**Impact of Telestroke Implementation on Emergency Department Transfer Rate**

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Abstract

**Background and Purpose**: Telestroke networks are associated with improved outcomes from acute ischemic stroke(AIS) patient and facilitate greater access to care, particularly in underserved regions. These networks also have the potential to influence patient disposition through avoiding unnecessary interhospital transfers. This study examines the impact of implementation of the VA National Telestroke Program (NTSP) on interhospital transfer among Veterans.

**Methods**: We retrospectively analyzed AIS patients presenting to the emergency department 21 VA hospitals. Transfer rates were determined before and after telestroke implementation at each site through review of administrative data and chart review. Patient and facility level characteristics were also collected to identify predictors of transfer. Comparisons were made using t-test, Wilcoxon rank sum, and chi-square analysis and predictors were assessed through multivariable logistic regression.

**Results**: We analyzed 3,488 stroke encounters (1,056 pre-NTSP and 2,432 post-NTSP). Following implementation, we observed an absolute 14.4% decrease in transfers (OR 0.39, 95% CI 0.19, 0.77) across all levels of stroke center designation. Younger age, higher stroke severity, and shorter duration from symptom onset were associated with transfer. At the facility level, hospitals with lower annual stroke volume were more likely to transfer although only one hospital actually saw an increase in transfer rates following implementation.

**Conclusions**: In addition to improving treatment in acute stroke, telestroke networks have the potential to positively impact the efficiency of interhospital networks through the avoidance of unnecessary transfers .

## Introduction

Telemedicine for acute stroke care (Telestroke) was originally proposed in the 1990s as a means to improve access to care and outcomes for patients experiencing an acute stroke.[1-3] Through the use of an audiovisual connection, a remote specialist can evaluate, diagnose, and treat patients presenting with symptoms of acute stroke, including making recommendations regarding alteplase and endovascular therapy. Over the past two decades, numerous benefits of telestroke have been realized including improved utilization rates for alteplase, improved access in geographically under-resourced areas, and reduced disparities in acute stroke care.[4, 5 6, 7 8]

Another anticipated benefit of an effective telestroke network is improved disposition recommendations to the appropriate level of care. Some patients may be best served by staying at a community facility while others warrant transfer to a higher level of care such as a primary or comprehensive stroke center.[9, 10] Interhospital transfer for stroke has increased over the past two decades, particularly with the expansion of eligibility for endovascular thrombectomy.[11-13] This has the potential to overburden tertiary centers with stroke mimics or thrombectomy-ineligible patients as well as to increase healthcare expenditures.[14-16] Telestroke consultation has been associated with improved accuracy of diagnosis[17] which potentially may avoid the unnecessary transfer of a patient with a stroke mimic to a stroke center while at the same time appropriately selecting those who need a higher level of care.

Transferring facilities are frequently rural and tend to be associated with lower use of acute stroke interventions.[18, 19] Urban-rural disparities have not improved over time[20] despite advances in other areas of acute stroke care and expansion of stroke systems of care. With significant variability in regional stroke systems and transfer patterns, telemedicine has the potential to expand access into underserved geographic regions and allow for the provision of guideline-concordant stroke therapies.[21,

[22] Furthermore, by reducing unnecessary transfers, appropriate lower acuity patients may be cared for within their local community with the added benefit of remaining closer to their family and social support.

In 2016, the Veterans Health Administration (VHA) implemented the VA National Telestroke Program (VA NTSP) representing both urban and rural facilities spread out over a diverse geographic landscape. The system comprises over 45 “spoke” facilities with a distributed “hub” of telestroke physicians from across the country (rather than centralized hub originating from one tertiary center). Although some telestroke networks have reported their experience with interhospital transfer, the impact of telestroke on stroke transfers when applied outside of a traditional “hub and spoke” telehealth model remains unknown.[23, 24] Furthermore, it is unclear how telestroke impacts transfer patterns across the continuum of facility types and geographic locations. The purpose of this analysis was to evaluate the impact of the VA NTSP on interhospital transfer rates for suspected stroke patients, and to examine the patient and facility factors associated with likelihood of transfer.

**Methods**

This project was conducted as part of the Department of Veterans Affairs National Telestroke Program (NTSP) Evaluation, which was approved by VHA national and local offices as an operational quality improvement project (non-research). The NTSP provided its first telestroke consultation in October 2017 and as of March 2021, the program was active in 40 VA facilities nationwide. Facilities are instructed to activate the NTSP for all patients with suspected stroke who arrive within 8 hours of last known well (LKW) time, and for those with severe stroke who arrive between 8 and 23 hours. Data that support the findings of this study are available from the corresponding author upon reasonable request.

*Facility Sample*

The first 21 facilities, who joined the NTSP in Fiscal Year (FY) 2017 or 2018, were included in this analysis. The pre-NTSP period was defined as the FY (October 1 – September 30) prior to the year in which each facility entered (either FY2016 or FY2017). The post-NTSP period was defined beginning with the date the facility activated the NTSP and continuing to September 30, 2020. In both periods, we identified Veterans with ischemic stroke diagnosis from either ED or inpatient discharge diagnosis codes; the cohort for analysis was then restricted to only those Veterans with an initial ED presentation.

*Outcomes and covariates*

Admission to the local VA facility versus transfer to a non-VA facility was identified using administrative data and confirmed by chart review. Facility pre- and post-NTSP transfer rates were defined as the number of Veterans transferred out divided by the total number of Veterans with ischemic stroke who had an ED presentation at that VA facility. All ED diagnoses of stroke were confirmed by independent chart review. Administrative data from the VA Central Data Warehouse were used to determine patient demographics, medical comorbidities, and ED arrival and discharge times. Patient last known well (LKW) time and NIH Stroke Scale (NIHSS) at presentation was determined by chart review; if NIHSS was not documented, standardized validated methodology was used to construct an NIHSS based on the initial physical examination.[25] Medical comorbidity diagnoses assessed with ICD10 codes were used to construct the Charlson comorbidity index (CCI).[26] Data were extracted at the level of the encounter; thus patients with more than one ED visit for stroke could be represented more than once in the dataset.

Facility characteristics in the pre-NTSP year were assessed using administrative data and standard VA designations including VA complexity level, total annual volume of stroke ED and inpatient encounters, and percent of stroke encounters for Veterans identified as rural residing based on zip code of primary address at the time of presentation. Facility local inpatient neurology access pre- and post-

NTSP was defined based on the presence of any inpatient neurology consultation (excluding NTSP consultation) completed at the facility during the period.

*Statistical Analysis*

Patient and facility characteristics were assessed for the entire cohort. Patient-level characteristics were compared between the pre- and post-program implementation time period using independent t-tests or Wilcoxon rank sum tests as applicable for continuous variables and Chi-square tests for categorical variables. Logistic regression was then used to determine the effect of participation in NTSP on the odds a patient is transferred while adjusting for patient and facility characteristics. More specifically, a generalized linear mixed model was fit to the encounter level data for the dichotomous outcome of transfer (yes/no). This including an indicator if the encounter occurred post-NTSP implementation, facility and patient level fixed effects, and also facility-level random intercept and program terms to allow the effect of the NTSP on odds of transfer to vary by facility. Additionally, the observed transfer rate was estimated in the pre- and post-NTSP time periods by facility and by VA stroke designation in the pre-NTSP period (Primary Stroke Center—alteplase availability 24/7, Limited Hours Stroke Facility—alteplase availability < 24/7, or Supporting Stroke Facility—not able to give alteplase).[27]

The multivariable logistic regression model included patient characteristics of age, race (Black, White, Other/Unknown), NIHSS at presentation, CCI, LKW time categorized as < 8, 8 - 24, or > 24 hours, and whether the encounter occurred post-NTSP implementation. Facility characteristics included whether the facility had local inpatient neurology available (Pre/Post program, Post only, or None/Pre only), the year of NTSP implementation (2017 or 2018), the facility annual stroke volume, and the percent of stroke patients in that facility who were designated by the VHA as rural residing.

Two sensitivity analyses were also conducted to examine robustness of the reported model results. In the first the full model was re-fit to include only the first admission from each patient (N =

3,289). In the second analysis, the full model was re-fit using only the first 12 months of post-Telestroke implementation time, since some sites were active in the program for a longer time span.

**Results**

During the study period, 3,488 stroke encounters from 3,289 individual patients were observed (1,056 pre-NTSP and 2,432 post-NTSP). Summary statistics for the encounter-level patient data are provided in Table 1. During the post-NTSP period, patients had a slightly lower NIHSS (median 2 vs 3), fewer were Black (25.0% vs 28.3%), more presented within 8 hours of LKW (31.5% vs 24.3%) and more received tPA (4.9% vs 3.3%). Patients generally presented outside the thrombolysis window (median time since LKW 5 hours, range 0 – 1391 hours). Facilities had relatively low annual ischemic stroke volume pre-NTSP (median encounters 40, range 10 – 268) (Appendix Table 1). The proportion of stroke encounters for rural patients at each facility varied widely (median % rural 36.2, range 3.0 – 91.3) and 15 of the 21 facilities had some access to inpatient neurology services in both pre- and post-NTSP periods.

A plot of the observed Facility ED transfer rates pre- and post-NTSP and grouped by VHA Stroke Designation is provided in Figure 1. On average, transfer rates decreased by 14.4% in the post-implementation period, and decreased transfer rates were observed among all levels of VHA Stroke Designation. From the logistic regression model (Table 2), younger age (OR = 0.93, [95% CI 0.89, 0.98] per 5 year increment), higher NIHSS (OR = 1.13, [95% CI 1.10, 1.15]), < 8 hours since LKW vs > 24 hours (OR = 3.23, [95% CI 2.49, 4.19]) were significantly associated with increased odds of transfer post-NTSP implementation. Of the facility characteristics, only the facility annual stroke volume was associated with transfer post-NTSP; with every additional 10 stroke encounters, the odds of transfer is reduced by 15% (OR per 10 encounters = 0.85, [95% CI 0.79, 0.92]). Overall, after adjusting for patient and facility characteristics, the implementation of VA NTSP resulted in a nearly 60% reduction in odds of transfer (OR = 0.39, [0.19, 0.77], Table 2). Based on the odds ratios and associated 95% confidence intervals estimated for each facility including the random effect terms (Figure 2, Appendix Table 2), after adjusting for patient and facility characteristics, the odds of transfer was significantly reduced in nine of the 21 facilities, and significantly increased odds of transfer in only one facility.

The initial logistic regression model fit to all patient encounters included random effects terms for both facility and patients within facility and the test of covariance was performed. The random effect for patient within facility was found not to be significantly different than zero (Appendix Table 3), which is not surprising considering only 178 patients had more than one encounter during the study period. Therefore, only facility random effects were included in the reported model. However, as a sensitivity analysis (Appendix Table 4), the model was fit to only the first encounter for each patient (N = 3289) and results were similar to the reported model (except age was no longer significant). Also, the analysis using only the first 12 months after NTSP implementation (Appendix Table 5) was also similar to the reported model with only a slightly weakened program effect (odds of transfer post-NTSP implementation: OR = 0.44, 95% CI = [0.22, 0.90]). Thus, both sensitivity analyses support our initial conclusion regarding the impact of the VA NTSP on the odds of transfer.

**Discussion**

This is one of the first robust analyses to consider patient and facility factors when examining the impact of a telestroke program implementation on ED interhospital transfers. Overall, implementation of a nationwide virtual telestroke program in the VHA was associated with a significant decrease in likelihood of stroke patients being transferred from the ED. Even after adjusting for other clinical factors related to likelihood of transfer, including age, stroke severity, and time of arrival, we still found that implementation of the NTSP was associated with a significant decreased likelihood of ED transfer for patients with suspected ischemic stroke. In addition to program implementation, other patient and facility factors were associated with likelihood of transfer in an appropriate and expected manner, with younger patients and those with more severe stroke, as well as those arriving sooner after stroke onset, being more likely to be transferred. Furthermore, we observed that annual stroke volume also predicted transfer rate with lower stroke volume facilities being more likely to transfer their suspected stroke patients.

Unlike the typical hub and spoke model where it may be preferable for patients to transfer from the smaller outlying facility to the academic center, the VHA telestroke system is more analogous to other national healthcare systems that may seek to avoid medically unnecessary transfers as a way to decrease overall costs within the healthcare system. Despite its national reach, the VHA is uniquely challenged by geographical distance between facilities that often limits VA to VA transfers for acute stroke care. As is recommended in current acute stroke guidelines, patients are usually transferred to the nearest hospital able to provide needed stroke services which usually is not a larger stroke-specialized VA facility that could be hours away.[28] With only a small number of VA facilities offering endovascular thrombectomy, evaluation for this service typically necessitates transfer to non-VA hospitals. The providers in the VA NTSP system are vascular neurologists familiar with the VHA system and able to determine if the patient's needs can be met by the local resources at the VA facility or if transfer to a higher level of care is indicated. Furthermore, as many of the smaller facilities lack on-site neurologic expertise, the telestroke provider is able to assess the patient for possible stroke mimic diagnoses and provide the basic recommendations for stroke diagnostic evaluation and early management (including secondary stroke prevention recommendations) that may facilitate the patient remaining at their local VA who would otherwise need to be transferred out. Ultimately, implementation of the NTSP has enhanced timely disposition of the patient to match their stroke needs while at the same time elevating the care provided at the local facility to minimize the need for unnecessary transfers.

Despite this complex healthcare system and the heterogeneous nature of the facilities in our sample, we observed a strong signal of decreasing transfers after NTSP implementation, with only one facility demonstrating a significant increase in transfers. We know that thrombolysis rates increased after NTSP implementation, so some of the increase in transfers may be for appropriate post-thrombolysis care unable to be provided at smaller facilities. Likewise, with the increase in endovascular treatments after the publication of the seminal clinical trials in 2015, [29] [30] [31] [32] some patients may have been transferred in the post-NTSP period because they were identified as potentially eligible for endovascular care. Integration of the NSTP protocols into each VA includes standardized criteria for stroke team activation. These processes have also been updated to incorporate extended window thrombectomy criteria[33] [34] which has likely further driven transfers for endovascular eligible patients with the goal of careful patient selection to avoid over transfer of those not likely to benefit from revascularization.[35, 36]

We initially hypothesized that absence of inpatient neurology consultation access might be associated with increased ED transfer rates, but we did not observe this relationship. Many of the facilities, although small by stroke volume, had some access to inpatient neurology both pre- and post-NTSP, which may be one reason why this factor was not associated with overall likelihood of transfers. It should be noted that our data does not provide granularity of subspecialization of neurologists, comfort levels with evolving stroke guidelines, or the extent of coverage provided to the ED. NTSP providers have vascular neurology expertise, participate in weekly consultant meetings, and undergo regular performance feedback by peers. The program as a whole provides a relatively standardized approach to stroke management that is evidence-based and guideline-concordant although it is not clear how this would compared to or complement the expertise provided by a general neurologist. The lack of association observed in our sample warrants further study to define what levels of access to neurology consultation are necessary for optimal stroke care provision.

Overall, we observed a transfer rate of approximately 15%, which is similar to or lower than rates reported by other networks.[24, 35, 37] This may be explained by the overall lower severity of stroke patients treated through the NTSP, as is evidenced by the low median NIHSS and low proportion of patients presenting during traditional thrombolytic windows. Ultimately, transfer practices also reflect the regional availability of resources and established networks between hospitals. Optimizing transfer networks is essential, particularly in the era of endovascular reperfusion therapies and the need to avoid over-triage to tertiary level centers. [35, 38, 39] Although transfer rates have been shown to increase with interhospital network connections, telestroke has the opportunity to provide thoughtful selection of which patients would benefit from transfer.[12] In doing so, telestroke can not only optimize stroke care for the patient but can also provide cost-effective solutions for both the transferring and receiving centers. [3, 40]

Despite robust administrative and chart review data, our study does have some limitations. Since most patients transferred to a non-VA hospital, we do not know what care was received post-transfer and thus the impact of transfers on eventual thrombolysis or endovascular care cannot be assessed. We also do not have a complete assessment of diagnosis and outcomes for stroke mimics, especially in the pre-implementation period where there was no stroke specialist evaluation, and reducing transfers of stroke mimics may also be an important contribution of a telestroke system of care. In FY2018, 33% of NTSP consults resulted in a diagnosis other than stroke or TIA, suggesting this could be a relatively common scenario. Finally, the VHA system of care and patient population is unique, so the extent to which these results are generalizable to other systems of care will vary based on the structure of the healthcare system and the telestroke program.

Telestroke is an important and increasingly common care modality that can improve access to timely stroke treatments, thus having the potential to improve stroke outcomes for patients and across populations. The cost of telestroke implementation relative to benefits that may derive from the program can be difficult to assess. Our analysis suggests that, within a national healthcare system, in addition to improving stroke treatment rates, a potential decrease in unnecessary ED transfers may be another way that telestroke improves the quality and the efficiency of stroke systems of care.

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## Figure Legend

Figure 1. Pre- and post-implementation transfer rates by facility and stroke center designation. Each facility (de-identified number) is presented based on their VA Stroke Center Designation category. Pre- (orange bar) and post- (blue bar) telestroke implementation transfer rates are displayed for each facility.

Figure 2. Plot of odds ratios for transfer post-implementation overall and by facility and stroke center designation.

Table 1: Patient characteristics before and after Telestroke program

| | Pre-Telestroke (N=1056) | Post-Telestroke (N=2432) | Total (N=3488) | P value |
|---|---|---|---|---|
| Age | | | | |
| Mean (SD) | 71.1 (11.3) | 70.8 (12.0) | 70.9 (11.8) | 0.538[1] |
| Median (Range) | 70.0 (38.0, 101.0) | 71.0 (23.0, 104.0) | 71.0 (23.0, 104.0) | |
| Gender, Male, n (%) | 1002 (94.9%) | 2295 (94.4%) | 3297 (94.5%) | 0.536[2] |
| Race | | | | 0.01[2] |
| Black | 299 (28.3%) | 607 (25.0%) | 906 (26.0%) | |
| White | 699 (66.2%) | 1633 (67.1%) | 2332 (66.9%) | |
| Other/Unknown | 58 (5.5%) | 192 (7.9%) | 250 (7.2%) | |
| NIHSS | | | | <0.001[1] |
| Mean (SD) | 4.2 (5.2) | 3.5 (4.5) | 3.7 (4.8) | |
| Median (Range) | 3.0 (0.0, 33.0) | 2.0 (0.0, 36.0) | 2.0 (0.0, 36.0) | |
| CCI | | | | 0.837[1] |
| Mean (SD) | 2.7 (2.6) | 2.7 (2.6) | 2.7 (2.6) | |
| Median (Range) | 2.0 (0.0, 15.0) | 2.0 (0.0, 16.0) | 2.0 (0.0, 16.0) | |
| Last known well | | | | <0.0001[2] |
| 0 - 8 h | 257 (24.3%) | 766 (31.5%) | 1023 (29.3%) | |
| 8 - 24 h | 117 (11.1%) | 399 (16.4%) | 516 (14.8%) | |
| > 24 h | 682 (64.6%) | 1267 (52.1%) | 1949 (55.9%) | |
| Last known well (h), n | 439 | 1302 | 1731 | |
| Median (Range) | 5 (0, 232) | 5 (0, 1391) | 5 (0, 1391) | 0.911[1] |
| tPA given, n (%) | 35 (3.3%) | 120 (4.9%) | 155 (4.4%) | 0.033[2] |

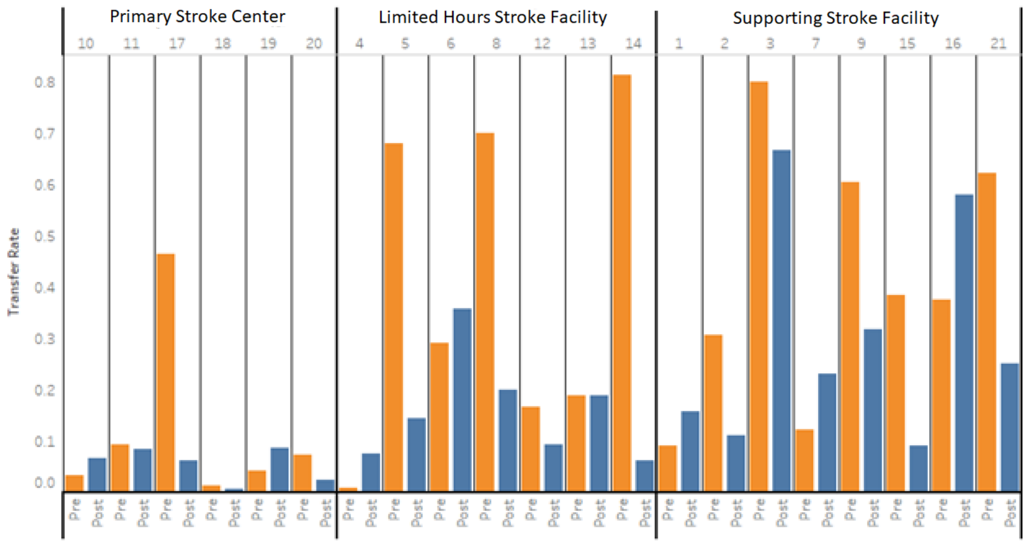
[1]Equal variance two sample t-test; [2]Chi-square test

Table 2: Odds Ratio for Transfer obtained from multiple logistic regression model with random effects for facility (intercept and program effect). (N = 3488 encounters, 518 transfers)

| Patient-level covariates | | Odds Ratio [95% CI] | P value |
|---|---|---|---|
| Age (5 year decrement) | | 0.93 [0.89, 0.98] | 0.008 |
| Race | Black vs White | 0.86 [0.61, 1.22] | 0.384 |
| | Other/Unknown vs White | 1.11 [0.70, 1.74] | 0.646 |
| NIHSS | | 1.13 [1.10, 1.15] | <0.0001 |
| CCI | | 0.98 [0.93, 1.02] | 0.305 |
| Last known well | < 8 h vs > 24 h | 3.23 [2.49, 4.19] | <0.0001 |
| | 8 - 24 h vs > 24 h | 1.02 [0.69, 1.49] | 0.934 |
| Presentation Post-Telestroke Program | | 0.39 [0.19, 0.77] | 0.007 |
| **Facility-level covariates** | | | |
| Local inpatient neurology | Post only vs None/Pre | 0.57 [0.14, 2.28] | 0.404 |
| | Post only vs Pre/Post | 1.63 [0.56, 4.70] | 0.343 |
| Facility year Telestroke implemented | 2018 vs 2017 | 1.88 [0.66, 5.34] | 0.218 |
| Facility annual stroke volume (per 10 stroke encounters) | | 0.85 [0.79, 0.92] | 0.001 |
| Percent rurality (per 10%)† | | 1.11 [0.92, 1.33] | 0.263 |

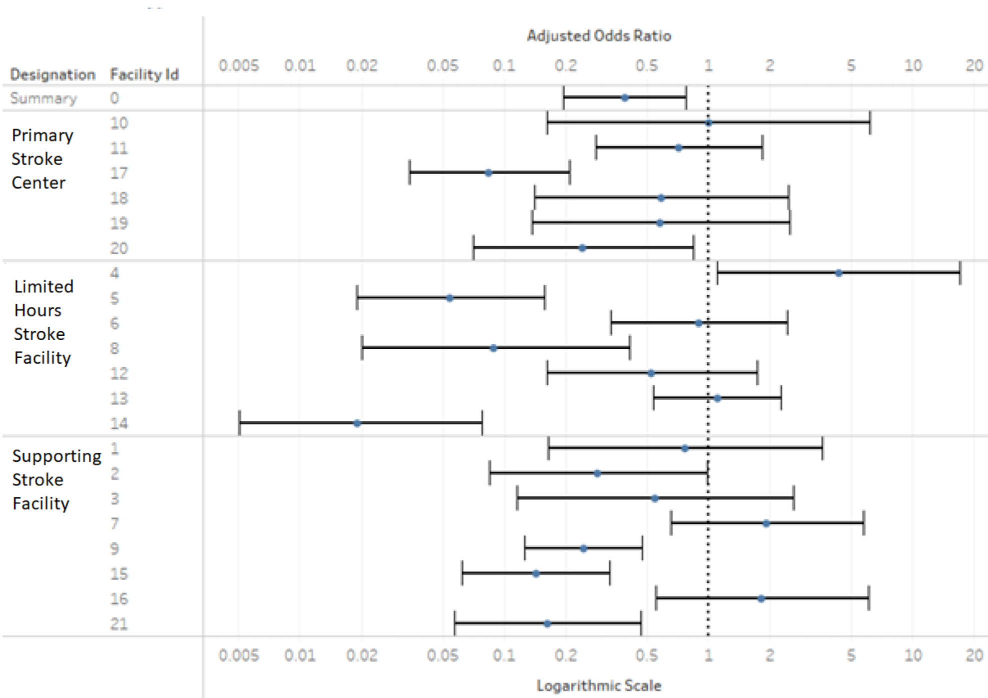
†Percent rurality indicates the percent of all stroke patients from that facility during the year prior to Telestroke that lived in a rural location. Covariance parameter estimates: random intercept for facility = 1.33 (standard error = 0.56), random program effect for facility = 2.05 (standard error = 0.78), and covariance = -1.34 (standard error = 0.60).

Figure 1.



Primary Stroke Center
Limited Hours Stroke Facility
Supporting Stroke Facility
10
11
17
18
19
20
4
5
6
8
12
13
14
1
2
3
7
9
15
16
21
Transfer Rate
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Pre
Post

Figure 2.


Adjusted Odds Ratio
Designation
Facility Id
0.005 0.01 0.02 0.05 0.1 0.2 0.5 1 2 5 10 20
Summary 0
Primary Stroke Center
10
11
17
18
19
20
Limited Hours Stroke Facility
4
5
6
8
12
13
14
Supporting Stroke Facility
1
2
3
7
9
15
16
21
Logarithmic Scale

Appendix Table 1: Facility characteristics

| | Total (N = 21) |
|---|---|
| Fiscal year 2017 VA complexity rating, n (%) | |
| 1a | 4 (19.0%) |
| 1b | 4 (19.0%) |
| 1c | 8 (38.1%) |
| 2 | 4 (19.0%) |
| 3 | 1 (4.8%) |
| Local inpatient neurology, n (%) | |
| None or Pre only | 3 (14.3%) |
| Post only | 3 (14.3%) |
| Pre and Post | 15 (71.4%) |
| Facility year Telestroke went live, n (%) | |
| 2017 | 7 (33.3%) |
| 2018 | 14 (66.7%) |
| Facility annual number of stroke encounters | |
| Mean (SD) | 63.6 (61.5) |
| Median (Range) | 40.0 (10.0, 268.0) |
| Percent rurality of patients with stroke (%) | |
| Mean (SD) | 40.3 (30.5) |
| Median (Range) | 36.2 (3.0, 91.3) |

Appendix Table 2: Odds Ratio for Transfer Pre-Telestroke program vs Post-Telestroke program by Facility obtained from final multivariable logistic regression model.

| | Pre-NTSP | Post-NTSP | | |
|---|---|---|---|---|
| Facility | Number of Transfers (Percent Transferred) | Number of Transfers (Percent Transferred) | OR [95% CI] | P value |
| 1 | 1(9.1%) | 13(15.9%) | 0.765 [0.163, 3.598] | 0.735 |
| 2 | 8(30.8%) | 4(11.1%) | 0.286 [0.084, 0.975] | 0.046 |
| 3 | 8(80%) | 12(66.7%) | 0.546 [0.115, 2.594] | 0.446 |
| 4 | 1(1%) | 15(7.5%) | 4.309 [1.094, 16.969] | 0.037 |
| 5 | 17(68%) | 9(14.5%) | 0.054 [0.019, 0.157] | <0.0001 |
| 6 | 7(29.2%) | 30(35.7%) | 0.897 [0.333, 2.417] | 0.829 |
| 7 | 4(12.1%) | 18(23.1%) | 1.925 [0.651, 5.694] | 0.237 |
| 8 | 7(70%) | 5(20%) | 0.089 [0.020, 0.408] | 0.002 |
| 9 | 32(60.4%) | 62(31.8%) | 0.243 [0.125, 0.471] | <0.0001 |
| 10 | 4(3.4%) | 1(6.7%) | 0.997 [0.162, 6.123] | 0.998 |
| 11 | 6(9.2%) | 20(8.5%) | 0.710 [0.278, 1.814] | 0.474 |
| 12 | 4(16.7%) | 11(9.2%) | 0.526 [0.162, 1.711] | 0.286 |
| 13 | 14(18.9%) | 38(18.9%) | 1.099 [0.534, 2.260] | 0.797 |
| 14 | 13(81.3%) | 4(6.2%) | 0.019 [0.005, 0.077] | <0.0001 |
| 15 | 25(38.5%) | 10(9.1%) | 0.142 [0.062, 0.324] | <0.0001 |
| 16 | 6(37.5%) | 22(57.9%) | 1.818 [0.547, 6.038] | 0.329 |
| 17 | 20(46.5%) | 8(6.2%) | 0.084 [0.034, 0.209] | <0.0001 |
| 18 | 3(1.3%) | 3(0.8%) | 0.586 [0.140, 2.452] | 0.464 |
| 19 | 1(4.2%) | 13(8.7%) | 0.579 [0.136, 2.477] | 0.461 |
| 20 | 4(7.4%) | 4(2.5%) | 0.242 [0.070, 0.835] | 0.025 |
| 21 | 23(62.2%) | 8(25%) | 0.163 [0.057, 0.466] | 0.001 |

Appendix Table 3: Odds Ratio for Transfer and test of covariance from logistic regression model including only random facility and patient within facility effects. (N = 3488 encounters, 518 transfers)

| | | Odds Ratio [95% CI] | P value |
|---|---|---|---|
| Admission post-Telestroke Program | | 0.45 [0.36, 0.56] | <.0001 |
| Tests of Covariance | Estimate | SE | P value† |
| Var (facility) = 0 | 1.579 | 0.537 | <.0001 |
| Var(patient(facility)) = 0 | 0.048 | 0.170 | 0.387 |

†P-value based on a mixture of chi-squares.

Appendix Table 4: Sensitivity Analysis 1- Odds Ratio for Transfer obtained from multiple logistic regression model with random effects for facility (intercept and program effect) including only unique patients (N = 3289 encounters, 485 transfers)

| Patient-level covariates | | Odds Ratio [95% CI] | P value |
|---|---|---|---|
| Age (5 years) | | 0.95 [0.90, 1.00] | 0.068 |
| Race | Black vs White | 0.87 [0.61, 1.23] | 0.413 |
| | Other/Unknown vs White | 1.07 [0.66, 1.71] | 0.778 |
| NIHSS | | 1.13 [1.10, 1.15] | <.0001 |
| CCI | | 0.97 [0.93, 1.02] | 0.278 |
| Last known well | < 8 h vs > 24 h | 3.21 [2.45, 4.19] | <.0001 |
| | 8 - 23 h vs >24 h | 1.02 [0.68, 1.51] | 0.939 |
| Admission post-Telestroke Program | | 0.38 [0.19, 0.75] | 0.005 |
| **Facility-level covariates** | | | |
| Local inpatient neurology | Post only vs None/Pre | 0.58 [0.15, 2.22] | 0.402 |
| | Post only vs Pre/Post | 1.58 [0.57, 4.43] | 0.356 |
| Facility year Telestroke implemented | 2018 vs 2017 | 1.96 [0.71, 5.43] | 0.178 |
| Facility annual stroke volume (per 10 stroke encounters) | | 0.85 [0.79, 0.92] | 0.001 |
| Percent rurality (per 10%)† | | 1.12 [0.93, 1.34] | 0.215 |

†Percent rurality indicates the percent of all stroke patients from that facility during the year prior to Telestroke that lived in a rural location.

Appendix Table 5: Sensitivity Analysis 2- Odds Ratio for Transfer obtained from multiple logistic regression model with random effects for facility (intercept and program effect) including up to 12 months of data for Telestroke program (N = 2346 encounters, 384 transfers)

| Patient-level covariates | | Odds Ratio [95% CI] | P value |
|---|---|---|---|
| Age (5 years) | | 0.93 [0.88, 0.99] | 0.032 |
| Race | Black vs White | 0.80 [0.54, 1.19] | 0.263 |
| | Other/Unknown vs White | 1.38 [0.79, 2.44] | 0.242 |
| NIHSS | | 1.13 [1.10, 1.16] | <.0001 |
| CCI | | 0.97 [0.92, 1.03] | 0.310 |
| Last known well | < 8 h vs > 24 h | 3.48 [2.54, 4.76] | <.0001 |
| | 8 - 23 h vs >24 h | 1.10 [0.69, 1.75] | 0.685 |
| Admission post-Telestroke Program | | 0.44 [0.22, 0.90] | 0.023 |
| **Facility-level covariates** | | | |
| Local inpatient neurology | Post only vs None/Pre | 0.72 [0.19, 2.79] | 0.617 |
| | Post only vs Pre/Post | 1.79 [0.65, 4.96] | 0.242 |
| Facility year Telestroke implemented | 2018 vs 2017 | 2.02 [0.73, 5.61] | 0.164 |
| Facility annual stroke volume (per 10 stroke encounters) | | 0.86 [0.79, 0.93] | 0.001 |
| Percent rurality (per 10%)† | | 1.13 [0.94, 1.36] | 0.171 |

†Percent rurality indicates the percent of all stroke patients from that facility during the year prior to Telestroke that lived in a rural location.