Effectiveness of an Interdisciplinary, Nurse Driven In-Hospital Code Stroke Protocol on In-Patient Ischemic Stroke Recognition and Management

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Background: In-hospital strokes account for up to nearly 1 in 5 strokes. Clinical outcomes, such as length of stay, disability, and mortality are worse for in-hospital strokes than for those that occur in the community. For a variety of reasons, stroke can be more difficult to recognize and treat in hospitalized patients. Earlier recognition of stroke results in better clinical outcomes, presumably due to faster diagnosis and subsequently, prompt treatment. *Methods:* This investigation was a retrospective, interrupted time series, observational study of all in-hospital stroke patients between 2008 and 2017. This investigation was a quality improvement project, and a waiver was granted from the institutional review board. We used Lean methodologies to standardize our stroke protocol and optimize skill-task alignment to improve the time from onset of symptoms to brain imaging (primary outcome). *Results:* Overall, we observed significant improvement in the time from onset of symptoms to brain imaging from a median of 69 minutes to 37 minutes (P = .002). *Conclusions:* If successfully implemented, this approach may be useful in other care settings with potential to improve stroke outcomes, and decrease associated complications of stroke.

Keywords: Stroke—quality improvement—lean methods—nursing team—rapid response team

Introduction

Up to 17% of all strokes occur in patients originally hospitalized for another diagnosis or procedure, and in-hospital strokes complicate between .04% and .06% of all admissions.[1,2] These in-hospital strokes are associated with higher mortality, longer length of stay, and greater disability than community-onset strokes.[3,4] As of 2015, the 30 day total cost of care for an in hospital stroke patient was $17,500.[1,2]

Multiple factors contribute to the high frequency and worsened outcomes of in-hospital stroke. Nonmodifiable factors include increased comorbidities of hospitalized patients, as well as a higher rate of contraindications to thrombolytic therapy. Higher incidence of stroke may be explained by increased thromboembolic events due to hypercoagulability induced by comorbid illness or surgery. Risk is further compounded by withdrawal of antithrombotic or anticoagulant therapy when the patient is admitted for a bleeding event, unable to take oral medications, or is at risk of bleeding due to necessary invasive procedures or other risk factors.[5]

Modifiable factors include delay in stroke recognition,[6–8] which can prevent the timely administration tissue of plasminogen activator (tPA) or endovascular therapy for otherwise suitable candidates.[9–11] Rapid identification of stroke in-hospital is difficult due to conditions that mimic stroke and the prevalence of delirium, which can render patients unable to self-report.[12,13] Furthermore,

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physicians, procedural personnel and equipment, including the CT scanner may be at some distance from the patient, and transportation of hospital patients can be challenging.[14,15] In 2010, a study in a single large hospital demonstrated time from symptoms to imaging to be 98 minutes in hospital versus 29 minutes in community onset stroke.[1] In the statewide Michigan Stroke Registry study, only 3.1% of patients with in-hospital strokes received brain imaging within the benchmark 25 minutes from symptom recognition.[4] In the American Heart Association/American Stroke Association national Get-With-The-Guidelines database, time to treatment for in-hospital strokes averaged 100 minutes, with only 1 in 5 patients achieving the goal of 60 minutes from symptoms recognition to treatment.[16]

Between December 2012 and July 2015, our institution undertook a series of improvement efforts built around 2 Lean kaizen events designed to improve the rapidity of diagnosis of inpatients with ischemic stroke through development of a Code Stroke process. The principles underlying the Code Stroke were to standardize early stroke care and to optimize skill-task alignment, empowering front line nurses to identify stroke and initiate care. The first Kaizen event focused on rapid identification of stroke symptoms, the creation of a standardized order set with a care protocol, as well as mutually agreed upon roles and responsibilities of various providers during the Code Stroke. With these measures in place, the second event led to empowerment of nurses to not only initiate the Code Stroke, but to place orders for imaging. The objective of this investigation was to determine the effectiveness of the Code Stroke process in improving the time to recognition and diagnosis of in-hospital strokes.

Methods

This investigation was a retrospective, interrupted time series, observational study of all in-hospital stroke patients between 2008 and 2017. This investigation was a quality improvement project and a waiver was granted from the institutional review board. The interventions were designed, tested, and implemented at a single, 336 bed, urban, and tertiary acute care hospital in the Pacific Northwest with approximately 470 physicians and 17,000 admissions annually. The organization uses Lean methodology as its structure for daily management and quality improvement. The primary outcome measure was time from onset of stroke symptoms to diagnostic brain imaging.

Intervention

The initial quality improvement event occurred 12/10/2012. Quality improvement Kaizen events at our institution follow a standard format. Teams of 4-8 individuals are assembled from representatives of the involved clinical areas, including leadership, as well as individuals who perform the daily work. Together, the Kaizen team goes through a brief educational program on how to do quality improvement, maps out the process to be improved, generates ideas, develops potential solutions, and tests of solutions through plan-do-study-act cycles at the actual clinical work site. These activities are all supported by an experienced team leader, and a set of standardized Lean improvement tools. The final improvement intervention is then rolled out to all sites over the following 30 days.[17]

All in-patient nurses received initial training on recognition of stroke, specifically facial droop, arm/leg weakness and speech changes, commonly referred to as the FAS symptoms. In the event of a positive FAS finding, the bedside nurse could make a single call for Rapid Response Team. Subsequently, the Rapid Response Team could then escalate to an in-house Code Stroke. The Rapid Response Team existed prior to this intervention, but the deliberate escalation to Code Stroke was novel. Triggered by a single call, the initiation of Code Stroke prompted pages to designated practitioners in neurology, diagnostic radiology, interventional radiology, hospital medicine, nursing, and pharmacy. The Code Stroke process was revisited at the second improvement event on 7/9/2015. At this point, critical care nurses (rather than physicians) were designated as the primary responders for the Rapid Response Team, and were given further specialized training in FAS stroke recognition. For Code Stroke patients with FAS symptoms, critical care nurses were granted autonomy to order noncontrast head CTs and CT angiograms, contact the neurologist directly, order blood work, and transport the patient to the CT scanner, all prior to physician involvement. Training and full implementation continued through 8/16/2016.

Data Collection

We identified in-hospital stroke patients from billing data using ICD9/10 codes and stroke code pager logs. Subjects were included if they had a length of stay of greater than 4 days (to exclude patients who arrived with stroke), and had a head CT or MRI study. All patient charts were reviewed, and subjects excluded if the final discharge diagnosis was other than ischemic stroke (transient ischemic attack, subarachnoid hemorrhage, encephalopathy etc.), or if stroke symptoms were present on admission.

For the purposes of this study, we defined FAS symptoms as facial droop/weakness, unilateral weakness (arm or leg), and/or speech change (aphasia or dysarthria) in accordance with American Heart Association guidelines. Because nurse training did not include recognition of non-FAS symptoms, patients who presented with only altered mental status, balance disorder, paralysis of the entire body, reduced sensation, or other non-FAS presentation were excluded.

Care process variables were obtained through manual chart review by 1 of 2 chart reviewers. These included:

symptom onset, time last seen well, Code Stroke, or Rapid Response Team call, as well as the time of initial CT/MRI imaging, time of tPA administration, and interventional radiology procedure start times. Additional patient data included: discoverer of the stroke symptoms (nurse, family, physician, and other), and any surgery or use of anticoagulants prior to onset of stroke symptoms. Since there were multiple possible sources of this data in the medical record, we used a formal hierarchy of documentation sources to improve data reliability. Ten percent of charts were reviewed jointly by the 2 reviewers to assess interobserver reliability. Documentation for the time of imaging was consistent and readily obtained for the duration of the study. In contrast, details of the onset of stroke symptoms were not consistently documented early on, but were standardized and became more consistent over the course of the study. Our reviewers were in 100% agreement for the time of imaging and in 80% agreement for the time of the onset of symptoms. All but one of the discrepancies in time of symptom onset occurred in 2009 or earlier, prior to any intervention. There was one disagreement for a case in July of 2014, postintervention 1, but before intervention 2. After this date, reviewers were in agreement for both time of stroke symptom onset and imaging.

Data Analysis

For analysis, we defined 3 time periods: preintervention period from 1/1/2008 to 12/10/2012, postintervention 1 period from 12/11/2012 to 7/9/2015, and a postintervention 2 period from 7/10/2015 to 12/31/2017. The primary analysis was comparing pre to postintervention 2 using Student's *t*test for the mean of continuous variables, Two-sample Wilcoxon rank-sum (Mann-Whitney) test for the median of continuous variables and chi-square for dichotomous variables. Median time to imaging, as opposed to the mean, was analyzed because the data is highly skewed. The skew is due to most of the imaging occurring in a relatively rapid time frame, but with a few delayed imaging outliers. The use the nonparametric Wilcoxon rank-sum statistic prevents these outliers from having too great an influence on the results. In addition, we analyzed the median time data graphically using box plots and time series run charts. All analysis were performed using STATA v.12.0 (College Station, TX).

Results

The study sample included 124 patients who experienced in-hospital stroke. During the 10-year study period, we observed no statistically significant change in age, gender, proportion of surgical patients, discharge diagnoses, rates of ischemic heart disease, or number of days until stroke (Table 1).

The proportion of strokes identified by the nurse (rather than family or another provider) increased over the study period from 56% (29 of 52) preintervention to 79% (23 of 29) postintervention 2 ($P < .001$). Likewise, the proportion of stroke patients with a Rapid Response or Code Stroke call increased from 43% (23 of 53) preintervention to 83% (29 of 35) postintervention 2 ($P < .001$) (Table 2). In an audit of the Code Stroke pages, we determined that 37% of pages (23 of 63) were confirmed strokes, with an additional 25% (16 of 63) other neurologic issues, such as seizure and delirium, which lead to immediate changes in management.

The primary outcome of time from symptom onset to imaging improved between the pre- and postintervention 2 periods, from a median of 68 minutes to 37 minutes ($P = .002$) (Table 2), corresponding to the times of the interventions (Fig 1). The median time from initial Code Stroke or Rapid Response to imaging also improved from 32 minutes to 17 minutes ($P < .001$). Of note, during the postintervention 1 period, this time was lower, at 11 minutes. The improvement from 32 minutes to 11 minutes

Table 1. *Patient characteristics, N = 124*

	Preintervention 01/01/2008-12/09/2012	Postintervention 1 12/10/2012-07/09/2015	Postintervention 2 07/10/2015-12/30/2017	Sig *P* (pre versus post)
Patients, number	53	36	35	
Age, mean (SD)	73 (11)	73 (11)	78 (11)	.06
Sex, female (%)	32 (61)	16 (44)	17 (49)	.28
Patient type				.13
Inpatient medical	36 (68)	24 (67)	20 (57)	
Inpatient surgical	14 (26)	12 (33)	15 (43)	
Other	3 (6)	0 (0)	0 (0)	
Any surgery (%)	35 (66)	23 (64)	24 (69)	.81
LOS, mean (SD)	13 (8)	12 (7)	19 (29)	.90
Ischemic heart disease*	9 (17)	8 (22)	10 (29)	.20
Admit to stroke symptoms, days (SD)	4.5 (4.2)	3.3 (3.0)	4.4 (5.5)	.91

*Heart disease is defined as ICD = 410, 411, 412, 413, 414, I20, I21, I22, I23, I24, I25.

Table 2. *Clinical outcomes*

	Preintervention 01/01/2008-12/09/2012	Postintervention 1 12/10/2012-07/09/2015	Postintervention 2 07/10/2015-12/30/2017	Sig P (pre- versus post-2)
Number patients	53	36	35	
Strokes identified by a nurse (%)	29 (56)	22 (48)	23 (79)	<.001
Code stroke called, number (%)	23 (43)	11 (31)	29 (83)	<.001
Imaging				
Means (SD)				
Symptoms to imaging min	360 (620)	374 (686)	97 (186)	.017
Code stroke to imaging min	33 (16) N = 23	13 (8) N = 11	22 (32) N = 29	.16
Medians (25,75 quartiles)				
Symptoms to imaging min	68 (40,323)	71 (37, 267)	37 (22,84)	.002*
Code stroke to imaging min	32 (22,40) N = 23	11 (7,19) N = 11	17 (11,23) N = 29	<.001*
Symptoms to imaging < 25 min (%)	5 (9)	4 (11)	9 (26)	.041
Symptoms to imaging < 60 min (%)	23 (43)	16 (44)	24 (69)	.020
Treatment				
tPA or endovascular, number (%)	7 (13)	4 (11)	7 (20)	.39
tPA, number (%)	6 (11)	2 (6)	4 (11)	.99
Endovascular, number (%)	3 (6)	3 (8)	4 (11)	.33

*Two-sample Wilcoxon rank-sum (Mann-Whitney) test.

was after the standardized order set and Code Stroke protocol were operationalized. The subsequent increase from 11 minutes to 17 minutes occurred after the transition from a single FAS positive assessment by the bedside nurse to include a confirmatory FAS positive assessment by the critical care nurse required to order imaging. The increase is most probably due to the time required for the critical care nurse to perform the confirmatory exam.

Run chart with a median time value charted for every 6 months. The 6-month interval was used due to the small number of events, yielding a minimum of 3 events per interval (2012, first half) and a maximum of 11 events in an interval (2013, first half). The dates of the first (12/10/2012) and second (7/10/2015) Lean improvement events are indicated with arrows. The dates 2/8/2016 and 8/16/2016 mark the beginning and completion of training for the nurses.

Figure 2 shows the median and range in the imaging times in the different time periods, through a box and whisker plot. In addition to the decrease in median (and mean), the range of imaging times decreased over the length of the study.

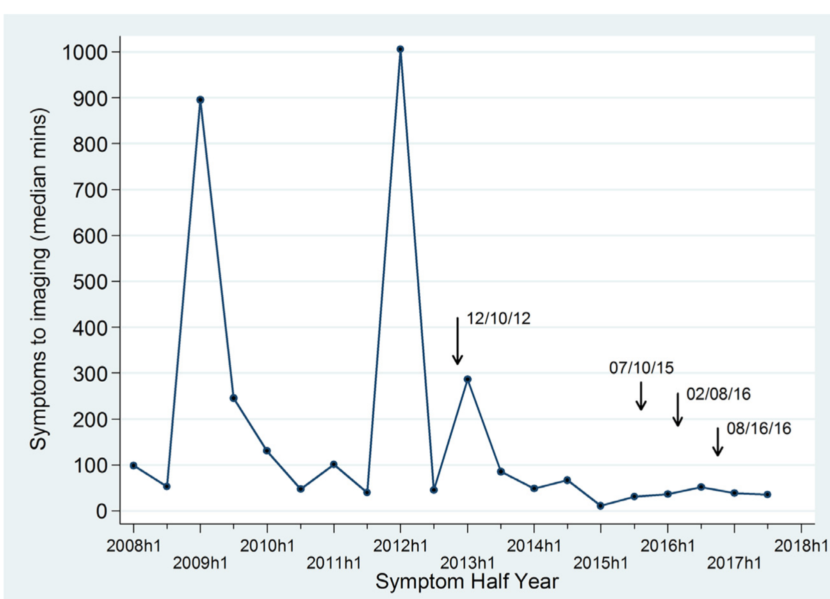

Figure 1. *Run chart, time elapsed (minutes) from symptoms to imaging.*

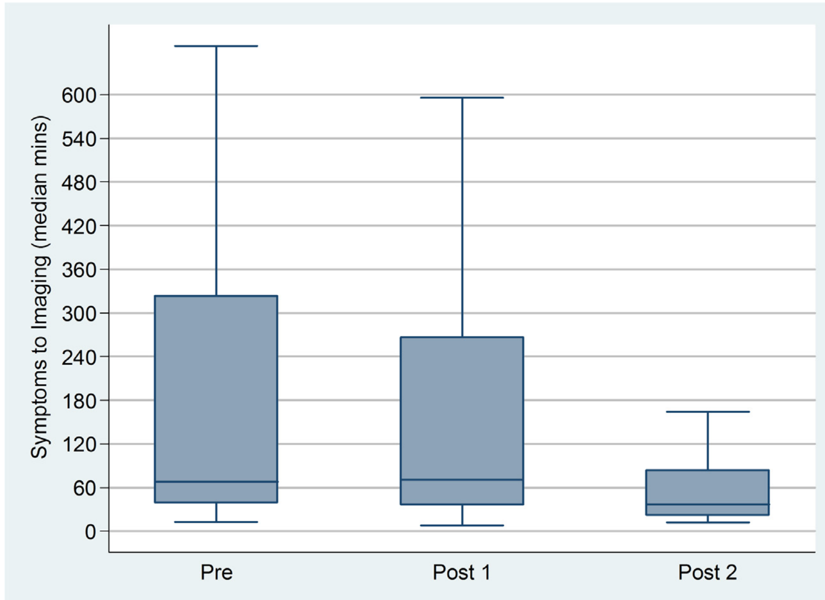

Figure 2. *Box plot, time elapsed (minutes) from symptoms to imaging.*

Box plot with median line at the 50th percentile, and shaded area between 25th and 75th percentiles for preintervention (01/01/2008-12/09/2012), postintervention 1 (12/10/2012-7/9/2015) and postintervention 2 (7/10/2015-12/30/2017) periods. The lines extending from the shaded box (whiskers) are adjacent values as defined by Tukey's interval. These boundaries represent values that are the highest and lowest, but not outlier or extreme values.

Discussion

The implementation of a nurse driven Code Stroke process for hospitalized patients with symptoms of acute stroke was associated with substantial improvement in the time from onset of symptoms to brain imaging from a median of 68 minutes to 37 minutes.

Lessons Learned

Rapid diagnosis and treatment of stroke are widely recognized as critical to functional outcomes.[9] However, timely stroke care in hospitalized patients is challenging. The Code Stroke interventions were designed to mitigate these challenges through standardizing care and empowerment of nurses. Bedside nurses spend the most time with hospitalized patients, so are the most appropriate to initiate the Code Stroke. Given that brain imaging is essential to establish a diagnosis of stroke, and since a noncontrast head CT is a relatively low risk procedure, it makes sense to leverage the first responder, the critical care nurse, to use the standardized order set to order imaging prior to physician involvement. Similar nurse initiated protocols have been successfully used in other conditions.[18] At some institutions, if a patient meets criteria for sepsis, nurses may initiate immediate interventions, including fluid administration and drawing of blood cultures. This approach has been associated with decreases in sepsis mortality, with concordant improvements in process measures including time to fluid and antibiotic administration.[19] This report is the first we are aware of that empowers nurses to initiate care, including imaging, for in-hospital stroke patients.

Given the low positive predictive value of the Code Stroke process (37%) observed in our study, resource utilization may be of concern. This is consistent with observations made in a similar study where improvement in the time from symptom onset to brain imaging came at the expense of the rate of false positives.[20] In some settings, the FAS exam has been found to have a sensitivity of 85% and a specificity of 68% to identify acute stroke and transient ischemic attack.[21] This translates to a positive predictive value of 73%, which might be attainable with further training and experience. Despite this gap, a 2014 cost-effectiveness analysis concluded that of all interventions studied, those that increased thrombolysis rates in acute stroke were cost-effective because of the major reduction of costs of dependency and long-term care after stroke. Specifically, the greatest cost savings were observed in interventions aimed at better recognition of stroke symptoms and recording of onset times.[22] The decrease in time to imaging and increased rate of stroke symptoms recognized by nursing in our study suggests that our interventions may also be cost-effective, though formal analysis is outside of the scope of this paper.

Similar improvement work has shown gains in speed of recognition of stroke symptoms and expediting treatment, but most of the research has focused on patients who present to the emergency department with stroke symptoms. Given the challenges of identifying and treating stroke in the hospital, and the worse clinical outcomes, there is a need for a specialized attention to expediting identification and treatment of hospitalized patients with strokes. In one small study (n = 38) of a physician driven Code Stroke process for hospitalized patients, time from symptom onset to CT scan was improved to 74 minutes.[20] In another small study (n = 70) of hospitalized patients who had a stroke, a Code Stroke protocol improved time to imaging (41 minutes) for cardiology and cardiovascular surgery patients, but those results were not significant in other patients at the same institution.[9] Our patient population is the largest studied to date, and was diverse, including both medical patients and surgical patients on all medical-surgical wards. Our approach is practical in that we leverage our inpatient nurses to quickly identify symptoms and unique because it enables our rapid response critical care nurses to enter initial clinical orders without physician oversight. These features are critical because, unlike in emergency departments, hospital physicians are not always located on the same unit as their patients.

Limitations

This work originates from a single institution, with a culture focused on Lean methodology and quality improvement, so the results may not be directly transferable to other institutions. We acknowledge that many hospital systems cannot support a team of stroke trained neurologists available in house 24 hours a day 7 days a week. However, we believe that the basic framework for the Code Stroke, and the approach to implementation should be broadly applicable and adaptable to different settings. For example, perhaps coupled with telemedicine, the nurse driven Code Stroke protocol is potentially a practical and effective solution for earlier in-hospital stroke recognition and treatment for such institutions. In other words, in Lean or any other improvement framework, institutions can adapt the concept of nurse initiated stroke care that we present to meet the needs of the specific clinical and quality improvement milieu.

The analysis is retrospective and uncontrolled. We do provide a detailed description of the interventions and the timeline in effort to demonstrate the temporal relationship between the Code Stroke implementation and the identified process improvements. However, we are not able to differentiate the relative contributions of each element of the Code Stroke protocol.

Symptom onset time was a critical variable for this study because it served as a starting time for measurement time to code stroke, CT and intervention. However, it was challenging to find the appropriate documentation prior to the intervention since an educational gap around the documentation of symptom onset time existed prior to our first intervention in 2012. In our observation, the quality of documentation increased steadily from 2008 to 2017.

We were not able to consider time to treatment as a primary outcome variable due to a small sample size and because the recommended treatment windows changed during the course of the study as new evidence became available. Recently, the DEFUSE 3 and DAWN trials demonstrated that, in some patients, there is benefit to endovascular therapy relative to standard therapy as far out as 16 to 24 hours respectively.[23,24] Thus, we would expect the proportion of eligible patients and the time to such interventions to increase, contrary to the decrease in time to treatment that we would anticipate with our intervention.

Another limitation is that the Code Stroke intervention was designed around FAS symptoms. There were 15 in-hospital stroke patients at our institution who did not present with FAS symptoms and were therefore excluded from this study. In 2018, nurse and physician training was updated to follow BE-FAST criteria. This covers the posterior circulation stroke symptoms balance and eyesight issues not previously covered by the FAST evaluation. This means that there are potentially more patients who might benefit from the implementation of this protocol.

Conclusions

A nurse initiated, standardized Code Stroke protocol that allows nurses to order imaging, blood draws and initiate neurology consultation prior to physician involvement was associated with improved time to imaging in hospitalized patients with acute stroke. If successfully implemented, there is potential to speed treatment and therefore improve stroke outcomes, and decrease associated complications.

Conflict of Interest

The authors report no conflicts of interest related to this work.

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