Improving Door-to-Needle Times for Acute Ischemic Stroke
Effect of Rapid Patient Registration, Moving Directly to Computed Tomography, and Giving Alteplase at the Computed Tomography Scanner

Noreen Kamal, PhD, PEng; Jessalyn K. Holodinsky, MSc; Caroline Stephenson, RN; Devika Kashayp, BA; Andrew M. Demchuk, MD, FRCPC; Michael D. Hill, MD; Renee L. Vilneff, BNSc, MN, RN; Erin Bugbee, BScN, RN; Charlotte Zerna, MD, MSc; Nancy Newcommon, RN, MN, NP; Eddy Lang, MD; Darren Knox, PT; Eric E. Smith, MD, MPH

***Background*—**The effectiveness of specific systems changes to reduce DTN (door-to-needle) time has not been fully evaluated. We analyzed the impact of 4 specific DTN time reduction strategies implemented prospectively in a staggered fashion.

***Methods and Results*—**The HASTE (Hurry Acute Stroke Treatment and Evaluation) project was implemented in 3 phases at a single academic medical center. In HASTE I (June 6, 2012 to June 5, 2013), baseline performance was analyzed. In HASTE II (June 6, 2013 to January 24, 2015), 3 changes were implemented: (1) a STAT stroke protocol to prenotify the stroke team about incoming stroke patients; (2) administering alteplase at the computed tomography (CT) scanner; and (3) registering the patient as unknown to allow immediate order entry. In HASTE III (January 25, 2015 to June 29, 2015), we implemented a process to bring the patient directly to CT on the emergency medical services stretcher. Log-transformed DTN time was modeled. Data from 350 consecutive alteplase-treated patients were analyzed. Multivariable regression showed the following factors to be significant: giving alteplase in the CT (32% decrease in DTN time, 95% confidence interval [CI] 38%–55%), stretcher to CT (30% decrease in DTN time, 95% CI 16%–42%), patient registered as unknown (12% decrease in DTN time, 95% CI 3%–20%), STAT stroke protocol (11% decrease in DTN time, 95% CI 1%–20%), and stroke severity (National Institutes of Health Stroke Scale score 6–8: 19% decrease in DTN time, 95% CI 6%–31%; National Institutes of Health Stroke Scale score >8: 27% decrease in DTN time, 95% CI 17%–37%).

***Conclusions*—**Taking the patient to CT on the emergency medical services stretcher, registering the patient as unknown, STAT stroke protocol, and administering alteplase in CT are associated with lower DTN time. **(*Circ Cardiovasc Qual Outcomes*. 2017;10:e003242. DOI: 10.1161/CIRCOUTCOMES.116.003242.)**

Key Words: acute stroke ■ computed tomography ■ door-to-needle time ■ quality improvement ■ thrombolysis

Faster treatment with intravenous alteplase (tissue-type plasminogen activator) results in better outcomes.[1] Although the benchmark door-to-needle time (DTN) has been set at 60 minutes,[2] many centers have been able to exceed this benchmark with median times from 20 to 51 minutes.[3–9] These local efforts have been supported by national and international efforts to reduce DTN time. For example, the American Heart Association's Target: Stroke initiative, which promoted 10 specific strategies to reduce DTN time, was associated with improvements in DTN time such that more than half of the patients were treated within the benchmark of 60 minutes.[10] Similarly, Europe and other countries have made significant strides toward improving DTN time with the SITS (Safe Implementation of Treatment in Stroke) Watch project.[11]

See Editorial by Prabhakaran and Mendelson

In this prospective cohort study of consecutive alteplase-treated patients, we analyzed the impact of 4 specific strategies to reduce DTN time at our single center: (1) a new single call activation system to notify the stroke team of an incoming severe stroke (termed STAT stroke) patient, (2) registering STAT stroke patients as unknown on arrival, prior to exact identification (ID), so that imaging and laboratories can be ordered; (3) moving STAT stroke patients directly to the computed tomography (CT) on the emergency medical services (EMS) stretcher, and (4) delivering alteplase on the CT table or in the imaging area. In contrast to many other studies of DTN time improvements, we implemented these strategies in

Received April 29, 2016; accepted October 26, 2016.

From the Department of Clinical Neurosciences (N.K., A.M.D., M.D.H., E.E.S.) and Department of Community Health Sciences (J.K.H.), Cumming School of Medicine, University of Calgary, Alberta, Canada; Calgary Stroke Program, Alberta Health Services (C.S., A.M.D., M.D.H., C.Z., N.N., D. Knox, E.E.S.) and Department of Emergency Medicine (D. Kashayp, E.B., E.L.), Foothills Medical Centre, Calgary, Alberta, Canada; Emergency Medical Services, Alterta Health Services, Calgary, Alberta, Canada (R.L.V.); and Hotchkiss Brain Institute (A.M.D., M.D.H., E.E.S.), University of Calgary, Calgary, Alberta, Canada.

Correspondence to Eric Smith, MD, MPH, University of Calgary, Room 2941, Health Sciences Bldg, 3330 University Dr SW, Calgary, AB, Canada T4N 2T1. E-mail eesmith@ucalgary.ca

WHAT IS KNOWN

- Faster treatment with intravenous alteplase improves outcomes from acute ischemic stroke.
- Quality improvement programs reduce alteplase door-to-needle times (DTN) (ie, the time from emergency department arrival to initiation of treatment), but the time reductions associated with individual strategies have not been well defined.

WHAT THE STUDY ADDS

- We determined the independent associations of 4 specific strategies for reducing DTN time for intravenous alteplase, using a prospective pre- and postintervention study design while simultaneously controlling for each strategy, as well as secular trends and patient characteristics.
- Administering alteplase in the diagnostic imaging area reduced DTN time by 32%; moving the patient to the diagnostic imaging area on the Emergency Medical Services stretcher reduced DTN time by 30%; registering the patient as unknown, prior to full identification by family members or an informant, reduced DTN time by 12%; and simultaneous notification by group pager of an incoming patient with high stroke severity reduced DTN time by 11%.

a staggered fashion and prospectively recorded the application of these strategies for each patient. Because the changes were implemented in a staggered fashion and not every patient was eligible for the STAT stroke pathway, we were able to use multivariable regression modeling to determine the effect of each strategy. For example, a patient with mild stroke symptoms may have been thrombolysed, but the STAT stroke single call activation change would not have been triggered in this case.

Methods

Interventions

Existing DTN time strategies at our center included EMS prenotification for all patients with stroke symptoms <12 hours, stroke protocols with standard work, a single call activation system, rapid laboratory testing, immediate review of CT images by the stroke team, review of DTN time performance, and quality improvement. During regular work hours, our acute stroke team includes an attending neurologist, a nurse practitioner, and a stroke fellow; on nights and weekends, the team includes an attending neurologist and a stroke fellow. Beginning in 2012, we started a new DTN time quality improvement project, based on the 6-sigma approach, that includes the DMAIC (Define, Measure, Analyze, Improve, Control) process.[12] The project was called HASTE (Hurry Acute Stroke Treatment and Evaluation) and has had 3 phases.

HASTE I started on June 6, 2012 and ended on June 5, 2013, and during this time, data were collected and analyzed to understand the current DTN time performance, along with planning of prospective interventions to be implemented in the next phase.

In HASTE II (June 6, 2013 to January 24, 2015), we implemented (1) a new triage level for severe stroke <4.5 hours from onset, termed STAT stroke, (2) registration of STAT stroke patients as unknown, allowing an immediate case record to be created, orders entered, and results assigned to that record, and (3) for all patients treated with alteplase, immediate mixing of alteplase on determining eligibility with administration of alteplase on the scanner table or just outside the CT suite, instead of transferring the patient to our stroke unit for treatment. STAT stroke patients had last known well to symptom onset <4.5 hours and severe stroke symptoms, defined as one or more of hemiplegia (operationally defined as inability to raise the arm or leg without support), aphasia, or decreased level of consciousness. The STAT stroke activation was triggered in the field through a motor test that was derived from the Cincinnati Prehospital Stroke Scale.[13] These criteria were designed to distinguish time-eligible patients with severe stroke, highly likely to be treated with alteplase, from patients with less severe stroke or unclear time of onset who were less likely to be treated. The STAT stroke pathway could be activated by EMS or by the emergency department (ED) nurse. When activated for a STAT stroke case, the stroke team was expected to cease all other activity and immediately proceed to ED triage to meet the patient on arrival. Thus, the intent of the STAT stroke protocol was to focus stroke team attention on the patients most likely to require alteplase, in the context of a busy ED with many milder or subacute stroke evaluations (>1500 stroke service admissions per year). The STAT stroke page went to the entire stroke team, regardless of whether they were on call; the page explicitly stated that a STAT stroke patient was arriving with an estimated time of arrival and some additional clinical details, such as last seen well time, sex, age, and presenting symptoms. This is in contrast to the preexisting single call activation, which was triggered after the patient was assessed in the ED, included all suspected stroke or TIA, was only sent to the neurologists on call, and did not indicate STAT stroke. The STAT stroke activation and registration as unknown interventions were implemented immediately at the start of HASTE II (June 6, 2013), and the administration of alteplase in CT or imaging area began on September 1, 2013.

In HASTE III (January 25, 2015 to June 29, 2015), we implemented a protocol to take STAT stroke patients directly to the CT scanner on the EMS stretcher. On arrival, EMS takes the patient to an awaiting ED bay, followed by rapid assessment for medical stability and neurological signs, then transport immediately to the scanner on the EMS stretcher without being transferred to a hospital bed.

Study Population

We analyzed consecutive patients treated with alteplase in our ED within 4.5 hours of last seen well, including patients who subsequently had endovascular acute stroke therapy. In-hospital stroke patients and transfer patients were excluded.

Measurements

ED admission time, EMS prenotification, and registration number were abstracted from ED triage records. STAT stroke notifications were identified by review of electronically recorded page logs. Location and time of alteplase administration was abstracted from nursing records. National Institutes of Health Stroke Scale (NIHSS) was assessed by a certified stroke team physician and recorded as part of a standard consultation template. We collected information on which interventions were applied to each patient through a robust mechanism: the STAT stroke activation was collected by reviewing the page logs; the registration as unknown was collected by the initial ED triage record that shows the patient ID sticker; and the location of alteplase administration location and stretcher-to-CT was collected by reviewing nursing documentation that actively collected this information. The charts were reviewed by 2 people (Dr Kamal and C. Stephenson); disagreements were resolved by consensus. Data were complete for all variables.

Statistical Analysis

Decrease in DTN time was analyzed using Wilcoxon rank-sum and Kruskal–Wallis tests, as well as with multivariable linear regression. Because the distribution of DTN time was skewed to the right, it was logarithmically transformed for linear regression. The univariable analyses compared the HASTE I, II, and III time periods. The analyses compared all the changes that were implemented: (1) the location that alteplase was administered (CT/imaging area, ED bay, or stroke unit); (2) whether the patient was moved directly to the CT on EMS stretcher; (3) whether the patient was registered as unknown; and (4) whether the STAT stroke prenotification protocol was used. Covariates were selected based on clinical knowledge of factors associated with DTN time: NIHSS (categorized as mild <6, moderate 6–8, or high >8), age, sex,[14] whether the patient was on an anticoagulant (which we hypothesized would be associated with longer DTN time because of the need for coagulation testing to determine alteplase eligibility),[15] arrival during regular business hours,[5] and EMS prenotification.[16] Calendar time (linear, in days) was included in the model to control for confounding by overall temporal trends. Because each HASTE phase would be colinear with the new DTN time improvement strategies, in our primary analysis, we modeled the strategies themselves rather than HASTE phase, whereas in a secondary analysis, we determined the effect of HASTE phases instead of the individual strategies. We used Cook's distance and the variance inflation factor to verify that the model findings were not unduly influenced by outlying values or colinearity between variables, respectively. Statistical analyses were done using Stata version 14 (StataCorp LP, College Station, TX).

Ethical Approval

Written consent from patients or next of kin was not obtained because this was a quality improvement study that involved assessment of the standard of care. This study was approved by the University of Calgary institutional review board.

Results

There were 350 consecutive eligible patients treated with alteplase during the HASTE project (June 6, 2012, to June 29, 2015). Mean age was 71.6 years (SD 16.35), 48.3% were women, and median NIHSS score was 13. The number of patients in each evaluated group is shown in Table 1 by HASTE phase.

The univariable analysis showed that median DTN time was lower during each time period of the HASTE project: 53 minutes in HASTE I, 45 minutes in HASTE II, and 35 minutes in HASTE III (*P*=0.0002; Table 2). There were 136 alteplase-treated STAT stroke pathway patients in HASTE II and III, out of 595 total STAT stroke pages. STAT stroke patients (n=136) had median DTN time of 42.5 minutes in HASTE II and 34 minutes in HASTE III (*P*=0.03), whereas non-STAT stroke patients (n=119) had median DTN time of 49.5 minutes in HASTE II and 41 minutes in HASTE III (*P*=0.33). Compared with HASTE I (baseline), the differences in DTN time were significant for STAT stroke patients (*P*=0.0003 for HASTE II and *P*<0.0001 for HASTE III compared with HASTE I); however, there was no difference in DTN time for non-STAT stroke patients when compared with baseline (*P*=0.48 for HASTE II and *P*=0.17 for HASTE III compared with HASTE I).

In univariable analyses, the following strategies were found to be associated with lower median DTN time (Figure): STAT stroke prenotification (median DTN time of 40 minutes versus 51 minutes without; *P*<0.0001); registering the patient as unknown (40 minutes versus 53 minutes when not registered as unknown; *P*<0.0001); and moving the patient to the CT on EMS stretcher (28 minutes versus 48 minutes; *P*<0.0001; Table 2). Median DTN time was lower when alteplase was administered in the CT (29 minutes versus 47 minutes when administered in the ED; *P*=0.0001).

The multivariable analysis that was adjusted for patient demographic factors, process factors, and study time showed that administering alteplase in the scanner or imaging area reduced DTN time by 32% compared with administering alteplase in the ED bay (*P*<0.0001; Table 2). Moving the patient to the CT on the EMS stretcher reduced the DTN time by 30% (*P*<0.001), registering the patient as unknown reduced the DTN time by 12% (*P*=0.013), and the STAT stroke page reduced the DTN time by 11% (*P*=0.032). Stroke severity was associated with DTN time. In univariable analyses, median DTN time was 43 minutes for severe strokes (NIHSS score >8) compared with 49 minutes for moderate strokes (NIHSS score 6–8) and 66 minutes for mild strokes (NIHSS score <5; *P*=0.0001). The

Table 1. Number of Patients in Each of the Following Category by HASTE Phase: Each of the Interventions, NIHSS, Anticoagulant Use, and EMS Arrival

	HASTE I, n (%)	HASTE II, n (%)	HASTE III, n (%)
Location treatment administered			
Stroke unit	44 (46.8)	20 (9.4)	1 (2.3)
ED bay	44 (46.8)	134 (62.9)	22 (51.1)
CT/imaging area	0 (0)	48 (22.5)	15 (34.9)
Angio suite	0 (0)	2 (0.9)	0 (0)
UTD	6 (6.4)	9 (4.2)	5 (11.6)
Stretcher to CT			
Yes	0 (0)	0 (0)	24 (55.8)
No	94 (100.0)	213 (100.0)	19 (44.2)
Patient registered as unknown			
Yes	7 (7.4)	99 (46.5)	25 (58.1)
No	84 (89.4)	107 (50.2)	17 (39.5)
UTD	3 (3.2)	7 (3.3)	1 (2.4)
STAT stroke page			
Yes	0 (0)	110 (51.6)	26 (60.5)
No	94 (100.0)	102 (47.9)	17 (39.5)
UTD	0 (0)	1 (0.5)	0 (0)
Anticoagulant use			
Yes	6 (6.4)	31 (14.6)	4 (9.3)
No	81 (86.2)	173 (81.2)	36 (83.7)
UTD	7 (7.4)	9 (4.2)	3 (7.0)
NIHSS			
Mild <5	13 (13.8)	29 (13.6)	6 (14.0)
Moderate 6–8	15 (16.0)	42 (19.7)	8 (18.6)
Severe >8	66 (70.2)	139 (65.3)	27 (62.8)
UTD	0 (0)	3 (1.4)	2 (4.6)
Arrival by EMS			
Yes	93 (98.9)	207 (97.2)	43 (100.0)
No	1 (1.1)	6 (2.8)	0 (0)

CT indicates computed tomography; ED, emergency department; EMS, emergency medical services; HASTE, Hurry Acute Stroke Treatment and Evaluation program; NIHSS, National Institutes of Health Stroke Scale; and UTD, unable to determine.

Table 2. Factors Associated With DTN time in Univariable- and Multivariable-Adjusted Analyses, Including HASTE Interventions

Independent Variable	N	Univariable Analysis: Median DTN time, min	Univariable Analysis: *P* Value	Multivariable Analysis: % Decrease in DTN time	Multivariable Analysis: 95% Confidence Interval	Multivariable Analysis: *P* Value	Multivariable Analysis: Mean Decrease in DTN time,* min
Sex							
Female	169	48	0.109	0.51	−9 to 9	0.909	0.30
Male	181	43					
Age (per year)	…	…	…	−0.10	−0.37 to 0.17	0.469	−0.06
Time, days	…	…	…	−0.03	−0.05 to -0.01	0.003	−0.02
Location treatment administered							
Stroke unit	65	62		−30	−47 to −15	<0.001	−18
ED bay	200	47	0.0001	Reference	…	…	…
CT/imaging area	63	29		32	23 to 39	<0.001	19
Stretcher to CT							
Yes	24	28	<0.0001	30	16 to 42	<0.001	18
No	325	48					
Patient registered as unknown							
Yes	132	40	<0.0001	12	3 to 20	0.013	7
No	208	53					
STAT stroke page							
Yes	136	40	<0.0001	11	1 to 20	0.032	6
No	213	51					
Anticoagulant use							
Yes	42	54	0.06	−9	−25 to 5	0.203	−5
No	290	43					
NIHSS							
Mild <5	48	66		Reference	…	…	
Moderate 6–8	65	49	0.0001	19	6 to 31	0.008	11
Severe >8	232	43		27	17 to 37	<0.001	16
HASTE phases				Not included			
HASTE I	94	53					
HASTE II	213	45	0.0002				
HASTE III	43	35					
EMS prenotification							
Yes	298	45	0.94	−17	−52 to 10	0.241	−10
No	8	45					
ED admission during business hours							
Yes	42	41	0.07	13	1 to 23	0.039	7
No	308	47					

Univariable analyses were performed using Kruskal–Wallis tests and Wilcoxon rank-sum tests as appropriate. Multivariable analyses were performed using linear regression (DTN time was log transformed as it was heavily right skewed). CT indicates computed tomography; DTN time, door-to-needle time; ED, emergency department; EMS, emergency medical services; HASTE, Hurry Acute Stroke Treatment and Evaluation program; and NIHSS, National Institutes of Health Stroke Scale.

*In reference to HASTE I mean DTN time of 59 min, holding all other factors constant.

multivariable analysis showed similar results: severe strokes (NIHSS score >8) had a 27% shorter DTN time compared with mild strokes (*P*<0.0001). There were no significant differences found by age, sex, anticoagulant use, and EMS prenotification. There were significantly lower DTN time (13%) during business versus after hours (*P*=0.039).

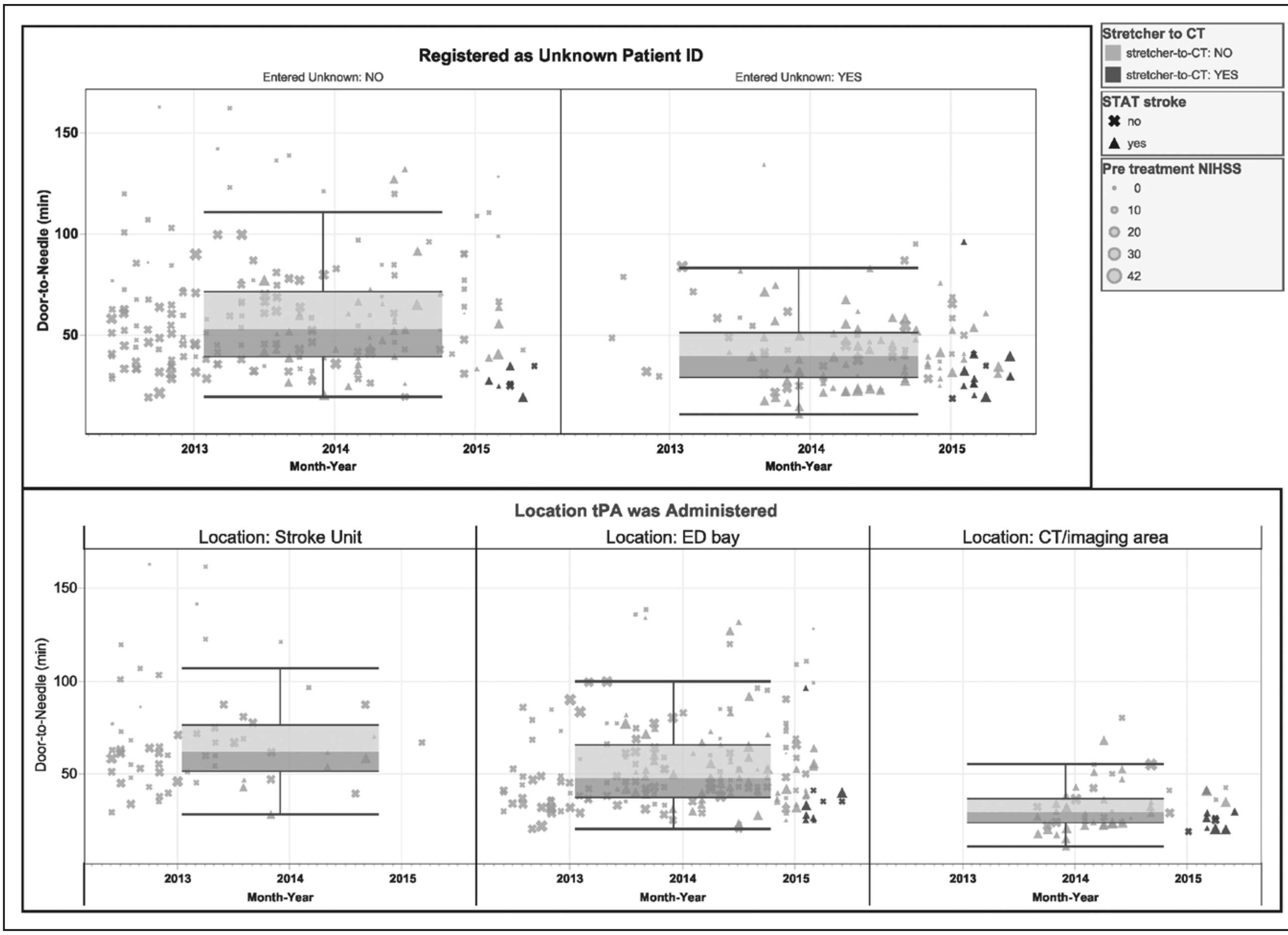

Figure. Door-to-needle times over the entire study period. **Top,** The comparison between registering the patient as unknown patient identification with fully registering the patient. **Bottom**, The comparison between the different locations where the alteplase is administered. Dark gray shows when the patient went directly to CT on EMS stretcher compared with light gray when this protocol was not followed. A mark shown as an x indicates when the STAT Stroke protocol was not followed and a mark shown by a triangle indicates when it was followed. The size of the mark increases with larger NIHSS. CT indicates computed tomography; ED, emergency department; EMS, emergency medical services; ID, identification; NIHSS, National Institutes of Health Stroke Scale; and tPA, tissue-type plasminogen activator.

In a secondary analysis, we estimated the effect of each HASTE phase controlling for demographics, time, stroke severity, and anticoagulant use (Table 3). This analysis showed that compared with HASTE phase I, HASTE phase II was associated with 16% lower DTN time (P=0.003) and HASTE phase II was associated with 31% lower DTN time (P<0.001).

Discussion

All the changes that were implemented were associated with significant improvements in DTN time. Administering alteplase in the scanner/imaging area and moving the patient to the CT scanner on EMS stretcher were associated with the largest reductions in DTN time. Many assessment and treatment aspects of the patient flow from the ED triage through to treatment can be done in parallel with a key exception: brain imaging is mandatory. Thus, the 2 key steps (door-to-CT and CT-to-needle) can be made faster with these 2 key changes.

It is important to have smaller changes in place to enable treatment in the imaging area and a direct-to-CT approach. These include creating a thrombolysis kit in a tackle box, which includes medications (antiemetic, antihypertensive, and antiepileptic), syringes, needles, intravenous catheters, and basic noninvasive airway tools (O_2 masks, nasal prongs, etc). The CT scanner and imaging area must have immediate access to suction to manage vomiting. Our kit contains a vial of alteplase, but also metoclopramide, dimenhydrinate, hydralazine, labetalol, midazolam, and necessary syringes, needles, tubing, and intravenous catheters to allow medication delivery acutely.

In this study, providing alteplase in the CT imaging area, rather than after transport back to the ED, shortened DTN time by 32%, controlling for stroke severity, demographics, calendar time trends, and other DTN time improvement strategies. This approach holds promise to reduce delays from imaging to needle, which can be substantial. A recent analysis of the Michigan Paul Coverdell Acute Stroke Registry showed that mean imaging-to-needle time (60.1 minutes) far exceeded mean door-to-imaging time (22.8 minutes), accounting for 64.6% of hospital variation in DTN time.[17] Prior work has identified that locating the CT scanner near the emergency room shortens treatment times.[3] We also compared providing alteplase in the CT imaging area to providing it on the stroke unit because our

Table 3. Association of HASTE Phases With DTN time

Independent Variable	N	% Decrease in DTN time	95% Confidence Interval	*P* Value	Mean Decrease in DTN time,* min
Sex					
Female	169	3	−7 to 12	0.535	2
Male	181				
Age (per year)	…	−0.18	−0.48 to 0.13	0.252	−0.11
Anticoagulant use					
Yes	42	−25	−45 to −8	0.003	−15
No	290				
NIHSS					
Mild <5	48	Reference	…	…	
Moderate 6–8	65	23	8 to 36	0.004	14
Severe >8	232	38	27 to 46	<0.001	22
HASTE phases					
HASTE I	94	Reference	…	…	
HASTE II	213	16	6 to 25	0.003	9
HASTE III	43	31	18 to 42	<0.001	19
EMS prenotification					
Yes	298	−5	−43 to 22	0.737	−3
No	8				
ED admission during business hours					
Yes	42	15	1 to 26	0.032	9
No	308				

Multivariable analyses were performed using linear regression (DTN time was log-transformed as it was heavily right skewed). DTN time indicates door-to-needle time; ED, emergency department; EMS, emergency medical services; HASTE, Hurry Acute Stroke Treatment and Evaluation program; and NIHSS, National Institutes of Health Stroke Scale.

*In reference to HASTE I mean DTN time of 59 min, holding all other factors constant.

institutional protocol differs from many others in that all tissue-type plasminogen activator–eligible or –treated patients go immediately from the CT scanner to the stroke unit if they are medically stable. They are transported back to the ED only if additional emergency treatment is required, such as intubation. In the new era of rapid endovascular thrombectomy for stroke, many patients will go directly from the CT to the endovascular suite. A novel aspect of our study is that we have quantitated the time savings associated with alteplase administration in the imaging suite. National quality improvement strategies to reduce imaging-to-needle time, including providing alteplase in the imaging suite, are needed.

Transporting the patient directly to CT while on the EMS stretcher was independently associated with a 30% reduction in DTN time. Because of congestion in our ED triage area and the physical layout of our ED, with the ED bays located between ED triage and the CT scanner, we planned for the ED physician, ED nurse, and acute stroke team to meet the patient in the ED bay, rather than the triage area, en route to CT. Therefore, our protocol could be considered a variant on the direct-to-imaging practice advocated as one of the key best practice strategies in the American Heart Association Target: Stroke program.[18] Our finding of a substantial DTN time reduction associated with direct transport to imaging is consistent with other studies.[19,20]

Routinely registering the patient with a unique unknown ID number, instead of identifying the patient and matching them to their known ID number, was associated with 12% lower DTN time. Assigning an ID number at our hospital involves matching 2 pieces of ID, a healthcare card and a photo ID, with verification by direct interview of the patient (or a family member if they are unable to communicate). Preregistration before patient arrival is not possible in our jurisdiction because privacy legislation in our province prevents transmittal of patient-identifiable information by EMS en route, and health system regulations prevent patient registration without confirmation by the patient or a witness. Because many stroke patients are not competent to identify themselves because of aphasia or impaired consciousness, the search for a witness to identify the patient can introduce delays of 10 to 15 minutes. During this time, CT imaging cannot be ordered because the patient is not registered in the electronic order entry system. Our understanding is that many other hospitals have similar delays where imaging cannot be ordered because the patient is not yet electronically registered (personal communications). To eliminate this delay, we routinely registered STAT stroke patients as unknown, adopting a protocol already in use for high priority trauma patients who are also usually unable to identify themselves because of depressed consciousness or severe pain. When witnesses arrive and the patient identity is later confirmed, the unique unknown number is then linked to the actual patient ID. Our STAT stroke prenotification page was associated with a moderate reduction DTN time (11%).

Greater severity of stroke was associated with faster treatment, consistent with other studies.[14] Milder stroke patients may not initially be recognized as acute stroke patients or may not be considered immediately as potential candidates for thrombolysis, with resultant failure to trigger the fast protocol changes we implemented. However, some patient factors associated with DTN time in large national studies, such as age, were not associated with lower DTN time at our site.[14] Finally, as expected, prenotification was not associated with shorter DTN time times because this was in place both before and after our interventions.

Strengths of this analysis include the prospective implementation of multiple process changes with a preintervention control phase and individual patient-level data on each process, allowing determination of the independent association of each process with lower DTN time. In contrast, recent highly cited papers either lacked a prospectively designed control phase[4] or implemented multiple interventions simultaneously without multivariable adjustment to determine the independent effects[20] of each intervention. We have also provided information on the effectiveness of relatively understudied interventions, including giving alteplase in the imaging suite and registration of the patient as unknown.

However, this study also has limitations. Although we used a prospectively designed preintervention control phase, the interventions were not randomly assigned, and therefore, our estimates may be affected by unmeasured confounding, even though we controlled for all known factors associated with DTN time in our study population. We took advantage of the fact that protocol changes are not invariably and immediately implementable, leading to some variation in whether HASTE interventions were implemented, which we could analyze. However, we did not collect reasons why specific interventions were not applied after the implementation date for the intervention. Most likely, variable application reflected incomplete adherence to the HASTE protocols, but we cannot exclude that other factors, such as delayed stroke recognition, could have played a role. We did not look at specific patient reasons for outlying times, including whether the stroke was initially mild but worsened; however, a prior study by our group using pre-HASTE data showed that outlying times were often related to delayed recognition, management of comorbid medical conditions, or systems factors.[21] This study was conducted in a single high-volume academic center, and future studies will be needed to understand whether the effects seen in this study are generalizable to other centers with other acute stroke protocols and to understand why specific changes were not applied through documentation of reasons when an intervention is not applied to a patient. We did not collect data on stroke mimics or tissue-type plasminogen activator–related hemorrhage; however, prior studies suggest that DTN time reduction programs do not increase the risk of tissue-type plasminogen activator complications.[10] Furthermore, specific changes may differ based on the policies and structures of different hospitals and jurisdictions; however, the effect of similar changes at other hospitals can be tested to determine their effect on DTN time. We did not experience undue burden on stroke team and ED CT resources when implementing the HASTE program, but the capacity for similar programs at other centers must be determined individually in light of available resources.

We reduced DTN time by implementing 4 key strategies and quantified their relative effect: STAT stroke prenotification protocol, registering the patient as unknown, administering alteplase in the CT scanner or imaging area, and moving the patient to the CT on the EMS stretcher. Two of these strategies were novel, less well-studied strategies that were independently associated with reductions in DTN time: giving alteplase in the imaging suite and immediately registering the patient with a unique unknown ID number on admission to allow entry of CT orders without delay. These newer strategies could be promoted in future regional and national DTN time quality improvement initiatives.

Disclosures

Dr Smith reports receiving funding for being a member of a data safety and monitoring board for Massachusetts General Hospital for the MR Witness trial. Dr Kamal reports that her salary is from QuICR Stroke Program and her membership in the Acute Stroke/TIA Expert Working Group for Alberta Health Service's Cardiovascular Health & Stroke Strategic Clinical Network. Dr Hill reports that he is the principal investigator for QuICR Stroke Program. Dr Lang reports his membership in the Acute Stroke/TIA Working Group for Alberta Health Service's Cardiovascular Health & Stroke Strategic Clinical Network. Dr Demchuk is the cochair for the Acute Stroke/TIA Working Group for Alberta Health Service's Cardiovascular Health & Stroke Strategic Clinical Network.

References

1. Emberson J, Lees KR, Lyden P, Blackwell L, Albers G, Bluhmki E, Brott T, Cohen G, Davis S, Donnan G, Grotta J, Howard G, Kaste M, Koga M, von Kummer R, Lansberg M, Lindley RI, Murray G, Olivot JM, Parsons M, Tilley B, Toni D, Toyoda K, Wahlgren N, Wardlaw J, Whiteley W, del Zoppo GJ, Baigent C, Sandercock P, Hacke W; Stroke Thrombolysis Trialists' Collaborative Group. Effect of treatment delay, age, and stroke severity on the effects of intravenous thrombolysis with alteplase for acute ischaemic stroke: a meta-analysis of individual patient data from randomised trials. *Lancet*. 2014;384:1929–1935. doi: 10.1016/S0140-6736(14)60584-5.
2. Marler JR, Winters JP, Emr M. *The National Institute of Neurological Disorders and Stroke: Proceedings of National Symposium on Rapid Identification and Treatment of Acute Stroke*. Bethesda, MD: National Institute of Neurological Disorders and Stroke; 1997.
3. Lindsberg PJ, Häppölä O, Kallela M, Valanne L, Kuisma M, Kaste M. Door to thrombolysis: ER reorganization and reduced delays to acute stroke treatment. *Neurology*. 2006;67:334–336. doi: 10.1212/01.wnl.0000224759.44743.7d.
4. Meretoja A, Strbian D, Mustanoja S, Tatlisumak T, Lindsberg PJ, Kaste M. Reducing in-hospital delay to 20 minutes in stroke thrombolysis. *Neurology*. 2012;79:306–313. doi: 10.1212/WNL.0b013e31825d6011.
5. Meretoja A, Weir L, Ugalde M, Yassi N, Yan B, Hand P, Truesdale M, Davis SM, Campbell BC. Helsinki model cut stroke thrombolysis delays to 25 minutes in Melbourne in only 4 months. *Neurology*. 2013;81:1071–1076. doi: 10.1212/WNL.0b013e3182a4a4d2.
6. Thortveit ET, Bøe MG, Ljøstad U, Mygland A, Tveiten A. Organizational changes aiming to reduce iv tPA door-to-needle time. *Acta Neurol Scand*. 2014;130:248–252. doi: 10.1111/ane.12204.
7. Chen CH, Tang SC, Tsai LK, Hsieh MJ, Yeh SJ, Huang KY, Jeng JS. Stroke code improves intravenous thrombolysis administration in acute ischemic stroke. *PLoS One*. 2014;9:e104862. doi: 10.1371/journal.pone.0104862.

8. Busby L, Owada K, Dhungana S, Zimmermann S, Coppola V, Ruban R, Horn C, Rochestie D, Khaldi A, Hormes JT, Gupta R. CODE FAST: a quality improvement initiative to reduce door-to-needle times. *J Neurointerv Surg*. 2016;8:661–664. doi: 10.1136/neurintsurg-2015-011806.
9. Van Schaik SM, Scott S, de Lau LM, Van den Berg-Vos RM, Kruyt ND. Short door-to-needle times in acute ischemic stroke and prospective identification of its delaying factors. *Cerebrovasc Dis Extra*. 2015;5:75–83. doi: 10.1159/000432405.
10. Fonarow GC, Zhao X, Smith EE, Saver JL, Reeves MJ, Bhatt DL, Xian Y, Hernandez AF, Peterson ED, Schwamm LH. Door-to-needle times for tissue plasminogen activator administration and clinical outcomes in acute ischemic stroke before and after a quality improvement initiative. *JAMA*. 2014; 311:1632–1640.
11. Safe Implementations of Treatments in Stroke. SITS-WATCH. https://sitsinternational.org/sits-projects/sits-watch.
12. Kwak Y-H, Anbari FT. Benefits, obstacles, and future of six-sigma approach. *Technovation*. 2006; 26:708–715.
13. Kothari RU, Pancioli A, Liu T, Brott T, Broderick J. Cincinnati Prehospital Stroke Scale: reproducibility and validity. *Ann Emerg Med*. 1999;33:373–378.
14. Fonarow GC, Smith EE, Saver JL, Reeves MJ, Bhatt DL, Grau-Sepulveda MV, Olson DM, Hernandez AF, Peterson ED, Schwamm LH. Timeliness of tissue-type plasminogen activator therapy in acute ischemic stroke: patient characteristics, hospital factors, and outcomes associated with door-to-needle times within 60 minutes. *Circulation*. 2011;23:750–758.
15. Xian Y, Liang L, Smith EE, Schwamm LH, Reeves MJ, Olson DM, Hernandez AF, Fonarow GC, Peterson ED. Risks of intracranial hemorrhage among patients with acute ischemic stroke receiving warfarin and treated with intravenous tissue plasminogen activator. *JAMA*. 2012; 307:2600–2608.
16. Lin CB, Peterson ED, Smith EE, Saver JL, Liang L, Xian Y, Olson DM, Shah BR, Hernandez AF, Schwamm LH, Fonarow GC. Emergency prenotification is associated with improved evaluation and treatment of acute ischemic stroke. *Circ Cardiovasc Qual Outcomes*. 2012;5: 514–522.
17. Sauser K, Levine DA, Nickles AV, Reeves MJ. Hospital variation in thrombolysis times among patients with acute ischemic stroke: the contributions of door-to-imaging time and imaging-to-needle time. *JAMA Neurol*. 2014;71:1155–1161. doi: 10.1001/jamaneurol.2014.1528.
18. Fonarow GC, Smith EE, Saver JL, Reeves MJ, Hernandez AF, Peterson ED, Sacco RL, Schwamm LH. Improving door-to-needle times in acute ischemic stroke: the design and rationale for the American Heart Association/American Stroke Association's Target: Stroke initiative. *Stroke*. 2011;42:2983–2989.
19. Ford AL, Williams JA, Spencer M, McCammon C, Khoury N, Sampson TR, Panagos P, Lee JM. Reducing door-to-needle times using Toyota's lean manufacturing principles and value stream analysis. *Stroke*. 2012;43:3395–3398. doi: 10.1161/STROKEAHA.112.670687.
20. Desai JA, Smith EE. Prenotification and other factors involved in rapid tPA administration. *Curr Atheroscler Rep*. 2013;15:337. doi: 10.1007/s11883-013-0337-5.
21. Choi PM, Desai JA, Kashyap D, Stephenson C, Kamal N, Vogt S, Bohm V, Suddes M, Bugbee E, Hill MD, Demchuk AM, Smith EE. Are all stroke patients eligible for fast alteplase treatment? An analysis of unavoidable delays. *Acad Emerg Med*. 2016;23:393–399. doi: 10.1111/acem.12914.

Circulation
Cardiovascular Quality and Outcomes

Improving Door-to-Needle Times for Acute Ischemic Stroke: Effect of Rapid Patient Registration, Moving Directly to Computed Tomography, and Giving Alteplase at the Computed Tomography Scanner

Noreen Kamal, Jessalyn K. Holodinsky, Caroline Stephenson, Devika Kashayp, Andrew M. Demchuk, Michael D. Hill, Renee L. Vilneff, Erin Bugbee, Charlotte Zerna, Nancy Newcommon, Eddy Lang, Darren Knox and Eric E. Smith

Circ Cardiovasc Qual Outcomes. 2017;10:
doi: 10.1161/CIRCOUTCOMES.116.003242
Circulation: Cardiovascular Quality and Outcomes is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231

Print ISSN: 1941-7705. Online ISSN: 1941-7713