals with either one or both infrastructure components, versus hospitals with neither component. Overall, a higher proportion of telestroke encounters occurred at urban spoke hospitals than rural, although this pattern switched for spoke hospitals without either infrastructure component. Similarly, a higher proportion of encounters occurred at large spoke hospitals compared to those that were small or medium, with the exception of being a spoke hospital with both infrastructure components.

Table 2 provides unadjusted primary and secondary outcome rates by the three stroke care infrastructure components. The mean DTN time was shorter among encounters that occurred at hospitals with stroke care infrastructure components versus those at hospitals with neither component (61.3 min for encounters at hospitals with both components and 57.9 min at hospitals with one component, vs. 80.8 min at hospitals with neither component, $p < .001$). Similar patterns were observed for the percentage of encounters involving a DTN time of ≤60 min (63.1% and 68.4% vs. 31.4%, $p < .001$) and ≤45 min (32.3% and 36.8 vs. 8.3%, $p < .001$). Other time metrics also were shorter for encounters at hospitals with stroke care infrastructure components versus those without, namely DTR time, registration to ATC call time, and tPA decision to administration time. No difference was found in ATC call to physician logon time or consult start to tPA decision time.

Table 3 provides results from multivariable regression models examining the adjusted association between stroke care infrastructure components and DTN time. The results remained robust when controlling for covariates. In adjusted analyses, telestroke encounters at spoke hospitals with stroke care infrastructure components involved shorter DTN times than those at hospitals with no stroke coordinators or stroke center certifications. For example, the mean DTN time was nearly 17 min shorter ($p < .01$) for encounters at hospitals with both stroke care infrastructure components relative to those at hospitals with neither infrastructure component. There were also significantly higher adjusted odds of achieving DTN times of ≤60 min or ≤45 min for encounters at hospitals with these stroke care infrastructure components than without.

The estimated DTN time difference between spoke hospitals with stroke care infrastructure components versus not was similar for encounters at hospitals with both infrastructure components and with only one infrastructure component. For example, encounters at hospitals with both components had three times the odds of having a DTN time of ≤60 min than encounters at hospitals with neither component. Correspondingly, encounters at hospitals with only one component had 2.8 times the odds of having a DTN time of ≤60 min relative to encounters at hospitals with neither component.

Table 4 shows results from multivariable regression models examining the adjusted association between stroke care infrastructure components and the secondary stroke quality-of-care outcomes. Telestroke encounters at spoke hospitals with stroke care infrastructure components involved shorter DTR times, registration to ATC call times, and tPA decision to administration times. For example, the mean DTR time was nearly 8 min shorter for encounters at hospitals with one or both stroke care infrastructure components, relative to those with neither component. For these secondary outcomes as well, the estimated difference between spoke hospitals with stroke care infrastructure components versus not was similar for encounters at hospitals with both infrastructure components and at hospitals with only one infrastructure component. The remaining two secondary outcomes were not significantly associated with the stroke care infrastructure variable in adjusted analyses.

Finally, we examined whether the adjusted associations between stroke care infrastructure components and the DTN time outcomes were different based on spoke hospitals' rurality and size. As seen in Table A5 in the Online Appendix, encounters in hospitals with at least one component of stroke care infrastructure involved shorter DTN times within each of the specific hospital type subgroups. However, the association between DTN time and stroke care infrastructure was generally stronger for small and medium hospitals than for large hospitals. This association was also stronger for rural hospitals than for urban hospitals.

Discussion

In this evaluation of the MUSC telestroke network, we found that telestroke encounters at spoke hospitals with at least one component of stroke care infrastructure (a stroke coordinator or stroke center certification) involved more timely stroke care than among encounters at hospitals with neither of these infrastructure components in place. Our findings also showed that the presence of both stroke coordinators and stroke center certifications was similarly beneficial to having just one infrastructure component. The pivotal role played by a stroke coordinator in a telestroke model has been well established in the literature and encompasses responsibilities that range from supporting the provision of care to analyzing quality performance data and accordingly developing evidence-based policies.[13-15] Stroke center certification requires that hospitals have an interdisciplinary program structure, use evidence-based clinical practice guidelines, and have formal performance improvement processes.[24]

This evaluation also revealed that some hospitals, based on size and location, experienced greater benefits from stroke care infrastructure. Specifically, stroke coordinators and certifications seem to benefit smaller and rural hospitals more—suggesting that having staffing or an external incentive to standardize processes and procedures may be more important for hospitals that may not have the volume of practice or resources to achieve better stroke outcomes via other mechanisms. High hospital volume has been associated with lower stroke mortality and better outcomes for other procedures and conditions, possibly due to increased resources, access to specialists, or lower complication rates.[25,26] Literature indicates patient- and community-level disparities in access to stroke-certified hospitals, wherein hospitals in rural and low-income service areas are less likely to have stroke certification.[27,28] The hub-and-spoke telestroke model especially offers small and medium spoke hospitals, with lower overall stroke volume, the ability to overcome barriers to access by drawing upon hub telestroke expertise, a standardized protocol of care, and additional support staff, which may contribute to more timely stroke care.[29] Since 41% of encounters in our analytic sample occurred at rural hospitals, implementing telestroke-related stroke care infrastructure components in rural settings could help alleviate existing urban/rural disparities in stroke care.[30]

A previous assessment of the MUSC telestroke service’s operational outcomes suggests that affiliation with the telestroke network led spoke hospitals to obtain and maintain their certification.[29] Most of the certified spoke hospitals participating in MUSC’s telestroke network were PSCs, meaning these hospitals must have advanced brain and cardiac imaging and an inpatient stroke unit.[31] Prior studies have shown that hospitals with a PSC designation show improvements in acute stroke evaluation and care and reduced mortality, compared to hospitals without such a certification.[32-34] Although these differences were not specifically found in the context of telestroke services, telestroke is often embedded within quality improvement activities at hospitals.[35] Thus, the process of stroke certification could help formalize and standardize telestroke protocols, among other processes, and lead to more efficient and effective care.

Our evaluation findings suggest ways that smaller and rural hospitals with limited resources may leverage the capacity and expertise of the hub hospital to improve the quality and timeliness of stroke care for patients. Future studies could[1] evaluate the exact mechanisms by which stroke care infrastructure components might contribute to improved patient outcomes, or[2] investigate other components of stroke or telestroke infrastructure, such as leadership and funding support, processes for health care team feedback, or standardized data collection. In addition, close to one-third of encounters in our analytic sample involved patients from racial minority groups, which indicates future research should investigate what effect stroke care infrastructure components may have on racial and ethnic disparities in stroke care.[28] Encounters at hospitals with neither stroke care infrastructure component had the highest proportion of patients from racial minority groups. Therefore, telestroke implementers need to ensure that stroke care supports are not inadvertently widening disparities in stroke care, identify interventions that improve equitable access to stroke care, and mitigate disparities in stroke quality-of-care outcomes among patients from racial and ethnic minority groups.

Evaluation limitations

The evaluation design prevents us from determining causality. We concluded that stroke quality-of-care outcomes are significantly better at spoke hospitals with stroke coordinators and/or stroke center certifications than at those without either component, but we cannot conclude that outcome improvements were caused by these infrastructure components. The small number of telestroke encounters prevented us from exploring the associations for certification alone. The stroke quality-of-care outcome measures relied on health care staff at the spoke hospitals accurately recording start and end times to telestroke care. The mis-entering of time, or relying on recall to enter time post encounter, could result in errors or outliers in the outcomes—which if systematically different, based on the stroke care infrastructure explanatory variable, could bias the observed associations.

Due to the lack of unique patient identifiers in the registry data provided by MUSC, we were unable to identify patients who had repeat telestroke encounters, and therefore we were unable to conduct analyses at the patient level, or, in other words, omit repeat encounters from the analytic sample. However, based on estimates provided by MUSC, such repeat encounters make up about 18% of the total sample, so their inclusion may have introduced selection bias, which we are unable to assess because the dataset is de-identified.

There was also a substantial amount of missing data in outcome and covariate measures (particularly race, which was often self-reported by the patient and/or not adequately recorded), limiting our sample size. Additionally, due to missing data in the date and time of patient transfers to another facility, we could not evaluate a measure of door-in door-out (DIDO) time. While we controlled for patient demographics and hospital-level factors in our analysis, we cannot rule out the possibility that selection bias may have impacted our results. Furthermore, we did not have medical history on patients, which limited our ability to control for comorbidities or other risks for poor outcomes; however, patient-level risk factors should not directly impact the timeliness of care. Finally, this evaluation was based on one hub-and-spoke telestroke model implemented in South Carolina, thereby limiting the generaliz-ability of the findings nationally.

Conclusions

In the MUSC telestroke network, encounters at spoke hospitals with a stroke coordinator, stroke center certification, or both of these components were associated with more timely stroke care than encounters at hospitals without either component. These results may be useful to other systems developing or implementing telestroke models, and particularly to spoke hospitals in determining how to allocate limited resources. Especially for rural or smaller hospitals, these stroke-related infrastructure components may be important mechanisms allowing them to successfully implement telestroke models and deliver high-quality patient care.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Table 1

Distribution of the analytic sample of telestroke encounters by demographic and hospital characteristics (2015-2022).

Characteristic	All Encounters (N=1,974)	Encounters at Spoke Hospitals With Both Infrastructure Components (n=1,197)	Encounters at Spoke Hospitals With Only One Infrastructure Component (n=500)	Encounters at Spoke Hospitals With Neither Infrastructure Component (n=277)	*p*-value
Reported age, mean (SD)	66.2 (15.2)	66.0 (15.4)	67.7 (15.0)	64.5 (14.6)	0.012
Reported sex, n (%)					0.168
Female	1,062 (53.8)	661 (55.2)	265 (53.0)	136 (49.1)	
Male	912 (46.2)	536 (44.8)	235 (47.0)	141 (50.9)	
Reported race, n (%)					
White	1,370 (69.4)	826 (69.0)	383 (76.6)	161 (58.1)	<.001
Racial minority groups	604 (30.6)	371 (31.0)	117 (23.4)	116 (41.9)	
Stroke severity (NIHSS) at encounter, mean (SD)	8.73 (6.69)	8.65 (6.68)	8.53(6.68)	9.42 (6.75)	0.169
Hospital location, n (%)					
Urban	1,158 (58.7)	709 (59.2)	345 (69.0)	104 (37.6)	<.001
Rural	816 (41.3)	488 (40.8)	155 (31.0)	173 (62.5)	
Hospital size, n (%)					
Large	800 (40.5)	625 (52.2)	95.0 (19.0)	80 (28.9)	<.001
Small/medium	1,174 (59.5)	572 (47.8)	405 (81.0)	197 (71.1)	

Denominator for proportions is the sample size listed in the header row.

NIHSS = National Institutes of Health Stroke Scale, SD = standard deviation.

Table 2

Unadjusted primary and secondary outcome rates for the analytic sample of telestroke encounters (2015-2022), by stroke infrastructure category of spoke hospitals.

Outcome	**All Encounters (N=1,974)**	**Encounters at Spoke Hospitals With Both Infrastructure Components (n=1,197)**	**Encounters at Spoke Hospitals With Only One Infrastructure Component (n=500)**	**Encounters at Spoke Hospitals With Neither Infrastructure Component (n=277)**	***p*-value**
DTN time,					
mean (SD)	63.2 (35.2)	61.3 (37.4)	57.9 (26.7)	80.8 (33.5)	<.001
≤60 min, n (%)	1,184 (60.0)	755 (63.1)	342 (68.4)	87 (31.4)	<.001
≤45 min, n (%)	594 (32.3)	387 (32.3)	184 (36.8)	23.0 (8.3)	<.001
DTR time, mean (SD)	19.1 (26.0)	18.0 (28.3)	17.7 (18.6)	26.5 (25.9)	<.001
Registration to ATC call time, mean (SD)	22.6 (26.8)	21.2 (29.3)	19.8 (18.6)	33.5 (25.9)	<.001
ATC call to physician logon time, mean (SD)	5.07 (4.50)	5.15 (4.79)	4.93 (3.76)	5.03 (4.45)	0.649
Consult start to tPA decision time, mean (SD)	19.1 (10.2)	19.0 (10.5)	19.2 (10.1)	19.0 (9.49)	0.966
tPA decision to administration time, mean (SD)	16.5 (16.2)	16.0 (15.9)	14.0 (13.8)	23.3 (19.3)	<.001

Denominator for proportions is the sample size listed in the header row.

ATC = admit transfer center, DTN = door-to-needle, DTR = door-to-registration, SD = standard deviation, tPA = tissue plasminogen activator.

Table 3

Adjusted association between DTN time and existence of stroke infrastructure components at spoke hospitals (2015-2022).

Variable	Mean DTN Time β (95% CI)	DTN Time ≤60 Min OR (95% CI)	DTN Time ≤45 Min OR (95% CI)
Encounter in spoke hospital with one stroke infrastructure component	−15.66 *** (−21.72 - −9.59)	2.81 *** (1.66 - 4.75)	4.00 *** (2.44 - 6.56)
Encounter in spoke hospital with both stroke infrastructure component	−16.99 *** (−23.81 - −10.17)	3.19 *** (1.91 - 5.34)	4.32 *** (2.71 - 6.89)
Reference category: Encounter in spoke hospital with neither component			

*** $p < 0.01$.

N=1,974 for all outcomes.

All models controlled for age, sex, race, and initial NIHSS score reported during the telestroke encounter and whether the encounter occurred at a rural or large hospital.

β = beta coefficient, CI = confidence interval, DTN = door-to-needle, NIHSS = National Institutes of Health Stroke Scale, OR = odds ratio.

Table 4

Adjusted association between secondary outcomes and existence of stroke infrastructure components at spoke hospitals (2015-2022).

Variable	**DTR Time β (95% CI)**	**Registration to ATC Call Time β (95% CI)**	**ATC Call to Physician Logon Time β (95% CI)**	**Consult Start to tPA Decision Time β (95% CI)**	**tPA Decision to Administration Time β (95% CI)**
Encounter in spoke hospital with one stroke infrastructure component	−7.71*** (−12.00 – −3.42)	−10.24*** (−14.44– −6.03)	0.04 (−0.43 – 0.62)	−0.62 (−2.67 – 1.43)	−6.80*** (−9.99 – −3.61)
Encounter in spoke hospital with both stroke infrastructure components	−7.25*** (−11.52–−2.98)	−10.33*** (−15.07– −5.60)	0.10 (−0.59 – 0.79)	−0.77 (−2.61 – 1.08)	−7.57*** (−10.72 – −4.41)
Reference category: Encounter in spoke hospital with neither component	–	–	–	–	–

*** $p < 0.01$.

N=1,974 for all outcomes.

All models controlled for age, sex, race, and initial NIHSS score reported during the telestroke encounter, whether the encounter occurred at a rural or large hospital.

ATC = admit transfer center, β = beta coefficient, CI = confidence interval, DTR = door-to-registration, NIHSS National Institutes of Health Stroke Scale, tPA = tissue plasminogen activator.