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Original Article

Implementation of an institution-wide acute stroke algorithm: Improving stroke quality metrics

Scott L. Zuckerman, Jordan A. Magarik, Kiersten B. Espaillat[1], Nishant Ganesh Kumar, Ritwik Bhatia, Michael C. Dewan, Peter J. Morone, Lisa D. Hermann[2], Anne E. O'Duffy[2], Derek A. Riebau[2], Howard S. Kirshner[2], J. Mocco[3]

Department of Neurological Surgery, [1]Vanderbilt Comprehensive Stroke Center, [2]Department of Neurology, Vanderbilt University School of Medicine, Nashville, Tennessee, [3]Department of Neurosurgery, Mt. Sinai School of Medicine, New York, USA

E-mail: Scott L. Zuckerman - scott.zuckerman@vanderbilt.edu; Jordan A. Magarik - jordan.a.magarik@vanderbilt.edu; Kiersten B. Espaillat - kiersten.brown@vanderbilt.edu; *Nishant Ganesh Kumar - nishant.ganesh.kumar@vanderbilt.edu; Ritwik Bhatia - ritwik.bhatia@vanderbilt.edu; Michael C. Dewan - michael.dewan@vanderbilt.edu; Peter J. Morone - peter.morone@vanderbilt.edu; Lisa D. Hermann - lisa.hermann@vanderbilt.edu; Anne E. O'Duffy - anne.e.oduffy@vanderbilt.edu; Derek A. Riebau - derek.a.riebau@vanderbilt.edu; Howard S. Kirshner - howard.kirshner@vanderbilt.edu; J. Mocco - j.mocco@mountsinai.org
*Corresponding author

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Abstract

Background: In May 2012, an updated stroke algorithm was implemented at Vanderbilt University Medical Center. The current study objectives were to: (1) describe the process of implementing a new stroke algorithm and (2) compare pre- and post-algorithm quality improvement (QI) metrics, specificaly door to computed tomography time (DTCT), door to neurology time (DTN), and door to tPA administration time (DTT).

Methods: Our institutional stroke algorithm underwent extensive revision, with a focus on removing variability, streamlining care, and improving time delays. The updated stroke algorithm was implemented in May 2012. Three primary stroke QI metrics were evaluated over four separate 3-month time points, one pre- and three post-algorithm periods.

Results: The following data points improved after algorithm implementation: average DTCT decreased from 39.9 to 12.8 min ($P < 0.001$); average DTN decreased from 34.1 to 8.2 min ($P \leq 0.001$), and average DTT decreased from 62.5 to 43.5 min ($P = 0.17$).

Conclusion: A new stroke protocol that prioritized neurointervention at our institution resulted in significant lowering in the DTCT and DTN, with a nonsignificant improvement in DTT.

Key Words: Algorithm, emergency medicine, neurology, neurosurgery, stroke, thrombectomy

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INTRODUCTION

Ischemic stroke is one of the leading causes of morbidity and mortality in the United States (US) resulting in approximately 795,000 first-time or recurrent strokes each year, of which 130,000 result in death.[37,42] Stroke costs are upwards of $41 billion annually due to medical expenses and work-hours lost.[42] Located in the stroke belt, ischemic stroke mortality rates in Tennessee are some of the highest in the country, where 58–125 per 100,000 individuals died from ischemic stroke versus approximately 42 per 100,000 individuals nationally during 2008–2010.[3,35,38] A major contributor to the inequity in stroke mortality rates across Tennessee is timely access to care, typically only available at major urban hospitals. The Center for Disease Control and Prevention (CDC) reported that approximately 22% of US counties did not have a hospital, 31% did not have a hospital emergency department (ED), and approximately 77% lacked hospitals with neurological services.[36] The paradigm, "*Time is brain*"[19,47] – that every passing minute reduces the chance of neurological recovery and worsens prognosis – continues to thrust efforts to reduce time to symptom recognition, patient transport, and neurological evaluation and intervention. In this regard, several studies have explored ways to expedite acute stroke care and improve triage times.[4,15,16,23-25,44,51,53,55,56]

While these studies provide insight into developing a stroke algorithm, we hope to describe our institutional experience, focusing on the process involved. The Vanderbilt University Medical Center (VUMC) Departments of Neurology, Neurosurgery, Radiology, and Emergency Medicine revised an existing protocol for the preparation, response, and treatment of ischemic stroke patients. Prior to May 2012, a previous stroke algorithm was in effect. According to the old algorithm, a patient with acute, nontraumatic focal neurologic deficit concerning for ischemic stroke was identified in the ED or as an inpatient. A stroke alert page was triggered if the symptom onset was within 8 hours of last known normal and the stroke team went to the identified location, where the National Institute of Health Stroke Scale (NIHSS) was performed and the patient underwent a noncontrast head computed tomography scan (HCT). If no hemorrhage was seen, an update page was sent out based on NIHSS (NIHSS <6 involved the stroke neurology team only; NIHSS >6 also included the interventional team). In both scenarios, the focus was to identify potential IV tPA candidates and initiate infusion as soon as possible. With the evolution of interventional therapy, it was recognized that this protocol was not designed to efficiently identify interventional candidates. A detailed review of the protocol identified several areas of improvement.

In May 2012, the new and revised algorithm was implemented, such that every patient underwent the same neurological evaluation in every suspected ischemic stroke case. Herein, we report our institution's development and implementation of a hospital-wide acute stroke algorithm to minimize treatment delays and expedite care. The current study objectives were to (1) describe the new stroke algorithm and revision process in detail (2) compare pre- and post-algorithm quality improvement (QI) metrics.

MATERIALS AND METHODS

VUMC is a 584-bed tertiary care center designated by the Joint Commission as a Comprehensive Stroke Center[22] for its ability to care for complex stroke patients. Below, we describe the updated stroke algorithm, and the process of change in addition to study methodology.

Creating a new algorithm: Process of change

Three goals guided the revision process, namely (1) comparing the algorithm to the heavily protocol based field of trauma care, (2) eliminating excessive point-of-care decision making, and (3) removing time delays. Each point is expanded below.

1. **Stroke trauma:** The field of trauma is replete with evidence-based algorithms. Examples of this include transfusion practices,[20,34,41] glucose management,[7,9,27,40] gunshot wounds,[1,28] and stab wounds.[5,6,50] By comparing stroke care to trauma practices, our goal was to reinforce a reproducible system, such that every stroke would be treated in an identical fashion. Each step, including admission, initial evaluation, labs, neurology exam, CT scan, tPA administration, and neurointervention was protocolized and made the same for each patient.
2. **Eliminate excessive point-of-care decision making:** The old algorithm contained several decision points. Eliminating such "on-the-fly" decisions would serve to minimize the influence of individual practitioner preferences. There would be no "if-then" choices; the same workup would ensue for every stroke patient. Furthermore, teams can work in parallel towards the next step once all parties are familiarized with the protocol.
3. **Remove time delays:** By gathering multiple departments together, it was possible to identify where the time delays were and how care could be expedited. Three examples are noted below:
    a. *Paging system.* In the prior system, when a patient was perceived to be a candidate for thrombectomy, the neurology team would have to determine which interventionalist was on call, manually page or call them, and wait for a response. In the new system, an updated stroke alert page went to all stakeholders,

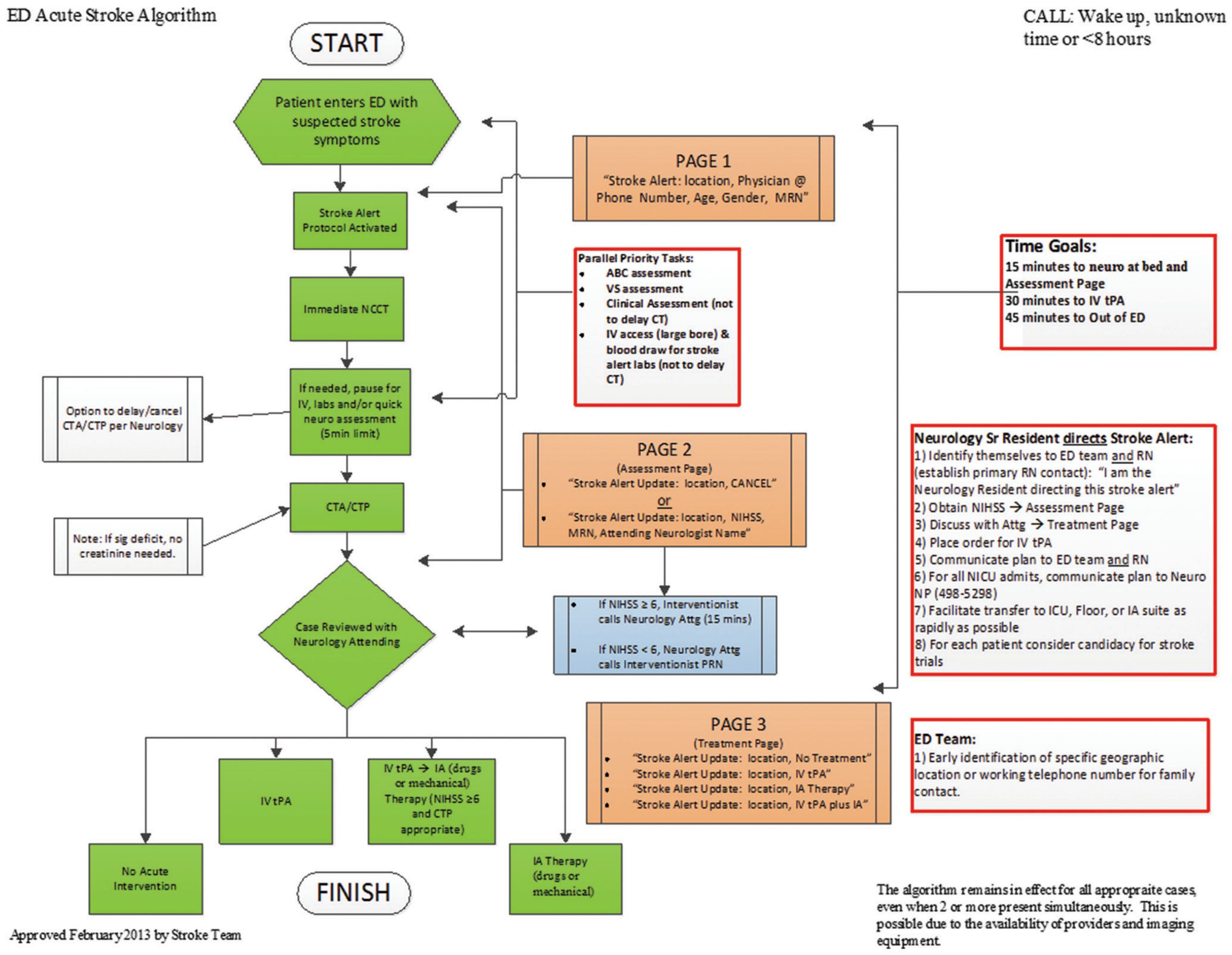
most importantly both the stroke neurologist and interventionalist. This allowed the stroke neurologist to focus on acute patient care while waiting for the interventionalist to call him/her directly.

b. *Decreasing antagonistic interactions*. Frustration had been expressed that, while there had long been a goal for rapid CT, there were physician variations with ED staff. Some staff insisted the patient remain in the room until a full exam was performed, while others wanted them rushed to CT. After discussion, the group decided that the primary goal after the code stroke was to transport the patient immediately to the CT scanner. Moreover, if neurology arrived and the patient was already in the CT scanner, there would be discord between radiology and neurology. Neurology would want to rapidly obtain an exam for IV tPA evaluation, however, radiology would not want to occupy their scanner indefinitely for a clinical exam. This was resolved by recognizing the urgency of the plain CT, and then agreeing to allow a 5-minute pause while the patient was on the CT scanner and allow for a rapid neurological assessment to identify potential IV tPA candidates.

c. *Limit CTA/CTP technicians*. VUMC previously rotated 36 CT technicians through all hospital scanners. This large volume of technicians resulted in limited exposure for each technician in performing the relatively specialized CTA and CTP scans. Limited technician experience created problems in the form of poor scan quality and inability to troubleshoot equipment problems. Though data does not exist to validate this change, halving the number of designated technicians theoretically increased experience, comfort level, speed, and study quality.

New algorithm

The current VUMC ED Stroke Algorithm is seen in Figure 1. The algorithm is triggered when a patient presents to the ED with the signs/symptoms of an acute stroke within the past 8 hours, upon waking, or if the patient was "found down" with stroke deficits of undetermined time of onset. The ED physician then



Time Goals:
15 minutes to neuro at bed and Assessment Page
30 minutes to IV tPA
45 minutes to Out of ED

Neurology Sr Resident directs Stroke Alert:
1) Identify themselves to ED team and RN (establish primary RN contact): "I am the Neurology Resident directing this stroke alert"
2) Obtain NIHSS → Assessment Page
3) Discuss with Attg → Treatment Page
4) Place order for IV tPA
5) Communicate plan to ED team and RN
6) For all NICU admits, communicate plan to Neuro NP (498-5298)
7) Facilitate transfer to ICU, Floor, or IA suite as rapidly as possible
8) For each patient consider candidacy for stroke trials

ED Team:
1) Early identification of specific geographic location or working telephone number for family contact.

The algorithm remains in effect for all appropraite cases, even when 2 or more present simultaneously. This is possible due to the availability of providers and imaging equipment

Approved February 2013 by Stroke Team

Figure 1: New stroke algorithm

activates a stroke alert by calling the communications center that sends out an initial stroke alert page (which includes the contact information of the individual triggering the stroke alert, the location of the patient and medical record number if known) to alert the first level team. The first level team, includes the ED Charge Nurse, ED Social Worker, Neuro ICU Charge Nurse, Neuro ICU Manager and Assistant Managers, Stroke Resident, Stroke Fellow, Stroke Attending, CT technicians in the ED, neuroradiologist, ED stat lab technician, and Stroke Coordinator. The interventional team is not alerted at this time, but includes the Stroke interventional fellow, Stroke interventional attending, OR radiology technicians, and the OR board.

While the team is being alerted, the nurse or paramedic in the ED brings the patient directly to the CT scanner for an immediate HCT to assess acute hemorrhage. While the patient is being loaded onto the CT table, critical labs are drawn including glucose and an iStat Chem 8+ basic metabolic panel (BMP) + Creatinine. The iStat offers data on renal function within 2 minutes, and the HCT and CTA head/neck may be performed in succession. During a 5-minute pause for software-driven image reconstruction, the neurology resident may perform an NIHSS evaluation and exam. Next, the CTP commences while the neurology resident contacts the communications center to send out an "Assessment Page" that includes the NIHSS, the patient's medical record number, and the name of the attending stroke neurologist. The resident then calls the stroke attending to discuss the results of the HCT. If the NIHSS is a 5 or less, there is no automatic notification to the interventional team and the stroke attending decides if the patient is IV tPA eligible. Should the stroke attending desire, he or she may also contact the interventional attending for discussion and input. If the NIHSS is a 6 or higher, the interventional attending calls the stroke attending, while the stroke attending focuses on direct care. The interventionalist is first notified by the mass page that has been sent. IV tPA is often not delayed for interventionalist/stroke neurologist discussions or review of advanced imaging (CTA, CTP) and may be pursued in addition to the consideration for intervention. The stroke resident then sends out a final page with the treatment or cancellation decision.

If there is a decision to start IV tPA, the stroke resident places the order in the computer while simultaneously giving a verbal order to the nurse to expedite the acquisition and infusion of IV tPA. If the patient is an intervention candidate, with or without IV tPA, the patient is transported to the interventional suite.

The algorithm has several efficiency-promoting features, the most important of which include uniform, consistent, stepwise algorithm progression. Figure 1 shows a linear path of green boxes, with six steps followed before any treatment decision is made. For each stroke patient, these 6 steps are followed.

Study design

The updated stroke algorithm was fully implemented in May 2012. Data was collected from four different time points, all comprising three-month periods. The first time point was January–March 2012, pre-stroke algorithm implementation. Only 3 months of pre-stroke data was available due to incomplete paper records. The subsequent three time points were all after stroke algorithm implementation; August–October 2012, January–March 2013, and September–November 2013. These specific time points were chosen due to availability of records as complete documentation was not available during the initial phases of algorithm implementation. Study participants included any patient suspected of having an ischemic stroke, which activated the stroke alert system. Patients excluded from the study were those <18 years old. Institutional review board approval was not required as this study fell under the purview of quality improvement and did not meet the criteria for research (IRB #140895).

Statistical analysis

Three QI data points were collected, namely, door to CT time (DTCT), door to neurology evaluation time (DTN), and door to IV tPA administration time (DTT). Though additional variables exist to evaluate acute stroke care, these were the variables previously collected by the institution, which was kept constant. All time points were treated as continuous variables, measured in minutes. Each post-algorithm implementation time period (August–October 2012, January–March 2013, and September–November 2013) was compared to the pre-algorithm implementation time period (January–March 2012).

Parametric data was presented as mean ± standard deviation and compared via the Student's *t*-test. A P value of <0.05 was considered statistically significant. Any missing data was handled using the available case approach, thus only full cases with data were used. The sample size for each QI measure floated. All statistical analysis was performed in STATA version 14 (College Station, TX: StataCorp LP).

RESULTS

All QI data is summarized in Table 1 and in graphic form in Figures 2-4. The total number of patients changed per each QI measure during each time period. Prior to stroke algorithm implementation, there were 81 code strokes evaluated for DTN compared to 71 DTCT. After the algorithm, there were higher numbers of DTCT time than DTN for each of the three post-algorithm time points. As stated earlier, only cases with complete

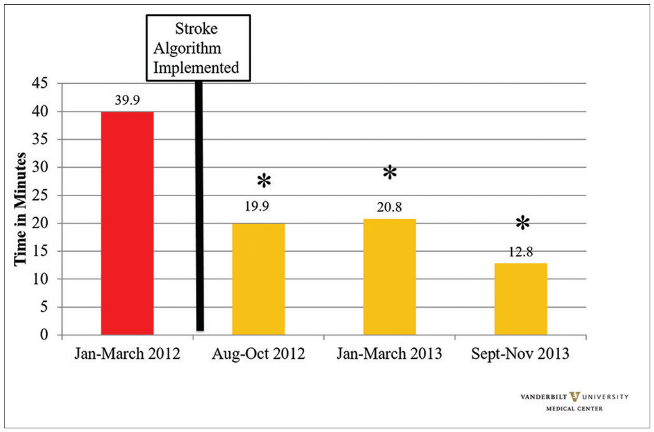


Figure 2: Time to CT

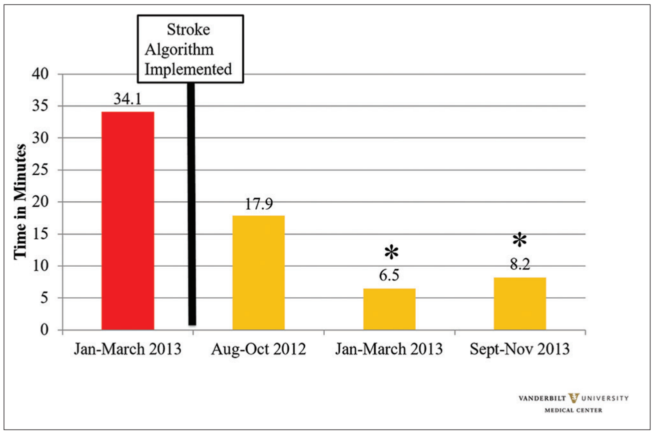


Figure 3: Time to neurologic evaluation

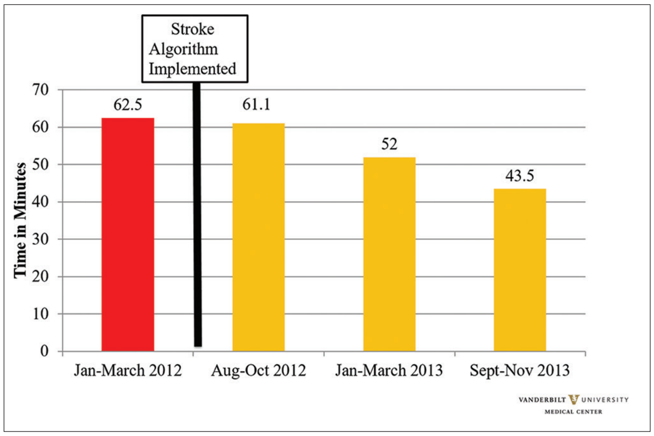


Figure 4: Time to IV tPA

data were analyzed. The sample size floated for each QI measure. Though the authors put forth their best effort to capture all data, some data was missing and could not be provided.

Door to computed tomography scan time (DTCT)

At each time point post-algorithm implementation, a significant decrease in DTCT was seen. Though a slight increase was seen from August–October 2012 (19.9 ± 28.8, $P = 0.019$) to January–March 2013 (20.8 ± 23.3, $P = 0.012$), this number dropped significantly in September–November 2013 (12.8 ± 20.0, $P < 0.001$). Each post-algorithm time period achieved statistical significance [Figure 2].

Door to neurology time (DTN)

At each time point post-algorithm implementation, except for the first data collection period, a significant decrease in DTN was seen. Though a non-statistically significant result was seen with a slight decrease in August–October 2012 (17.9 ± 25.0, $P = 0.054$), statistical significance was seen in the following 2 months where the time to neurology time plummeted in January–March 2013 (6.5 ± 8.9, $P < 0.001$) and September–November 2013 (8.2 ± 6.9, $P < 0.001$) [Figure 3].

Door to tPA time (DTT)

Despite significant findings seen in CT and neurology time, DTT did not achieve a level of statistical significance. The time to IV tPA dropped from 62.5 ± 44.9 min to 43.5 ± 21.5 minutes ($P = 0.169$). However, the goal time to DTT of 45 min was achieved [Figure 4].

DISCUSSION

Herein, we describe the revision and implementation of an acute stroke algorithm and report pre- and post-algorithm quality metrics. The intervention was a joint effort between multiple departments, physicians, nurses, and hospital staff to provide a unified, consistent method of assessment and treatment of suspected ischemic stroke patients. After algorithm implementation, a statistically significant decrease in several key quality metrics was observed.

In ischemic stroke, the correlation between earlier revascularization and improved outcomes has been well established.[12,18,26,39] The current study demonstrated a nearly 20-minute decrease in thrombolytic treatment times. Among 58,353 US patients receiving tPA, Saver *et al.*[46] demonstrated that, for every 15-min decrease in time to tPA, the odds of in-hospital mortality and symptomatic hemorrhage decreased, whereas the odds of ambulation at discharge and discharge home was increased.[46] The same has been shown with acute endovascular thrombectomy.[49] Spiotta *et al.* dichotomized 159 patients into early and late recanalization groups (≤60 min vs. >60 min), and found the likelihood of achieving a good outcome was higher in the early group compared with the late group (53.6% vs. 30.8%; $P = 0.009$). Below we review relevant studies showing improvement in stroke times after major QI changes.

Several institutional-wide stroke algorithms have gained traction in improving stroke outcome

Table 1: Pre- and post-stroke algorithm quality improvement data

	Jan-March 2012		Aug-Oct 2012	*P* (95% CI)	Jan-March 2013	*P* (95% CI)	Sept-Nov 2013	*P* (95% CI)
No. of Patients per QI measure	CT: 71 Neuro: 81 tPA: 13	New Stroke Algorithm Implemented May 2012	CT: 106 Neuro: 79 tPA: 15	NA	CT: 130 Neuro: 139 tPA: 11	NA	CT: 142 Neuro: 138 tPA: 14	NA
Door to CT (min), mean±SD	39.9±79.2		19.9±28.8	0.019* (3.3, 36.5)	20.8±23.3	0.012* (4.3, 33.7)	12.8±20.0	<0.001* (13.2, 40.9)
Door to Neurology (min), mean±SD	34.1±70.0		17.9±25.0	0.054 (−0.25, 32.7)	6.5±8.9	<0.001* (15.8, 39.4)	8.2±6.9	<0.001* (14.1, 37.7)
Door to tPA (min), mean±SD	62.5±44.9		61.1±28.2	0.925 (−27.3, 30.0)	52.0±22.6	0.491 (−20.5, 41.5)	43.5±21.5	0.169 (−8.6, 46.5)

**P* value is significant

metrics.[14,29,45,48,53] In the largest study to date, Fonarow *et al.*[14] compared 27,319 pre-intervention patients to 43,850 post-intervention patients across a national registry. The intervention consisted of 10 evidence-based care strategies to improve stroke reperfusion, including pre-notification by emergency services, a single stroke page, and rapid brain imaging, among others. Time to tPA, in-hospital mortality, discharge home, and symptomatic hemorrhage rates significantly improved according to the study's conclusion. Other regional studies have used similar techniques to improve stroke care in North Carolina,[43] New York,[17] Texas,[18] and internationally,[52] in addition to institutional reports linking streamlined care with improved stroke metrics, each with positive results.[15,21,30,32]

Several other QI interventions have been linked to improved time to treatment such as pre-notification by EMS,[29,31] a single code stroke activation system,[33] and point-of-care lab testing.[58] Tong *et al.*[54] reviewed a large stroke database covering 1,287 hospitals, and found that the time to treatment was positively associated with use of EMS, daytime stroke, and higher stroke severity. Van Schaik *et al.*[55] identified several independent factors in delay for door to needle time treatment including uncertainty about symptom onset, coagulation status, fluctuating neurological deficit, and incorrect triage in 1,756 patients. Recent studies have even introduced the novel concept of a mobile stroke unit, with imaging and thrombolysis achieved in the field.[2,10,11,57,59,60]

Interestingly, while our changes resulted in significant reductions in DTCT and DTN evaluation, there was a non-significant reduction in the DTT. Potential reasons for the non-significant reduction include pre-hospital delays and in-hospital delays, as outlined by Desai *et al.*[8] Pre-hospital delays include time to contacting EMS, history taking, and awareness of onset of stroke symptoms by patients and their family. In-hospital delays, which was the target of this study, includes factors such as obtaining imaging, patient history and physical, appropriate lab-work, and efficient communication of patient information among the team. In addition, IV tPA administration is often the final treatment in a stroke algorithm, with many successive steps before it. Although few things hinder a neurologist from obtaining a quick exam, it makes intuitive sense that the final step would be the most difficult to alter, where each prior step has the potential for delay. Another possible explanation, in reviewing the 10 key strategies recommended by the Target: Stroke initiative is delays in mixing tPA medication and setting up the bolus pump, prior to brain imaging, so that it is ready for delivery as soon as a decision is made.[13] Looking closely into these factors and implementing changes to lower these time periods may help in achieving significant reductions in DTTT.

Overall, the ischemic stroke community has seen an expansion in initiatives to expedite acute stroke care. Efforts have been made to improve time to imaging, neurologic evaluation, and intravenous or intra-arterial treatment. We have aimed to describe our institutional experience in detail for the benefit of other institutions. Only through successful collaboration, across departments, physicians, nurses, and hospital staff, can systems be improved and care of the acute stroke care be expedited.

The current study is not without limitation. First, this is a retrospective study of a prospectively maintained database. Because of the quality improvement nature of our study, we failed to collect demographic data of patients. Thus, race, gender, and age could not be accounted for in the statistical analysis. In addition, due to gaps in data collection, QI data was not available for all pre- and post-intervention months. Third, while we demonstrated improved quality metrics at the initial stroke evaluation, we did not collect long-term clinical outcomes including modified Rankin scores to determine what effect, if any, these improved metrics had on clinical outcome. Future direction of the study will be to include clinical outcomes, as well as include analysis of interventional therapies as these are an important adjunct to intravenous thrombolytics, are time sensitive, and subject to delays in initial acute stroke triage.

CONCLUSION

An institutional-wide acute stroke algorithm was successfully designed and implemented through a multi-disciplinary approach. After revision and implementation, significant lowering in the time for CT scan and neurology evaluation, and a non-significant improvement in time to IV tPA administration was seen. Future studies should focus on correlating individual patient factors with time parameters, in addition to long-term patient outcomes.

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Nil.

Conflicts of interest

The study was approved by Institutional Review Board (#140895).

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