An Innovative, Multidisciplinary, Process-Driven Approach to Acute Stroke in a Community Health System Network

Richard D Fessler, MD,[1] Chiu Yuen To, DO,[2] Vickie Gordon, NP-C, PhD,[3] Carrie Stover, MSN, NP-C,[4] Robert Dunne, MD[5]

[1]Department of Surgery, St. John Hospital and Medical Center; [2]Department of Surgery, Division of Neurosurgery, Providence Hospital and Medical Center; [3]Department of Neuroscience, St. John Providence Health System; [4]Van Elslander Neuroscience Center of Excellence, St. John Providence Health System; [5]Department of Emergency Medicine, St. John Hospital and Medical Center, Detroit, MI

Stroke is one of the major causes of death and disability in the United States, yet it is undertreated by many major medical centers across the country. Timely recognition and treatment of acute ischemic stroke remains a challenge due to confusing clinical presentations, hospital logistics, communication barriers among providers, and lack of standardized treatment algorithms. By creating a system-wide Code Stroke protocol, St. John Providence Health System improved documentation, increased intravenous tissue plasminogen activator delivery, reduced specialist call-back times, improved door-to-computer tomography scan and door-to-needle time, and identified appropriate patients for endovascular therapy.

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KEY WORDS

Code Stroke • Algorithm • Stroke triage • Stroke Alert

Stroke is a leading cause of mortality among developed countries, accounting for 15 million deaths worldwide each year.[1] In the United States, it is the fourth leading cause of death and the number one cause of adult disability. An estimated 6.8 million Americans over the age of 20 have had a stroke, comprising 2.8% of the population.[2] Approximately 795,000 people have a new or recurrent stroke yearly in the United States, out of whom 134,000 (17%) are likely to die.[1-3] Stroke accounted for approximately 134,000 deaths in 2008.[4,5] On average, someone has a stroke every 40 seconds and someone dies of a stroke every 3.1 minutes[1,2]; among all patients with a transient ischemic attack, 12% will die within 1 year due to stroke or related causes.[6] Meta-analyses of cohorts of patients

have shown the short-term risk of stroke after transient ischemic attack to be between 3% and 10% at 2 days and between 9% and 17% at 90 days.[2,7,8] Immediate care of stroke patients accounted for $28.3 billion in direct medical expenses[9] and $53.9 billion in indirect medical expenses in 2008.[3] More than half of the total cost of caring for a stroke patient accrues 3 years after the initial stroke occurs.[3]

In 2003, the Joint Commission established criteria for the designation of Primary Stroke Centers. These sites meet specific requirements for the delivery of treatment to this vulnerable population.[10] St. John Providence Health System (SJPHS) has established three Primary Stroke Centers with five campuses in Southeast Michigan that are accredited by the Joint Commission. Members of the stroke team at each hospital campus met on a weekly basis to review process issues and developed a system-wide Code Stroke protocol. All stroke team members maintain National Institutes of Health Stroke Scale (NIHSS) certification and participate in yearly mock Code Stroke drills to assess and refresh their skill sets. The three Primary Stroke Centers offer a comprehensive, multispecialty team approach that has improved stroke treatment. Quantified patient outcomes clearly demonstrate these improvements and indicate that utilizing a system-wide Code Stroke protocol can result in highly effective and efficient care.

At SJPHS, the stroke response process is known as Code Stroke*. When a patient presents with stroke symptoms to an SJPHS emergency department, a streamlined fully accountable process is initiated.*

The Code Stroke Process

At SJPHS, the stroke response process is known as *Code Stroke*. When a patient presents with stroke symptoms to an SJPHS emergency department (ED), a streamlined fully accountable process is initiated (Figure 1). This protocol is set in motion if the patient presents within 8 hours of stroke symptom onset or if the time of onset is unknown. The initial assessment is completed within 5 minutes when emergency medical services (EMS) or triage in the ED identifies a patient as having stroke-like symptoms. Those who meet the criteria for an acute stroke are placed in a high acuity ED bed. Within 10 minutes, the ED physician evaluates the patient, confirms stroke symptoms, generates an NIHSS score, and readies the patient for a computed tomography (CT) scan. The Stroke Alert protocol is activated by the 15-minute mark.

Once the Stroke Alert is activated, an automated alert is sent to the on-call stroke neurologist, neuroendovascular surgeon, CT technician, radiologist, ED operational manager, and bed coordinator. During minutes 16 to 45, CT brain and CT perfusion (CTP) studies are performed and a final radiologist read is called in to the ED physician. The Code Stroke process includes CTP studies on all acute stroke patients in order to identify those who are potential candidates for neurointervention. CTP also assists with clinical decision making for patients with unclear signs and symptoms despite a relatively low NIHSS. When performed at the same time as an initial CT, a CTP study adds minimal scanning time and does not have a significant impact on tissue plasminogen activator (tPA) delivery time. Once the studies are completed, the ED physician, neurologist, and neuroendovascular surgeon confer and reach a consensus on a treatment recommendation which may include intravenous (IV) tPA/alteplase, neuroendovascular treatment versus conservative treatment, or potential randomization into a clinical trial if indicated.

The key component to the Code Stroke process at SJPHS is the Stroke Alert packet, which is placed on all charts in ED triage when a possible stroke patient has been identified. The Stroke Alert packet contains the Recommended Time Line (Figure 1), which is also replicated within the electronic health record, an informational handout for patients and families, and a Reference Sheet for Health Care Providers (Figure 2), providing talking points relative to the risk and benefit of IV tPA delivery. The packet also includes an IV tPA inclusion/exclusion criteria checklist (Figure 3), a worksheet for the NIHSS, an IV tPA dosing chart, an algorithm for management of intracranial hemorrhage following thrombolytic therapy (Figure 4), and an order set for intracranial hemorrhage following initiation of thrombolytic therapy (Figure 5).

Quality Assurance

Depending on volume, multidisciplinary quality assurance meetings are held on a weekly, biweekly, or monthly basis at each SJPHS hospital to evaluate all Code Stroke activations in terms of timeliness of assessment and treatment, and to conduct a review of any complications. These evaluations allow for the identification of trends and provide continuous opportunities for improvement. Physician representatives from the four service areas (neurology, emergency medicine, radiology, and endovascular neurosurgery) meet to address care and logistical issues internally. Multiple ancillary specialties are represented, including radiograph

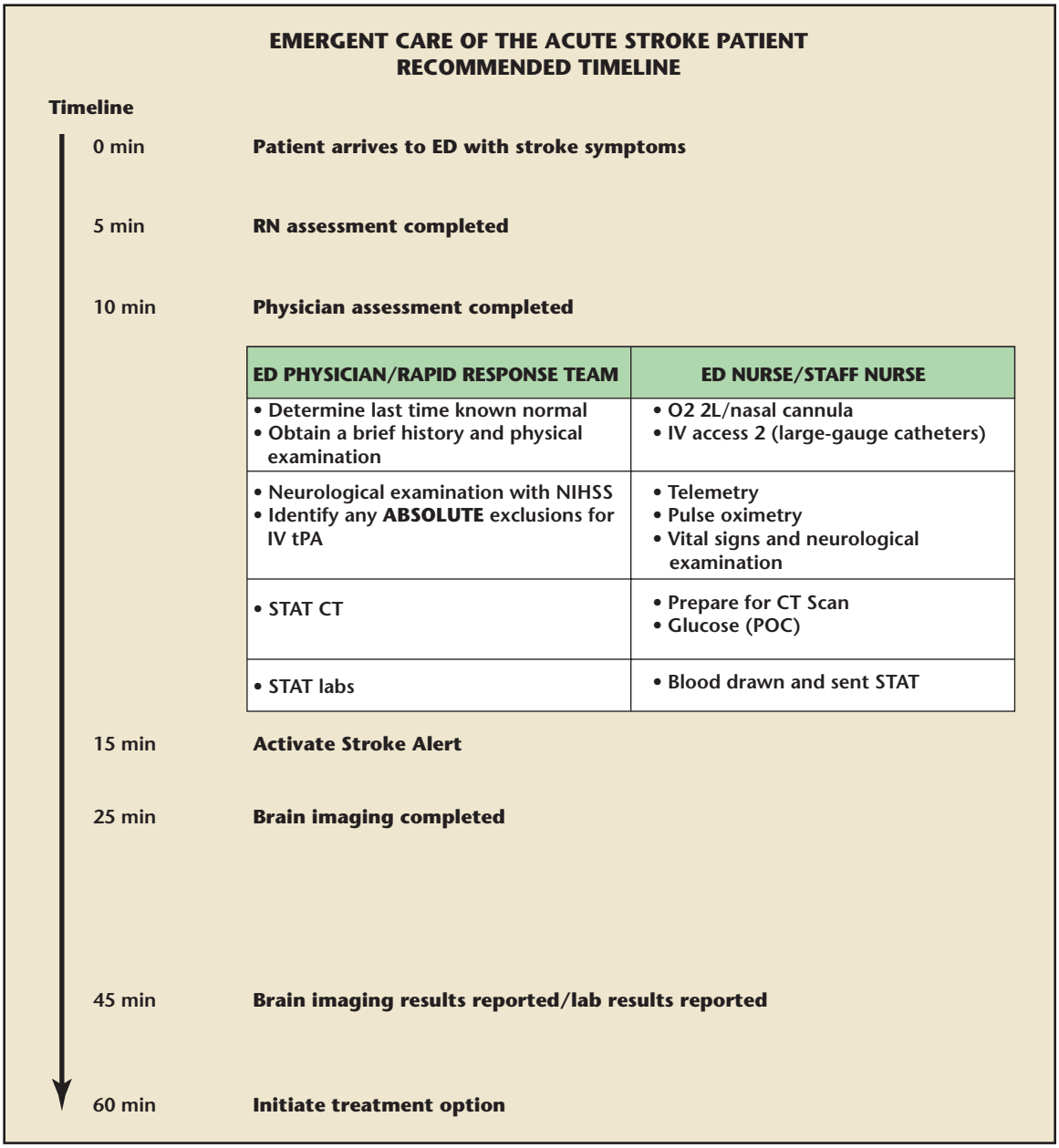

Figure 1. Recommended time line for Code Stroke Alert. CT, computed tomography; ED, Emergency Department; IV, intravenous; POC, point of care; RN, registered nurse; STAT, immediate; tPA, tissue plasminogen activator.

technicians, CT technicians, stroke team members, and quality assurance personnel. Figure 6 depicts a typical worksheet and data points, which are utilized to evaluate the process and assign accountability. ED physicians, rapid response team members, neurologists, neuroendovascular surgeons, and radiologists are provided with benchmarks for response times, treatment rates, and outcomes.

The Code Stroke program at SJPHS was initiated in mid-2009. Figure 7A shows IV tPA administration rates from 2005 to 2011. Figure 7B shows all patients discharged with a diagnosis of stroke over the same time period. The graph shows an improvement in IV tPA administration at one of the hospital sites from $< 2\%$ to $> 10\%$ during the 3 years following initiation of the program.

Quality Metrics for Improving Code Stroke

During the multidisciplinary quality assurance meetings, physician response times, NIHSS documentation, tPA treatment or reason for nontreatment, endovascular candidates, CT times, and radiology read times were reviewed. The SJPHS team made several improvements to improve these metrics, as follows.

Figure 2. Reference sheet for healthcare providers. CT, computed tomography; ICH, intracerebral hemorrhage; LOC, level of consciousness; mRS, modified Rankin scale; NIHSS, National Institutes of Health Stroke Scale; PT, prothrombin time; PTT, partial thromboplastin time; tPA, tissue plasminogen activator.

REFERENCE SHEET FOR HEALTH CARE PROVIDERS

Benefit of tPA	Benefit of No tPA
Less than 3 hours tPA (alteplase) 17% – Normal at 24 hours 31% – Normal at 3 months 20% – Less chance of moderate to severe disability or death	**Less than 3 hours no tPA (alteplase)** 3% – Normal at 24 hours 20% – Normal at 3 months
3 to 4.5 hours* tPA (alteplase) 52% – Normal at 3 months (mRS 0-1) 28% – Chances of returning to an independent lifestyle compared with no tPA	**3 to 4.5 hours no tPA (alteplase)** 45% – Normal at 3 months (mRS 0-1)
Risk of tPA	**Risk of No tPA**
Less than 3 hours tPA (alteplase) 17% – Mortality 40% – Severe Disability or Death 17% – Deterioration within 36 hours 6.4% – Symptomatic ICH	**Less than 3 hours no tPA (alteplase)** 21% – Mortality 48% – Severe Disability or Death 18% – Deterioration within 36 hours 0.6% – Symptomatic ICH
3 to 4.5 hours* tPA (alteplase) 7.7% – Mortality 7.9% – Symptomatic ICH	**3 to 4.5 hours no tPA (alteplase)** 8.4% – Mortality 3.5% – Symptomatic ICH
*This does not extend the treatment window for acute stroke. Early treatment remains essential. Treatment with alteplase (tPA) within the first 1.5 hours after onset of stroke doubles the efficacy compared to 1.5–3 hours after onset. For 1 patient to have a favorable ourcome (mRS 0-1) after 3 hours, 14 patients will require treatment.	
Frequency of ICH by Baseline NIHSS Score With tPA Treatment	
NIHSS 0-5 2% – ICH NIHSS 6-10 3% – ICH NIHSS 11-15 5% – ICH NIHSS 16-20 4% – ICH NIHSS > 20 17% – ICH	Note: Patients with NIHSS greater than 20 return to normal more frequently with tPA; the rate of death or severe disability is still high (65-70%) either way.
Intracerebral Hemorrhage	
Symptoms ICH	– NIHSS decrease in LOC (1a) ≥ 1 – Increase in NIHSS ≥ 4 – Acute hypertension – Nausea – Vomiting – New headache
If you suspect ICH	– Discontinue tPA (alteplase) – Obtain stat CT – Draw blood for PT, PTT, fibrinogen, type, and screen – Prepare cryoprecipitate 5-8 U – Prepare platelets 6-8 U – Fresh frozen plasma 5-8 U
ICH verified on CT	– Obtain lab results – Stat neurosurgery consult – Consider cryoprecipitate and platelets – Consider hematology consult – Consider second CT to assess ICH progress

Figure 3. Intravenous tissue plasminogen activator inclusion/exclusion criteria checklist. BGM, blood glucose monitoring; CT, computed tomography; ICH, intracerebral hemorrhage; IV, intravenous; GI, gastrointestinal; GU, genitourinary; NIHSS, National Institutes of Health Stroke Scale; tPA, tissue plasminogen activator.

CONSIDERATION FOR INTRAVENOUS THROMBOLYTICS
IV tPA INCLUSION/EXCLUSION CHECKLIST

YES	NO	INCLUSION CRITERIA
		Onset of symptoms ≤ 4.5 hrs (270 min) prior to treatment
		Age ≥ 18 years
		Clinical diagnosis of stroke with measurable deficit

YES	NO	ABSOLUTE EXCLUSION CRITERIA
		Evidence of intracerebral hemorrhage on pretreatment CT head
		CT findings of infarct > 1/3 territory
		Clinical presentation suggestive of subarachnoid hemorrhage
		Active internal bleeding
		Known bleeding diathesis including: – Platelet count < 100,000 – On heparin (w/in 48 h) and elevated partial thromboplastin time (PTT) – International normalized ratio (INR) ≥ 1.7 – Direct thrombin inhibitor (eg, dabigatran) **OR** direct factor Xa inhibitor (eg, rivaroxaban) within 72 h
		Intracranial surgery, serious head trauma, or previous stroke within 3 mo
		Any history of intracerebral hemorrhage, arteriovenous malformation, cerebral aneurysm
		Blood pressure: systolic > 185 or diastolic > 110 on repeated measurement at time of treatment
		Glucose ≤ 50/BGM at time of treatment
		Patient and family declined and/or refused treatment

YES	NO	ADDITIONAL EXCLUSION CRITERIA (3-4.5 h following symptom onset)
		Age > 80
		Major neurological deficits NIHSS > 25 (stroke severity)
		History of stroke **AND** diabetes
		Receiving anticoagulant therapy regardless of INR

YES	NO	CAUTIONS/WARNINGS
		Low molecular weight heparin (LMW) administered in the past 24 h at therapeutic doses (excludes prophylactic doses of 40 mg or less)
		Minor symptoms or rapid improvements
		Major neurological deficits (multi-lobar) CT > 1/3 cerebral hemisphere
		Major surgery or serious trauma (excluding head trauma) within 14 days
		History of frank GI or GU hemorrhage within 21 days
		Arterial puncture at noncompressible site within 7 days
		Acute MI in previous 3 mo (not concurrent)
		Seizure at onset of stroke symptoms suggestive of postictal neurological impairment
		Lumbar puncture within 7 days
		Pregnancy

Figure 4. Algorithm for management of intracranial hemorrhage following thrombolytic therapy. The algorithm was developed for use during a clinical trial. All or part of this algorithm may be adapted for use of thrombolytic therapy of stroke for approved indications. The application of this algorithm may have to be modified in order to function with resources available in particular location. aPTT, activated partial thromboplastin time; CT, computed tomography; FFP, fresh frozen plasma; PT, prothrombin time; STAT, immediately; tPA, tissue plasminogen activator.

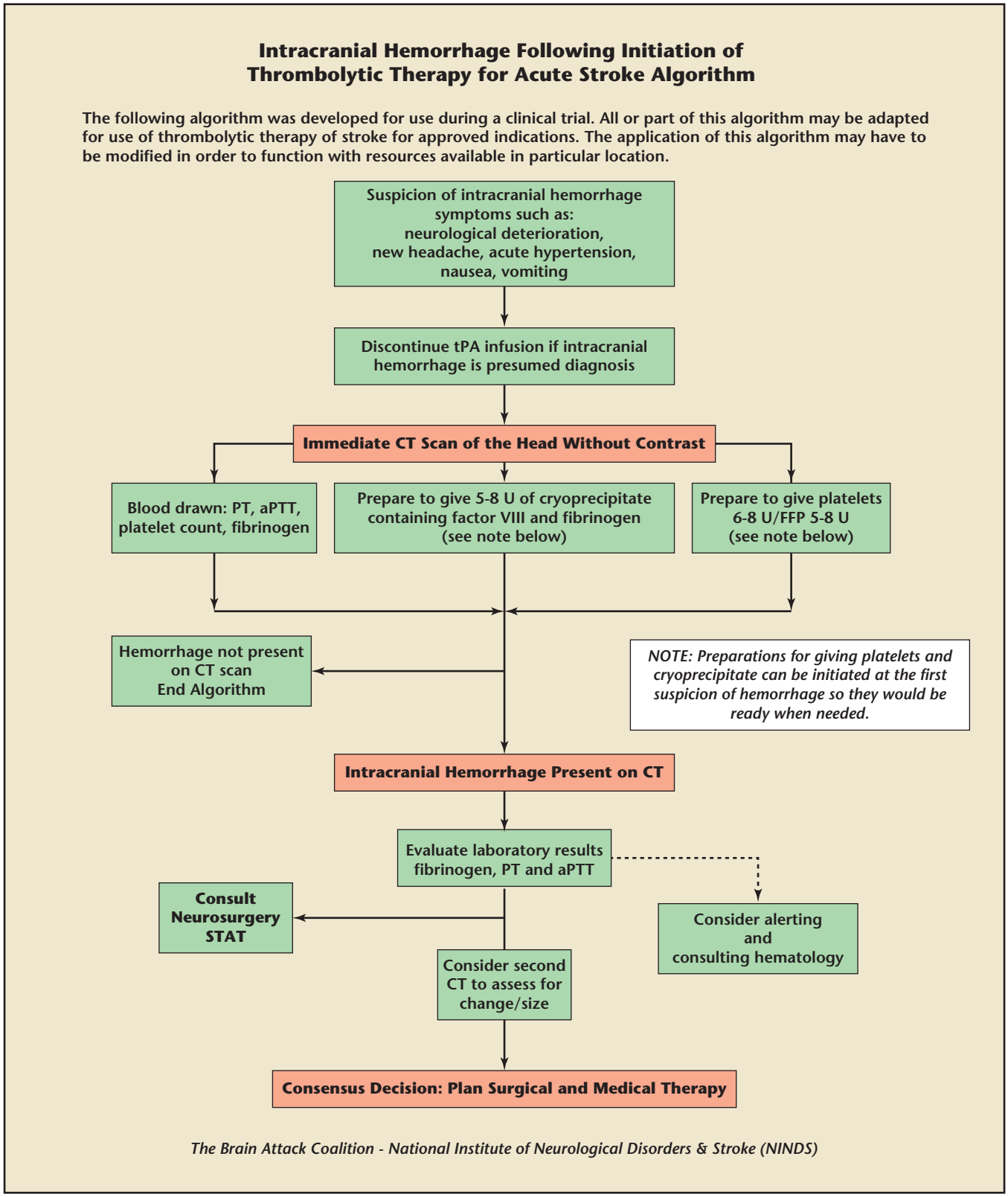

Figure 5. Order set for intracranial hemorrhage following initiation of thrombolytic therapy. aPTT, activated partial thromboplastin time; CBC, complete blood count; CT, computed tomography; INR, international normalized ratio; PT, prothrombin time; STAT, immediately; tPA, tissue plasminogen activator.

Intracranial Hemorrhage Following Initiation of Thrombolytic Therapy for Acute Stroke Orders

Allergies/Reactions	Height: Inches Cm	Weight: Actual Estimated	Kg Lb

For use with patients who experience neurological deterioration, sudden severe headache, acute uncontrolled hypertension, nausea, and vomiting, and intraparenchymal hemorrhage is considered likely:

☒ STOP tPA infusion
☒ STAT CT of the head without contrast RE: intracranial bleed
☒ STAT labs: CBC, aPTT, PT/INR, fibrinogen, type, and cross
☒ Neuro checks every 15 min
☒ Vital signs every 15 min
Cryoprecipitate_____ units (5-8 U recommended)
Fresh frozen plasma_____ units (5-8 U recommended)
Platelets_____ units (6-8 U recommended)
☒ STAT consult neurosurgery if ICH confirmed

Emergency Verbal Order or Telephone Order/read back by:		Date:	Time:
Transcriber's Signature:		Date:	Time:
Prescriber's Printed Name:	Noting Nurse's Signature:	Date:	Time:
Prescriber's Signature:	**Complete Call-back Number:** ( )___ ___ ___ ___ ___ ___ ___ ___	**Date:**	**Time:**

Form transmitted to pharmacy: Date/Time: _____ **By:** _____

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Intracranial Hemorrhage following Initiation of Thrombolytic Therapy for Acute Stroke Orders

Monthly Call-back Schedules and PerfectServe Electronic Paging System

By creating a monthly stroke call-back schedule for neurology and endovascular neurosurgery, both services are called simultaneously and provide backup for one another. For any call to a specialist not answered within 14 minutes, a PerfectServe® (Knoxville, TN) notification is automatically generated to the chief of the neurology telemedicine network program or the endovascular neurosurgery program director. Response times are then shared among specialists on a monthly basis.

Figure 6. Weekly stroke process data sheet listing objective time benchmarks for each Code Stroke Alert at each of the participating hospitals within St. John Providence Health System. Significant delays in diagnosis and treatment are examined and recommendations are made to improve identified defects in the system. CT, computed tomography; ED, Emergency Department; EMS, emergency medical services; fu, follow-up; ICH, intracerebral hemorrhage; INR, international normalized ratio; IV tPA, intravenous tissue plasminogen activator; MOD, emergency department module; NIH, National Institutes of Health Stroke Scale; RM, resuscitation module.

Sample spreadsheet

Date of Focus	*Symptom Onset Time*	*Arrival Time*	*Code Stroke Alert*	*CT Ordered*	*CT Complete*	*CT Resulted*	*Arrival to call*	*Call to Complete*	*Complete to result*	*Arrive to Read*	*IV tPA*	*Door to needle*	*NIH*	*Comments*	*EMS*	*MOD*
10/29/2010	1600	1616	16:26	16:26	16:49	16:57	10	23	8	41	N		1	Dunne to fu with NIH - visual fields 0	N	RM
10/30/2010	2302	2311	23:11	23:18	23:46	23:57	0	35	11	46	N		3	Improving sx	Y	RM
10/31/2010	1031	1131	11:43	11:45	12:04	12:10	12	21	6	39	N		4	?hx of ICH INR 1.3, ?seizure	N	RM
11/3/2010	07:30	808	8:16	8:16	8:43	8:51	8	27	8	43	Y @ 0943	95	25	waiting for family, tPA ordered at 09:30	Y	RM
11/4/2010	630 (wake up)	921	9:28	9:29	10:04	10:14	7	36	10	53	N		12	neg perf defect	Y	RM
11/4/2010	1345	1840	18:50	18:50	19:25	19:29	10	35	4	49	N		7	neg perf defect	N	RM
11/5/2010	1344	1444	15:26	14:49	15:00	15:22	42		22		N		4	bleed - fall on coumadin	Y	RM
11/5/2010	yesterday	1627	16:43 no name	16:45	17:23	17:34	16	40	11	67	N		12	neg perf defect	N	RM
11/6/2010	130	150	2:00	2:02	2:22	2:37	10	22	15	47	Y @ 0326	96	9	tPA ord - no date time sig -Dunne to fu	N	RM
11/7/2010	1515	1607	16:33	16:23	16:52	16:59	26	19	7	52	N		3	Triage issue - ED to fu		RM

NIHSS Documentation

Prior to initiation of the Code Stroke program, nearly one-third of ED evaluations lacked NIHSS documentation that, along with response time, was designated as primary quality metrics. All patient charts are now reviewed each week at a multidisciplinary stroke quality assurance meeting. Individuals failing to appropriately document stroke evaluations are contacted and encouraged to improve their clinical documentation. Figure 8 shows the rate of NIHSS documentation before the Code Stroke program (approximately 70%) versus after initiation of benchmarking and education (nearly 100%). The second set of bars compares average neurologist call-back time to the ED before the initiation of the Code Stroke program (> 22 min) versus after the initiation of the program (< 2 min). With education and benchmarking relative to peers, NIHSS documentation and physician response times improved without further intervention.

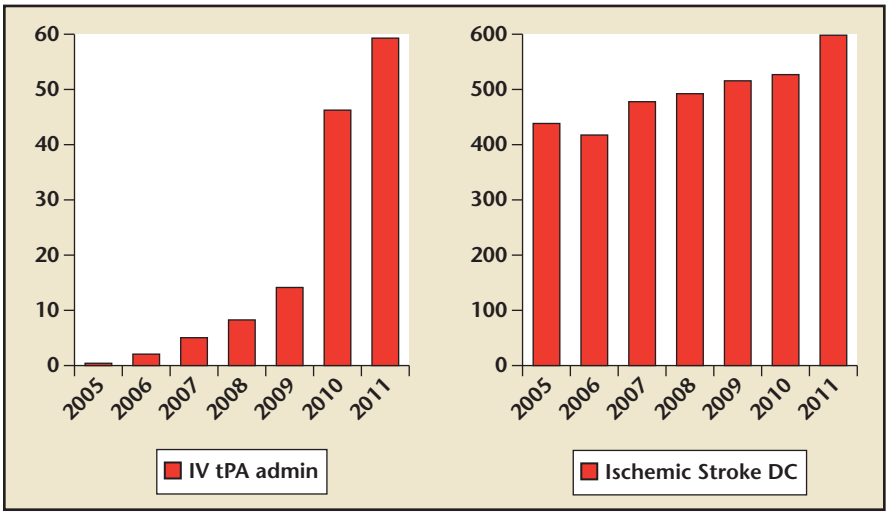
Results of the Code Stroke Process

ED Triage and Time to CT

As the Code Stroke program was expanded to other facilities within SJPHS, the data consistently indicated that, in those institutions in which the Code Stroke protocol is followed, the times to treatment and overall IV tPA delivery rates are several times faster than the national average.[11-13] Those facilities that do not participate wholeheartedly in the process tend to deliver at higher rates than the national average, but are far lower than the SJPHS internal best standard. Figure 9 provides a 6-month snapshot of data from late 2010, collected from four hospital campuses within SJPHS.

Sites 1, 2, and 3 have neuroendovascular coverage 24 hours per day, 7 days per week, and teleradiology is available for immediate viewing of imaging studies at all

Figure 7. **(A)** Number of patients received IV tPA at one of the participating St. John Providence Health System hospitals from 2005 to 2011. **(B)** Number of patients with acute ischemic stroke as a discharge diagnosis from 2005 to 2011. DC, discharge; IV tPA, intravenous tissue plasminogen activator.



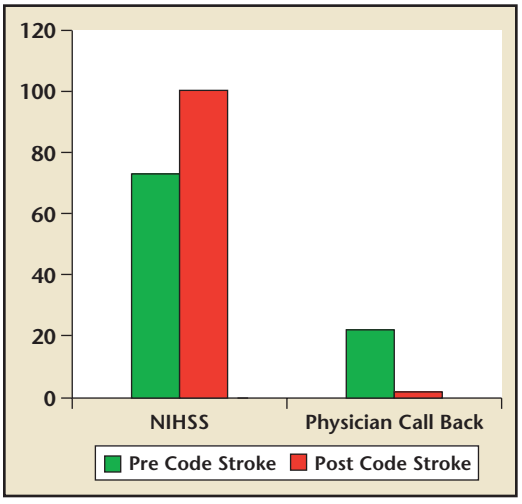
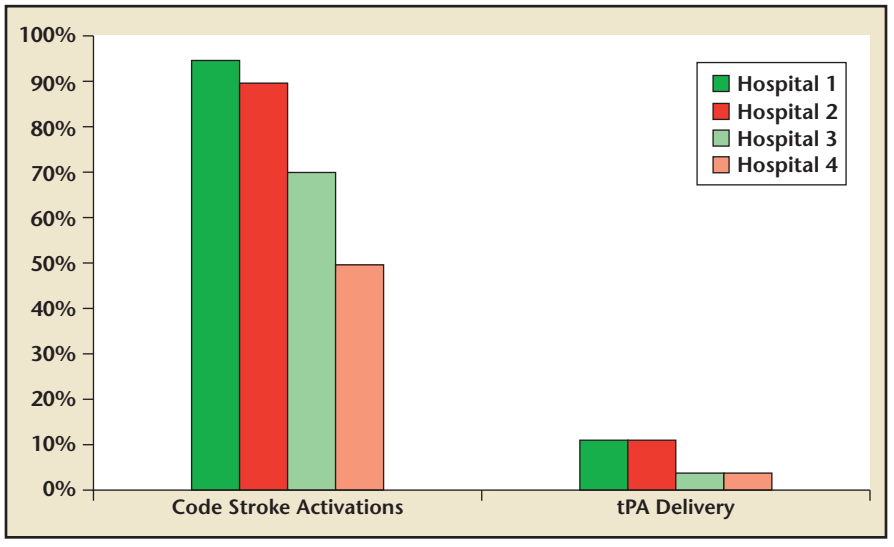


Figure 8. Percentage of acute ischemic stroke patients with NIHSS documented on admission as well as physician call-back time (in minutes) before and after the implementation of Code Stroke protocol. NIHSS, National Institutes of Health Stroke Scale.

Figure 9. Percentage of Code Stroke activations of patients with acute ischemic stroke at four primary stroke center designated emergency departments within St. John Providence Health System as well as IV tPA administration rate in each Emergency Department in 2010. IV tPA, intravenous tissue plasminogen activator.

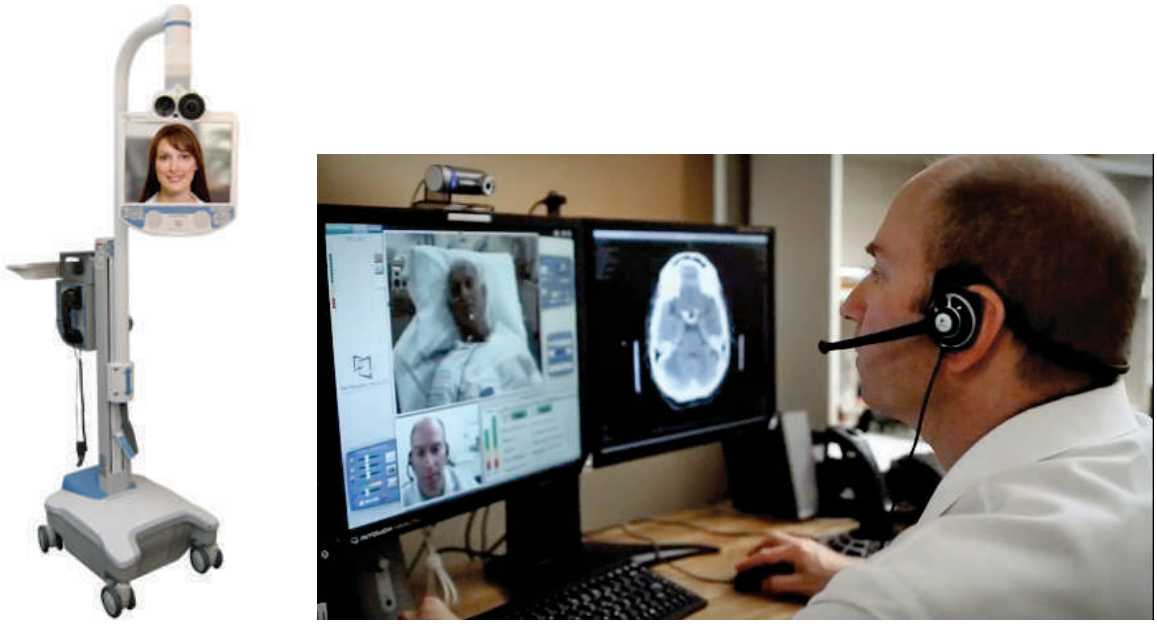


facilities. Each facility had access to an InTouch Health RP-Lite® (Santa Barbara, CA) robot (Figure 10). Two sites routinely activated Code Stroke Alerts upon patient triage in the EDs, alerting the CT, neurology, and neuroendovascular teams. This activation occurred uniformly for > 90% of all patients at Sites 1 and 2.

Two campuses had differential protocol adherence: Site 3 failed to routinely activate the Code Stroke until after the ED physician evaluation and image acquisition. Site 4 altered the Code Stroke activation to an evaluation by resident staff and midlevel providers rather than initiating immediate alerts to neurology and neuroendovascular specialists. Sites 1 and 2 delivered IV tPA at an 11% rate to all patients triaged as stroke victims during 2011. Patients presenting at Sites 3 and 4 received treatment with IV tPA at a rate of 4%. These rates are percentages of the total number of IV tPA doses given relative to the total number of stroke discharges, not the percentage of eligible patients. In addition, Sites 3 and 4 acquired a greater number of imaging studies per stroke patient than Sites 1 and 2. Data evaluation has resulted in an ongoing program of process improvement at each hospital in the health system.

Time to CT is a primary determinant of door-to-needle time, and is highly process dependent. A Code Stroke Alert notifies the CT team and the room is readied for an emergent study. An IV line is started in the ED and a nonenhanced CT head scan is done, followed by CTP and/or CT angiogram of the head and neck. A radiologist interprets these studies, and the final read is expected to occur within the 45-minutes from arrival to allow for treatment within an hour (or 15-minutes for nonenhanced CT of the head as well as CTP). A history

Figure 10. InTouch Health RP-Lite® (Santa Barbara, CA) robot allows stroke neurologist to remotely assess the patient via the use of telemedicine technology in the form of high-quality videoconferencing.



of contrast reaction is not considered an absolute contraindication to IV contrast and these patients are not delayed in their evaluation.[14] The interpretation times and accuracy of interpretation between different radiologists and sites are compared and reviewed on a weekly or biweekly basis.

The initial interpretation time averaged 26 minutes from CT completion. Several changes were made to the process to shorten this time frame. Upon downloading images into the pictorial archiving system, studies are now designated as *STAT* to alert the radiologist at his or her reading station. Radiologists also receive a notification page with Code Stroke Alerts. On-time reads were initially difficult to obtain; however, through continued education, benchmarking, and peer review, average interpretation times dropped from 26 minutes to 8 minutes after completion of the study. Figure 11 shows the steady progression of improvement in read times following the implementation of these interventions. Persistent outliers are sent for peer review and individual process improvement intervention.

IV tPA Administration

Once the patient returns from CT, the decision as to whether the patient is an IV tPA candidate has already been made based on colleague-to-colleague discussions, care algorithms, and potential CT results. To decrease the delivery and mixing time for IV tPA, the medication is now stored within the ED for immediate availability. Patients are then transferred to the neuroscience intensive care unit for observation and ongoing evaluation.

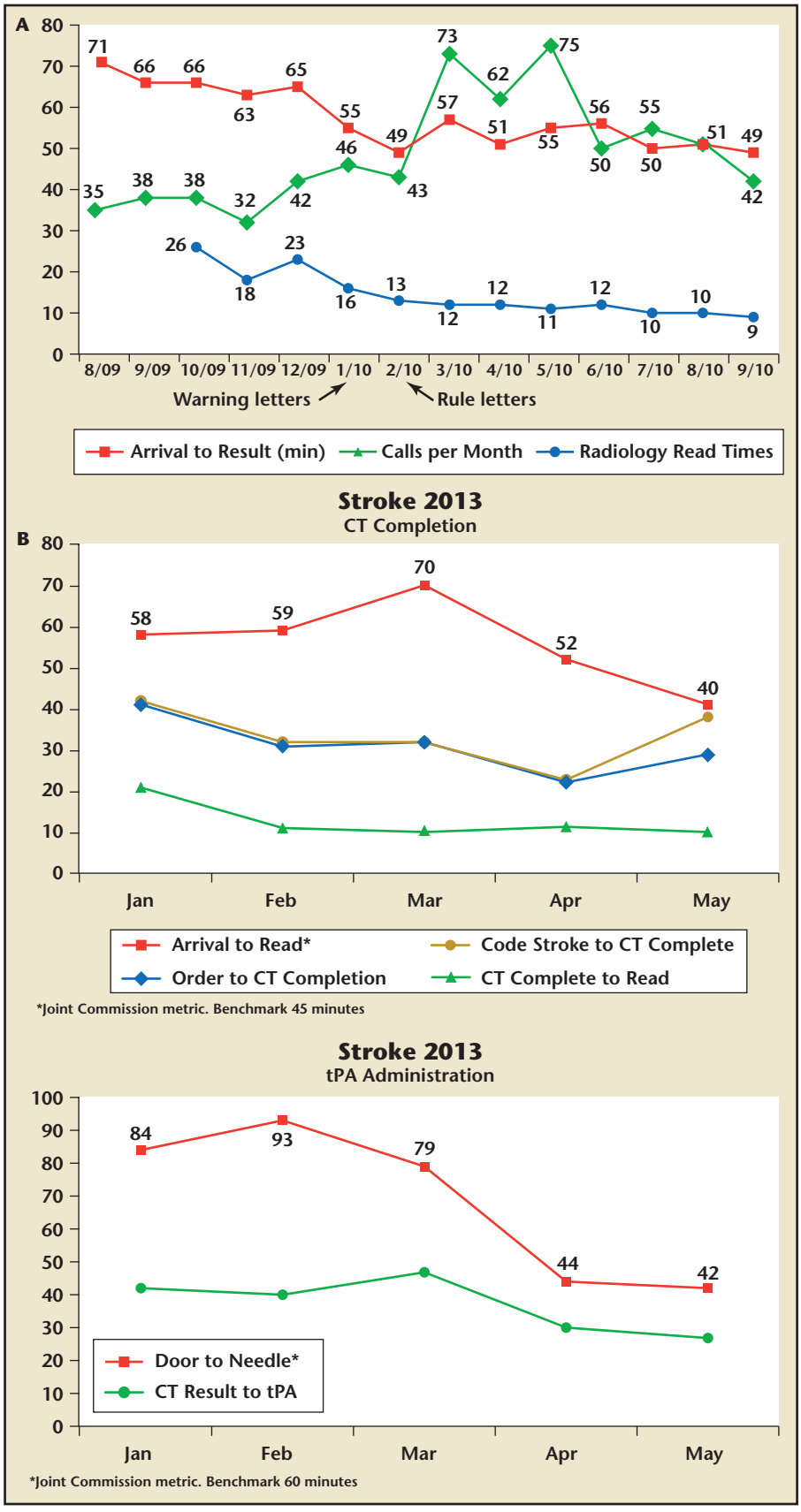
Determination of Appropriate Candidates for Intervention

Identifying patients as potential interventional candidates is accomplished with physiologic imaging as combined with guidelines published by the American Heart Association and Society of Neurointerventional Surgery.[15-17] For patients with major vessel occlusion, CT perfusion is relied on to identify areas of reversible ischemia.[18-20] Every patient who is part of the Code Stroke process receives a CT perfusion scan that is reviewed by a neuroendovascular specialist at the time of completion. This not only identifies potential candidates for interventional therapy, but also identifies those patients who have completed infarcts not demonstrated by a plain CT. By vigilantly adhering to the Code Stroke protocol, complications related to recanalization of ischemic dead tissue have been minimized.

Discussion

Despite the high prevalence of acute ischemic stroke, it remains a major challenge for many hospital systems to accurately diagnose these patients in a timely manner in order to provide life-saving treatments that are time dependent. Many hospital systems across the world are working on ways to address this concern by creating triage systems, EMS algorithms, new scoring systems, new protocols in the ED, or by developing a hub-spoke relationship with tertiary

Figure 11. **(A)** Code Stroke data at one of the participating St. John Providence Health System hospitals from August 2009 to September 2010. Door to CT result time is shown in *red*, number of calls per month is shown in *green*, and interpretation time from CT completion to result (in minutes) is shown in *yellow*. **(B)** Data from first 5 months of 2013 showing that benchmarks are continuing to improve 4 years after implementation of code stroke. CT, computed tomography; tPA, tissue plasminogen activator.



stroke centers and incorporating telemedicine in this process.[21-27]

Rapp and colleagues[28] were among the first to introduce the concept of Code Stroke in 1997 when they described the concept of developing a pathway in order to facilitate identification and subsequently provide treatments of these patients with recombinant tPA in the National Institute of Neurological Disorders and Stroke (NINDS) study.[28] They detailed an EMS Stroke Alert activation process preferentially triaging these patients and obtaining noncontrast CT scan as a priority, followed by beginning IV thrombolytics. Insufficient details, however, were provided with regard to how to successfully achieve these benchmarks in a timely manner, with the exception of creating a pathway and placing these patients on a high acuity level. The main purpose of the paper was to educate the medical community in recognizing stroke as a medical emergency and that reperfusion/thrombolytic therapy should be the main goal of treatment in the initial phase of stroke.

The Europeans have extensive experience in rapidly identifying and treating patients with acute ischemic strokes, particularly in Spain. In 2004, Alvarez-Sabín and colleagues[29] described the clinical benefits following the implementation of a specialized urgent stroke care system by going through a three-step process: (1) developing a stroke team and Code Stroke protocol, (2) creating a stroke unit, and (3) incorporating an on-call stroke neurologist. Noted improvements include a decreased length of stay, decreased hospital mortality, and decreased institutionalization of these patients. De Leciñana-Cases and associates[30] described the relevance of a Code Stroke protocol, stroke unit, and stroke network in the organization of acute stroke

care that emphasized the need for coordinated care led by the stroke neurologist, available consultants in a multitude of specialties, and the creation of a dedicated stroke unit. Although these elements helped to improve implementation of the treatment protocols, details of the protocol itself were not provided. Clua-Espuny and associates[31] described the implementation of Code Stroke model in Terres de l'Ebre, Spain. Among 380 patients that were treated, a 13.9% thrombolytic usage rate was achieved; however, the article was not published in English-language literature and the differences between the health care systems of the United States and Spain have to be taken into account. Nevertheless, achieving a 13.9% IV thrombolytic rate is a noteworthy accomplishment.

Prabhakaran and colleagues[32] recently published a study stating that IV tPA infusion rate increases in primary stroke centers over time are significantly higher than in nonstroke certified centers. By having a specific stroke protocol, more patients may be qualified for treatment with IV tPA. Finally, Theiss and coworkers[33] evaluated the effect of the telestroke network over a 4-year period and found that the rate of thrombolytic use increased and in-hospital mortality decreased.

González and associates[34] recently published their acute stroke imaging algorithm that incorporated nonenhanced CT of the head, CT angiogram, and diffusion magnetic resonance imaging (MRI) in the identification of penumbra and quantifying the ischemic core. They defer to CTP only if a patient cannot receive diffusion MRI. Although their algorithm is very reasonable and has achieved positive results, it is often difficult to reproduce due to the limited availability of MRI scanners.

In order to develop a Code Stroke process, a few key components must be addressed: (1) recognizing potential stroke patients from presentation (prehospital, in the ED, or on the floor); (2) obtaining fast and appropriate diagnostic studies; (3) interpreting complex clinical presentations together with the diagnostic results; and (4) providing timely treatment. Though each of these components appears simple, many obstacles may lie ahead; therefore, developing a Code Stroke protocol at an institutional level remains the most feasible way to tackle this problem. While developing the protocol at SJPHS, logistical issues were encountered such as physician call-back time, imaging availability, bed availability, time for radiology interpretation, delay from pharmacy for mixing and delivering of IV tPA, and availability of neuroendovascular services. Full support from hospital administration, physicians, clinical staff, and ancillary personnel is absolutely vital to the success of such a process. Through a stepwise approach, every one of these obstacles was identified, and attempts were made to address them in an effective manner. This resulted in the creation of a Code Stroke model that has ultimately translated into significant improvements in objective benchmark measures that are successfully reproducible on a system-wide basis. The model is also being adapted by many other health systems across the nation.[23,35] A particularly valuable component of the SJPHS approach is the built-in mechanism that continues to evaluate the protocol by means of weekly reviews of all stroke patients. These reviews identify the deficits, missed benchmarks, and reasons for not providing certain interventions that may be otherwise overlooked. The resulting recommendations are then translated directly into everyday clinical practice across the system. No model is perfect, which is why the SJPHS protocol remains dynamic in nature—so that it can adapt to new advances and seamlessly incorporate new evidence-based practices, guidelines, and techniques in treating this challenging disease.

Conclusions

The outcome following an acute ischemic stroke depends on a timely diagnosis and reperfusion of the ischemic brain. By creating a Code Stroke protocol, the process of identifying and subsequently providing appropriate treatments for patients with ischemic stroke in a timely and effective manner has been streamlined. A Code Stroke protocol delivers specialty care to the patients' points of access to the health system and eliminates traditional obstacles with objective and measurable outcome improvements. The process was successfully implemented at one hospital site, then subsequently scaled to the health system, and, finally, to a network level. The SJPHS protocol may be used as a model for other centers to enhance their stroke programs and achieve similar positive results. ■

References

1. Lloyd-Jones D, Adams RJ, Brown TM, et al; American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Heart disease and stroke statistics—2010 update: a report from the American Heart Association. *Circulation*. 2010;121:e46-e215.
2. Go AS, Mozaffarian D, Roger VL, et al; American Heart Association Statistics Committee and Stroke Statistics Subcommittee. Heart disease and stroke statistics—2013 update: a report from the American Heart Association. *Circulation*. 2013 Jan 1;127:e6-e245.
3. Centers for Disease Control and Prevention. Chronic Disease Prevention and Health Promotion. Heart Disease and Stroke Prevention—At a Glance 2011. http://www.cdc.gov/chronicdisease/resources/publications/AAG/dhdsp.htm. Accessed August 12, 2014.
4. Towfighi A, Saver JL. Stroke declines from third to fourth leading cause of death in the United States: historical perspective and challenges ahead. *Stroke*. 2011;42:2351-2355.
5. Foraker RE, Rose KM, McGinn AP, et al. Neighborhood income, health insurance, and prehospital delay for myocardial infarction: the atherosclerosis risk

in communities study. *Arch Intern Med*. 2008;168:1874-1879.
6. Weintraub WS, Spertus JA, Kolm P, et al. Effect of PCI on quality of life in patients with stable coronary disease. *N Engl J Med*. 2008;359:677-687.
7. Parkin L, Sweetland S, Balkwill A, et al; Million Women Study Collaborators. Body mass index, surgery, and risk of venous thromboembolism in middle-aged women: a cohort study. *Circulation*. 2012;125:1897-1904.
8. Heit JA, Melton LJ 3rd, Lohse CM, et al. Incidence of venous thromboembolism in hospitalized patients vs community residents. *Mayo Clin Proc*. 2001;76:1102-1110.
9. Heidenreich PA, Trogdon JG, Khavjou OA, et al. Forecasting the future of cardiovascular disease in the United States: a policy statement from the American Heart Association. *Circulation*. 2011;123:933-944.
10. The Joint Commission. Advanced Certification Comprehensive Stroke Centers. http://www.jointcommission.org/certification/advanced_certification_comprehensive_stroke_centers.aspx. Accessed August 12, 2014.
11. Reeves MJ, Arora S, Broderick JP, et al; Paul Coverdell Prototype Registries Writing Group. Acute stroke care in the US: results from 4 pilot prototypes of the Paul Coverdell National Acute Stroke Registry. *Stroke*. 2005;36:1232-1240.
12. Kleindorfer D, Lindsell CJ, Brass L, et al. National US estimates of recombinant tissue plasminogen activator use: ICD-9 codes substantially underestimate. *Stroke*. 2008;39:924-928.
13. Cronin CA. Intravenous tissue plasminogen activator for stroke: a review of the ECASS III results in relation to prior clinical trials. *J Emerg Med*. 2010;38:99-105.
14. Brockow K, Christiansen C, Kanny G, et al. Management of hypersensitivity reactions to iodinated contrast media. *Allergy*. 2005;60:150-158.
15. Latchaw RE, Alberts MJ, Lev MH, et al; American Heart Association Council on Cardiovascular Radiology and Intervention, Stroke Council, and the Interdisciplinary Council on Peripheral Vascular Disease. Recommendations for imaging of acute ischemic stroke: a scientific statement from the American Heart Association. *Stroke*. 2009;40:3646-3678.
16. Meyers PM, Schumacher HC, Higashida RT, et al. Indications for the performance of intracranial endovascular neurointerventional procedures. A scientific statement from the American Heart Association Council on Cardiovascular Radiology and Intervention, Stroke Council, Council on Cardiovascular Surgery and Anesthesia, Interdisciplinary Council on Peripheral Vascular Disease, and Interdisciplinary Council on Quality of Care and Outcomes Research. *J Neurointerv Surg*. 2010;2:177-188.
17. Blackham KA, Meyers PM, Abruzzo TA, et al; Society for NeuroInterventional Surgery. Endovascular therapy of acute ischemic stroke: report of the Standards of Practice Committee of the Society of NeuroInterventional Surgery. *J Neurointerv Surg*. 2012;4:87-93.
18. Silvennoinen HM, Hamberg LM, Lindsberg PJ, et al. CT perfusion identifies increased salvage of tissue in patients receiving intravenous recombinant tissue plasminogen activator within 3 hours of stroke onset. *AJNR Am J Neuroradiol*. 2008;29:1118-1123.
19. Turk AS, Magarick JA, Frei D, et al. CT perfusion-guided patient selection for endovascular recanalization in acute ischemic stroke: a multicenter study. *J Neurointerv Surg*. 2013;523-527.
20. Kleinman JT, Mlynash M, Zaharchuk G, et al. Yield of CT perfusion for the evaluation of transient ischaemic attack [published online ahead of print December 11, 2012]. *Int J Stroke*. doi: 10.1111/j.1747-4949.2012.00941.x.
21. Schwamm LH, Holloway RG, Amarenco P, et al. A review of the evidence for the use of telemedicine within stroke systems of care: a scientific statement from the American Heart Association/American Stroke Association. *Stroke*. 2009;40:2616-2634.
22. Schwamm LH, Audebert HJ, Amarenco P, et al. Recommendations for the implementation of telemedicine within stroke systems of care: a policy statement from the American Heart Association. *Stroke*. 2009;40:2635-2660.
23. Brown EV. Robotic assistance remedy. The Michigan Stroke Network utilizes remote presence robots to bring needed specialists to stroke patients at remote hospitals. *Health Manag Technol*. 2008;29:18-21.
24. Sattin JA, Olson SE, Liu L, et al. An expedited code stroke protocol is feasible and safe. *Stroke*. 2006;37:2935-2939.
25. Tai YJ, Weir L, Hand P, et al. Does a "code stroke" rapid access protocol decrease door-to-needle time for thrombolysis? *Intern Med J*. 2012;42:1316-1324.
26. Asimos AW, Norton HJ, Price MF, Cheek WM. Therapeutic yield and outcomes of a community teaching hospital code stroke protocol. *Acad Emerg Med*. 2004;11:361-370.
27. Dalloz MA, Bottin L, Muresan IP, et al. Thrombolysis rate and impact of a stroke code: a French hospital experience and a systematic review. *J Neurol Sci*. 2012;314:120-125.
28. Rapp K, Bratina P, Barch C, et al. Code Stroke: rapid transport, triage and treatment using rt-PA therapy.

MAIN POINTS

- Stroke is one of the major causes of death and disability in the United States, yet it is undertreated by many major medical centers across the country. Timely recognition and treatment of acute ischemic stroke remains a challenge due to confusing clinical presentations, hospital logistics, communication barriers, and lack of standardized treatment algorithms.
- In 2003, the Joint Commission established criteria for the designation of Primary Stroke Centers, which meet specific requirements for the delivery of treatment to the vulnerable stroke population.
- At St. John Providence Health System (SJPHS), the stroke response process is known as *Code Stroke*. When a patient presents with stroke symptoms to an emergency department, a streamlined fully accountable process is initiated; this protocol is set in motion if the patient presents within 8 hours of stroke symptom onset or if the time of onset is unknown.
- As the Code Stroke program was expanded to other facilities within SJPHS, the data consistently indicated that, in those institutions in which the Code Stroke protocol is followed, the times to treatment and overall intravenous tissue plasminogen activator delivery rates are several times faster than the national average.
- Time to computed tomography (CT) scan is a primary determinant of door-to-needle time, and is highly process dependent. The initial interpretation time averaged 26 minutes from CT completion, and on-time reads were initially difficult to obtain. Through continued education, benchmarking, and peer review, average interpretation times have dropped from 26 minutes to 8 minutes after completion of the study.
- In order to develop a Code Stroke process, a few key components must be addressed: (1) recognizing potential stroke patients from presentation (prehospital, in the emergency department, or on the hospital floor); (2) obtaining fast and appropriate diagnostic studies; (3) interpreting complex clinical presentations together with the diagnostic results; and (4) providing timely treatment.

The NINDS rt-PA Stroke Study Group. *J Neurosci Nurs*. 1997;29:361-366.
29. Alvarez-Sabín J, Molina C, Montaner J, et al. Clinical benefit following the implementation of a specialized urgent stroke care system [in Spanish]. *Med Clin (Barc)*. 2004;122:528-531.
30. De Leciñana-Cases MA, Gil-Núñez A, Díez-Tejedor E. Relevance of stroke code, stroke unit and stroke networks in organization of acute stroke care—the Madrid acute stroke care program. *Cerebrovasc Dis*. 2009;27(suppl 1):140-147.
31. Clua-Espuny JL, Piñol-Moreso JL, Gil-Guillén FV, et al. The stroke care system in Terres de l'Ebre, Spain, after the implementation of the Stroke Code model: Ebrictus Study [in Spanish]. *Med Clin (Barc)*. 2012;138:609-611.
32. Prabhakaran S, McNulty M, O'Neill K, Ouyang B. Intravenous thrombolysis for stroke increases over time at primary stroke centers. *Stroke*. 2012;43:875-877.
33. Theiss S, Günzel F, Storm A, et al. Using routine data for quality assessment in NeuroNet Telestroke care. *J Stroke Cerebrovasc Dis*. 2013;22:984-990.
34. González RG, Copen WA, Schaefer PW, et al. The Massachusetts General Hospital acute stroke imaging algorithm: an experience and evidence based approach. *J NeuroIntervent Surg*. 2013;5(suppl 1):i7-i12.
35. Michigan Stroke Network. Meet the Clinical Team. Richard Fessler, MD. http://www.michiganstrokenetwork.com/about_us/clinical_team/v/Richard_Fessler_MD/about.aspx. Accessed August 12, 2014.