RESEARCH

Door in door out and transportation times in 2 telestroke networks

Sami Al Kasab, MD*, Eyad Almallouhi, MD*, Jillian Harvey, PhD, Nancy Turner, BSN, RN, Ellen Debenham, RN, CCRC, Juanita Caudill, RN, Christine A. Holmstedt, DO, and Jeffrey A. Switzer, DO, MCTS

Correspondence
Dr. Al Kasab
sami-alkasab@uiowa.edu

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Abstract

Background
Inter-hospital transfer is important in the treatment of acute stroke. We sought to assess door in to door out (DIDO) time at spoke sites, and transportation time between spoke sites and thrombectomy-capable stroke center (TSC) in 2 large, rural telestroke networks.

Methods
Records of patients treated with tissue plasminogen activator through 2 telestroke networks between March 2017 and December 2017 were reviewed. Mann–Whitney test was used to compare median times, and a generalized linear regression model was used to predict the total time of care controlling for transportation distance.

Results
Eighty-five patients were included with median NIH stroke scale on presentation of 13 (interquartile range [IQR] 7–17), median door to needle time 49 minutes (IQR 40–62), and median DIDO 111 minutes (IQR 92–157). Eighteen patients (21%) underwent computed tomography angiography (CTA) at spoke prior to transportation. Median DIDO was 169 minutes for patients who received CTA before transfer, compared with 107 minutes for patients who did not ($p = 0.0004$). Median door-to-groin time at TSC was 68 minutes for the CTA group and 85 minutes in the non-CTA group ($p = 0.832$). Controlling for distance, the predicted time of care from spoke door in time to groin puncture at TSC (sDTG) is 93.68 minutes longer for patients who receive CTA prior to transport ($p = 0.034$).

Conclusion
In the included telestroke networks, the sDTG time is longer when CTA is conducted at spoke site prior to transportation to TSC. New strategies are urgently needed to decrease sDTG when CTA is done prior to transfer to TSC.

The effectiveness of acute ischemic stroke treatment has improved considerably with intravenous alteplase (tissue plasminogen activator [tPA]) and more recently with mechanical thrombectomy. The degree of effectiveness of these interventions, however, is time-dependent and largely depends on achieving reperfusion of the brain tissue as quickly as possible.[1–7] While intravenous alteplase is readily available in most hospitals, mechanical

*S. Al Kasab and E. Almallouhi contributed equally as co-first authors.

Department of Neurology (SAK), University of Iowa; Department of Neurology (EA, NT, ED, CAH), Medical University of South Carolina, Charleston; Department of Healthcare Leadership and Management (JH), College of Health Professions, Medical University of South Carolina, Charleston; and Department of Neurology (JC, JAS), Augusta University.

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thrombectomy is primarily available in large primary and comprehensive stroke centers (thrombectomy-capable stroke centers [TSCs]). Recent trials have shown that mechanical thrombectomy can be effective up to 24 hours from last known well.[8] Under our current system of care, patients presenting to community hospitals are evaluated through a telestroke network for eligibility for tPA, and are transferred to the nearest TSC for thrombectomy evaluation when a large vessel occlusion (LVO) is suspected or confirmed.[1] Recently, there has been a focus on shortening the time a patient with a suspected LVO spends at the spoke hospital and expediting transfer time to the TSC thrombectomy capable center, to aid rapid revascularization.[9] The duration of door in to door out (DIDO) in the first facility, as well as the delay during transportation and transportation method to the TSC, are essential in determining the long-term functional outcome in patients with LVO.[10,11] We sought to examine the DIDO and transportation times across 2 large telestroke networks and assess the telestroke care process for causes of delay in treatment.

Methods

Setting

The study examines the care processes for telestroke patients admitted to 2 comprehensive stroke centers located in the southeastern United States (Medical University of South Carolina [MUSC] and Augusta University). The MUSC telestroke program was started in 2008 and has evolved to include more than 26 partner hospitals in a hub-and-spoke model.[12–15] The Augusta University (AU) telestroke program was established in 2003 and has grown to cover 30 sites throughout Georgia.[16,17]

All participating spoke sites are provided with wireless Remote Evaluation of Acute Ischemic Stroke carts that are activated by spoke emergency room physician once a patient with suspected acute stroke arrives. Telestroke consults usually take place in the emergency room either before or after the computed tomography (CT) scan. Some spoke hospitals routinely performed CT angiogram (CTA) after tPA to confirm the presence of LVO prior to transfer to a TSC. When this was done, CTAs were obtained following the initiation of tPA treatment. Patients were transferred to the TSC using air transportation with a helicopter or ground transportation using an ambulance.

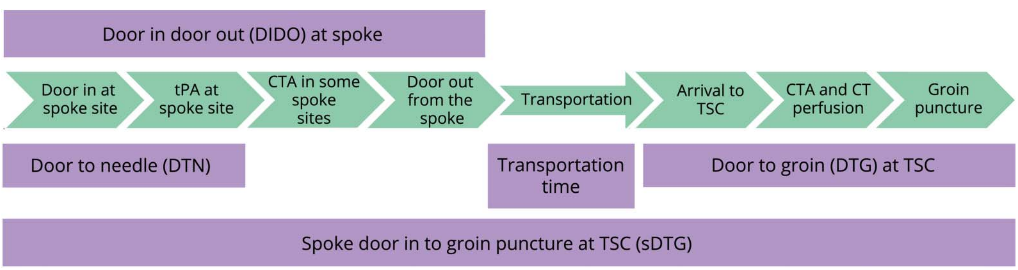
Data collection

We conducted a retrospective chart review of the prospectively collected data for all patients who received intravenous tPA through telestroke networks. The study period was from March 2017 through December 2017. Included patients received a telestroke consultation, tPA at a spoke hospital and were transferred to TSC for mechanical thrombectomy candidacy evaluation. The following data were collected from the charts: age, race, sex, and National Institute of Health stroke scale on admission, whether a CTA was done prior to transportation, transportation method, and receipt of thrombectomy. In addition, we collected door to needle (DTN) at the spoke center, time from giving tPA to spoke door out, DIDO at spoke center, the transportation time between spoke site and TSC, the door-to-groin (DTG) at TSC, and the total time from spoke door in to groin puncture at TSC (sDTG). The different time-to-care metrics are illustrated in the figure Additional time variables were constructed by aggregating time stamp data across the spoke and TSC care processes. sDTG time is the aggregate of 3 time points: (1) DIDO, (2) the transportation time, and (3) the DTG time. Our explanatory variables were air vs ground transportation controlling for distance and CTA prior to transportation vs no CTA.

Statistical analysis

Descriptive statistics were used to describe patient demographic and clinical characteristics between the groups using *t* tests and χ^2 as appropriate. Due to the non-normal distribution of the time data, the Wilcoxon Rank-sum (Mann–Whitney) test was used to compare median times between different groups. An alpha level of 0.05 was used as the level of statistical significance. We report the median times and interquartile range for each time period. Finally, for those patients who underwent thrombectomy at a TSC hub site, we estimate a generalized linear regression model using gamma distribution and a logit link to predict the total time of treatment as a function of CTA

Figure Illustration of the time-to-care metrics



CTA = CT angiography; DIDO = door in door out time; DTG = door to groin; DTN = door to needle; sDTG = spoke door in time to groin puncture at TSC; tPA = tissue plasminogen activator; TSC = thrombectomy-capable stroke center.

prior to transportation controlling for distance in miles from the spoke to the TSC. The analysis was conducted in Stata 14.2.

Standard protocol approvals, registrations, and patient Consents

Authors confirm that the study is observational minimal risk study and no consent is required per the MUSC and Augusta University institusional policy. Our study was approved by the institutional review board of the MUSC and Augusta University.

Data availability

Anonymized data not published within this article will be made available by request from any qualified investigator. Investigators interested in working with the data should contact the corresponding author.

Results

Study participants

Between March and December of 2017, a total of 87 patients met the study criteria of receiving tPA in a spoke hospital and transfer to a TSC hub for thrombectomy evaluation. Two patients were excluded because of insufficient data in charts, resulting in a final sample of 85 patients. Mean age was 64.8 (95% confidence interval: 61.5–68.1), 42 (49%) patients were male, 46 (54%) were white. Median NIH stroke scale on presentation was 13 (interquartile range [IQR] 7–17). Twenty-five (29.4%) patients received mechanical thrombectomy upon arrival to the TSC. Median DTN time was 49 (IQR 40–62) minutes. Median DIDO was 111 (IQR 92–157) minutes. Patients' demographic characteristics are summarized in table 1.

Table 1 Baseline characteristics of the study cohort and comparison between patients in the CTA group and patients in the non-CTA group

Variable	All patients (n = 85)	CTA group (n = 18)	Non-CTA group (n = 67)
Age, mean (SD)	64.81 (15.57)	65.17 (13.82)	64.72 (16.17)
Race, n (%)			
Black/African American	28 (32.94)	5 (27.78)	23 (34.33)
White	46 (54.12)	11 (61.11)	35 (52.24)
Other	11 (12.94)	2 (11.11)	9 (13.43)
Sex, n (%)			
Female	43 (50.59)	10 (55.56)	33 (49.25)
Male	42 (49.41)	8 (44.44)	34 (50.75)
Admission NIH stroke scale, median (IQR)	13 (7–17)	10.5 (7–16)	13 (7–17)
Mode of transport[a], n (%)			
Air	37 (45.12)	4 (22.22)	33 (51.56)
Ground	45 (54.88)	14 (77.78)	31 (48.44)
Distance between the spoke site and TSC in miles, mean (SD)	76.5 (25.5)	61.3 (22.9)	80.4 (24.4)
Thrombectomy receipt (yes), n (%)	25 (29.41)	8 (44.44)	17 (25.337)

Abbreviations: n = number; CTA = computerized tomographic angiography; TSC = Thrombectomy-capable stroke center; CTA group = patients who received CTA at spoke site prior to transfer to TSC; Non-cta group = patients who did not receive CTA at spoke site prior to transfer to TSC; IQR = interquartile range.
[a] Mode of transportation was not available for 3 patients.

Only 18 (21%) patients had CTA done before transfer to the thrombectomy center. Comparison between the group of patients who received CTA vs those who did not is summarized in table 1. No significant difference was found in mean age, race, sex, admission NIH stroke scale on presentation or median distance to the TSC. However, a larger percentage of the non-CTA patients were transported by air ($p = 0.027$). Patients in the CTA group were more likely to receive thrombectomy upon arrival to TSC (8 patients, 44%) than patients in the Non-CTA group (17 patients, 25%) without reaching a statistical significance (p-value = 0.115). The most common reason for not receiving thrombectomy in patients in the CTA group was the absence of salvageable penumbra on CT perfusion upon arrival to the TSC hub.

Difference in time-to-care metrics

Table 2 summarizes the difference in the patients' time to care metrics. There were no significant differences in DTN times between the 2 groups. Median tPA to door out from spoke for the CTA group was 101.5 (IQR 63–136) minutes and 55 (IQR 35–71) minutes for the Non-CTA group (p-value < 0.0001). DIDO time was longer in the CTA group compared to the Non-CTA group. Median DIDO for the patients who received CTA at spoke sites was 169 (IQR 149–200) minutes, compared with 107 (IQR 81–137) minutes for patients who did not (p-value < 0.0004). Mean distance from TSC was 61 miles for the CTA patients and 81 miles for the non-CTA patients ($p = 0.0035$). CTA in addition to CT perfusion were performed upon arrival to the TSC in all patients who did not have CTA done at spoke sites and in 15 (83.3%) patients who already received vessel imaging at a spoke.

DTG and sDTG times were available only for 20 patients of the 25 who received mechanical thrombectomy. Median DTG time at TSC was 68 (IQR 33–223) minutes for the CTA group and 85 (IQR 57–109) minutes in the Non-CTA group ($p = 0.832$). sDTG (the total time from the initial presentation at spoke to groin puncture at TSC) was 286 (IQR 262–469) minutes in the CTA group and 241 (IQR 207–259) minutes in the non-CTA group ($p = 0.0501$). Results from the generalized linear regression model predict that patients who have CTA done prior to transportation will have a 93.68 minutes' longer sDTG time (p-value = 0.034) controlling for the distance between sites.

Air vs ground transportation

Median transportation time was 70 (IQR 49–88) minutes. Thirty-seven patients (45%) were transferred to air ambulance and 45 (55%) transferred by ground ambulance. Mode of transportation was not available for 3 patients. No significant difference was found in mean age, race, sex, or NIH stroke scale of patients (table 3). Median transportation time when air transportation was used was 66 (IQR 45–72) minutes and 86 (IQR 55–105) minutes for ground transportation ($p = 0.0092$). Patients who were transferred by air were more likely to receive mechanical thrombectomy upon arrival to TSC (13 patients, 35%) than patients who were transferred by ground (12 patients, 26%). However, the difference was not statistically significant (p-value = 0.41). The median distance to TSC was 5 miles greater for patients transported by air than by ground, 83 vs 78 miles, respectively ($p = 0.02$).

Discussion

Inter-hospital transfer plays a pivotal role in the treatment of acute stroke in patients with LVO in the age of mechanical thrombectomy.[1,10,11] Causes of delay of care should be identified to provide the best possible functional outcome for acute ischemic stroke patients who are eligible for mechanical thrombectomy. The direct effect of the delay between symptom onset to reperfusion and long-term functional outcome in patients with acute stroke secondary to LVO has been well established in the literature.[10,11] In this study, we looked at the DIDO and transportation times in 2 large rural telestroke networks to identify potential causes of delay. Median DIDO was 111 minutes which is close to the published results from different countries including Denmark,[18] Australia,[19] and the United States.[11] DIDO has been used for a long time as a proven performance measure for ST-Elevation myocardial infarction patient.[20]

Delays in inter-hospital transfer prolong ischemia and increase the likelihood of a poor outcome in acute stroke patients.[21] Our study shows that most of the delay at spoke sites occurs during the period between tPA administration and door out. This delay is longer in patients who received CTA prior to transfer to TSC. Obtaining CTA prior to transportation was associated with a predicted 93.68 minutes delay in the total time from initial presentation at the spoke to groin puncture at TSC (sDTG) when controlling for distance. The delay in transportation in CTA patients was partially due to the fact that most spoke sites only obtain a CT of the head upon the initial assessment, and the CTA is obtained only after tPA administration has begun. Since CTAs can avoid futile transfers to TSCs, they remain an important component of spoke hospitals evaluation.[22] In addition, Boulouis et al. suggested that obtaining vascular imaging at spoke prior to transfer can help in not only identify intracranial occlusions, but also assess collateral blood vessels which may further provide additional information to determine thrombectomy candidacy.[23,24] Our study has shown that thrombectomy was performed in 44% of patients who had CTA done prior to transfer as opposed to 25% in patients who did not have CTA done which shows that performing CTA prior to transfer improved patient selection for transfer even though the difference was not significant likely secondary to small sample size. Improving patient selection for transfer to TSC and avoiding futile transfers can help in decreasing the cost of patient care, patient and family discomfort as well as the burden on the TSC hubs, and allow the stroke teams at TSCs to cover more spoke sites. One study has shown that total cost of care for a transferred patient with acute stroke is higher by about 27,000 USD in average than a similar patient who was directly admitted.[25]

Our study shows that most of the delay at spoke sites occurs during the period between tPA administration and door out.

Table 2 Summary of patients' transfer times

	All patients, median (IQR)	CTA prior to transport, median (IQR)	No CTA, Median (IQR)	*p* Value
DTN time at spoke sites	49 (40–62)	47.5 (33–92)	49 (41–61)	0.6625
tPA administration to door out time	58 (38–90)	101.5 (63–136)	55 (35–71)	<0.0001
DIDO at spoke sites	111 (92–157)	169 (149–200)	107 (81–137)	0.0004
Length of transport (IQR)	70 (49–88)	77.5 (65–105)	69 (48–88)	0.164
TSC door to puncture time[a]	84.5 (54.5–111)	68 (33–223)	85 (57–109)	0.8323
Spoke door in to TSC groin puncture (sDTG)[a]	243 (210.5–278)	286 (262–469)	241 (207–259)	0.0501

Abbreviations: DIDO = door in to door out; DTN = door to needle; IQR = interquartile range; tPA = tissue plasminogen activator; TSC = thrombectomy capable stroke center.
[a] Available only for 20 of patients.

Table 3 Baseline characteristics of the air transportation group and the ground transportation group

	Air, n = 37[a]	Ground, n = 45[a]	*p* Value
Age mean (SD)	64.03	64.73	0.8415
Race n (%)			0.255
Black/African American	10 (27.03)	18 (40)	
White	21 (56.76)	24 (53.33)	
Other	6 (16.22)	3 (6.67)	
Sex n (%)			0.267
Female	21 (56.76)	20 (44.44)	
Male	16 (43.24)	25 (55.56)	
NIHSS on admission	15 (9–17)	11 (6–18)	0.3552
Intra-arterial procedure (yes)	13 (35.14)	12 (26.67)	0.407
Distance in miles to comprehensive stroke center median (IQR)	83 (74–98)	78 (68–83)	0.0208

Abbreviations: IQR = interquartile range; n = number.
[a]Mode of transportation was not available for 3 patients.

One solution to improve DIDO time at spoke sites could be obtaining CTA upfront with the non-contrast CT head prior to giving tPA in patients who may be candidates for thrombectomy. This will reduce the time needed to take the patient from the CT scanner back to the emergency room to receive tPA then again to the CT scanner to get CTA. While this approach may slightly prolong DTN time, it might help to shorten DIDO time at spoke sites and DTG at TSC. Another suggestion is performing the telestroke consultation while in the CT scanner to decide who needs to get the CTA done without delay. One of expected challenges to this approach is that the CT scanner cannot be used for other patients during the telestroke consult which introduces a resources utilization issue.

Improving the total time from obtaining the CTA at spoke sites to interpreting the imaging would result in improving the DIDO time.

Other strategies are needed to decrease DIDO within the spoke sites and to determine appropriate indications for CTA prior to transfer. A new protocol has been developed using Los-Angeles motor scale of 4 or higher as a threshold to obtain CTA at spoke sites resulted in 40 minutes reduction in time to groin puncture.[11] Improving the total time from obtaining the CTA at spoke sites to interpreting the imaging would result in improving the DIDO time. In addition, initiating the transfer process at the time of the telestroke consult prior to imaging interpretation for patients with high clinical suspicion for LVO can also save time at spoke and shorten DIDO time. Our spoke centers do, however, initiate transfer at the time of stroke alert when clinical suspicion is high. Asif et al.[21] studied the factors that play a role in prolonging DIDO and transportation times. Authors identified some factors for delay including the delay in CT acquisition, decision to treat time, in hospital policies, time of day (working hours vs after hours), and communication with TSC.

Our study has shown that patients who underwent CTA at spoke sites did not have shorter DTG time on arrival to the TSC hub. That is likely secondary to the fact that the neuro-interventional team is not usually activated in most cases until vascular imaging is repeated at the TSC hub to insure the persistence of the target occlusion, the absence of symptomatic hemorrhagic transformation, and the presence of salvageable penumbra. Notifying the neuro-interventional team earlier in the process may result in shorter DTG time at the TSC hub

Table 4 Proposed solutions to improve the DIDO and sDTG times, and avoid futile transfers

Suggested solutions to improve DIDO at spoke sites and avoid futile transfers
Obtaining CTA upfront with the non-contrast CT head prior to giving tPA in patients who may be candidates for thrombectomy
Doing the telestroke consultation while in the CT scanner to decide who needs to get the CTA done without delay.
Using LVO scales to determine who needs CTA done at spoke
Improve the time from obtaining CTA to imaging interpretation
Initiating the transfer process at the time of the telestroke consult prior to imaging interpretation for patients with high clinical suspension for LVO
Additional suggested solutions to improve the total time of care (sDTG)
Notifying the neuro-interventional team prior to patient's arrival to TSC
Taking patients who had CTA done at spoke sites to the angiography suite on arrival to the TSC hub without repeating the imaging

Abbreviations: CTA = computerized tomographic angiography; DIDO = Door in to door out; LVO = Large vessel occlusion; tPA = tissue plasminogen activator; TSC = Thrombectomy-capable stroke center.

which may justify obtaining the CTA upfront at the spoke sites. Another suggestion would be by taking patients who had CTA done at spoke sites to the angiography suite on arrival to the TSC hub without repeating the vascular imaging. This will require the spoke sites to be able to perform perfusion imaging in addition to the vessel imaging to avoid the need for repeated imaging at the TSC hub if the neurologic examination remains stable upon arrival. This is particularly important for patients presented at a late window (>6 hours), where perfusion scan plays a key role in the decision making of mechanical thrombectomy. Further research studies are needed to determine the outcomes of both abovementioned strategies to reduce the DTG time at the TSC hub.

Air transportation has been used for acute stroke patients for a few years because it has been shown to decrease transportation time.[26] Our study shows that the additional DIDO time accrued by receiving a CTA prior to transport is longer than any additional gains received by selecting a faster transportation method. Many spoke sites had made tremendous improvements in their DTN times.[13,27,28] In many cases, the DTN processes may have little room for further efficiencies. Across the examined care processes of DIDO time, transportation time, and TSC door to puncture time, DIDO accounted for the longest time frame. Therefore, telestroke programs seeking to improve time to treatment may find additional opportunities for efficiencies within the DIDO workflow.

Our study has several limitations. First, although the telestroke logs at MUSC and AU are prospectively maintained, the study parameters were reviewed retrospectively. Second, there may be hospital specific delays that we were unable to identify in this study for spoke which conduct CTA routinely prior to transfer in comparison to the other spokes. Third, due to the small sample size of patients who received a mechanical thrombectomy, we are unable to control for additional variables including mode of transport in the regression model. Finally, the mode of transfer (air or ground) was either determined by the treating physician at the hub or spoke or by weather conditions. However, our study has a few important strengths including the multi-center design and the control for distance for the time analysis.

In conclusion, DIDO and sDTG times for endovascular candidates in 2 large, rural, statewide telestroke network were prolonged. CTA obtained in a serial fashion post-tPA exacerbated delays in the inter-hospital transfer that were not overcome by shorter times to groin puncture at the hub. Multiple solutions were discussed to improve the DIDO and sDTG times, and avoid futile transfers table 4.

TAKE-HOME POINTS

- → Inter-hospital transfer is important in treatment of acute stroke.
- → Door in to door out time was longer when CTA is conducted prior to transfer.
- → Strategies are needed to improve door in to door out time at spoke sites and door to groin time at thrombectomy-capable stroke centers.

Author contributions

S. Al Kasab: drafting/revising the manuscript, data acquisition, study concept or design. E. Almallouhi: drafting/revising the manuscript, data acquisition, study concept or design, analysis or interpretation of data, study supervision. J. Harvey: drafting/revising the manuscript, study concept or design, analysis or interpretation of data, statistical analysis. N. Turner: data acquisition. E. Debenham: data acquisition, study supervision. J. Caudill: data acquisition. C.A. Holmstedt: drafting/revising the manuscript, data acquisition, study concept or design, study supervision. J.A. Switzer: drafting/revising the manuscript, data acquisition, study concept or design, analysis or interpretation of data.

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Disclosure

S. Al Kasab serves on the editorial board of *Avicenna* journal and performs telestroke and teleneurology consultations for the Medical University of South Carolina. E. Almallouhi, J. Harvey, N. Turner, E. Debenham, and J. Caudill reports no disclosures. C. A. Holmstedt serves as an adjudicator for Ischemia Care. J. A. Switzer performs telestroke and teleneurology consultations at Augusta University Medical Center (10% clinical effort). Full disclosure form information provided by the authors is available with the full text of this article at Neurology.org/cp.

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