Original Article

Timely Reperfusion in Stroke and Myocardial Infarction Is Not Correlated
An Opportunity for Better Coordination of Acute Care

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Background—Timely reperfusion is critical in acute ischemic stroke (AIS) and ST-segment–elevation myocardial infarction (STEMI). The degree to which hospital performance is correlated on emergent STEMI and AIS care is unknown. Primary objective of this study was to determine whether there was a positive correlation between hospital performance on door-to-balloon (D2B) time for STEMI and door-to-needle (DTN) time for AIS, with and without controlling for patient and hospital differences.

Methods and Results—Prospective study of all hospitals in both Get With The Guidelines-Stroke and Get With The Guidelines-Coronary Artery Disease from 2006 to 2009 and treating ≥10 patients. We compared hospital-level DTN time and D2B time using Spearman rank correlation coefficients and hierarchical linear regression modeling. There were 43 hospitals with 1976 AIS and 59 823 STEMI patients. Hospitals' DTN times for AIS did not correlate with D2B times for STEMI ($\rho=-0.09$; $P=0.55$). There was no correlation between hospitals' proportion of eligible patients treated within target time windows for AIS and STEMI (median DTN time <60 minutes: 21% [interquartile range, 11–30]; median D2B time <90 minutes: 68% [interquartile range, 62–79]; $\rho=-0.14$; $P=0.36$). The lack of correlation between hospitals' DTN and D2B times persisted after risk adjustment. We also correlated hospitals' DTN time and D2B time data from 2013 to 2014 using Get With The Guidelines (DTN time) and Hospital Compare (D2B time). From 2013 to 2014, hospitals' DTN time performance in Get With The Guidelines was not correlated with D2B time performance in Hospital Compare (n=546 hospitals).

Conclusions—We found no correlation between hospitals' observed or risk-adjusted DTN and D2B times. Opportunities exist to improve hospitals' performance of time-critical care processes for AIS and STEMI in a coordinated approach. (***Circ Cardiovasc Qual Outcomes***. 2017;10:e003148. DOI: 10.1161/CIRCOUTCOMES.116.003148.)

Key Words: American Heart Association ■ fibrinolysis ■ myocardial infarction
■ stroke ■ tissue-type plasminogen activator

There are important parallels between the emergent care of acute ischemic stroke (AIS) and ST-segment–elevation myocardial infarction (STEMI). The central tenet of emergency care is the same: timely reperfusion is critical and is associated with better patient outcomes.[1–8] Both require rapid recognition of symptoms in the prehospital, triage, and emergency department (ED) setting; both require an urgent diagnostic test in the ED before evaluation for time-sensitive therapeutic intervention; and both require expedient mobilization of staff and resources to achieve time benchmarks.

As the time-critical nature of reperfusion for STEMI patients was recognized, targeted national quality improvement efforts, registries such as the American Heart Association's Get with the Guidelines (GWTG), and required reporting by the Centers for Medicare and Medicaid Services (CMS) focused on improving timely treatment with fibrinolysis or percutaneous coronary intervention.[9] Major improvements have been realized, so that now the vast majority of STEMI patients have intervention within the guideline-recommended time window of 90 minutes (door-to-balloon [D2B] time).[10]

Likewise, emergent treatment with intravenous tPA (tissue-type plasminogen activator) for AIS patients has more recently become a focus for quality improvement efforts. Guidelines recommend door-to-needle (DTN) time for tPA

WHAT IS KNOWN

- Previous studies have found modest correlation in hospital performance on cardiovascular care, with correlation in hospitals' performance on process and quality measures for cardiac conditions.
- Thus, there seems to be spillover between performance on cardiovascular conditions within hospitals.

WHAT THE STUDY ADDS

- This study found no correlation between hospital performance on D2B time for STEMI and DTN time for AIS.
- This held in observed and in risk-adjusted analyses.
- These results suggest that future research should consider how to implement synergistic quality improvement strategies across conditions.

within 60 minutes,[11] and CMS requires reporting on tPA delivery.[12] Recent gains have been made in AIS care, in particular among hospitals participating in the Target: Stroke initiative.[13] Yet despite these guideline recommendations and quality measures, many eligible stroke patients continue to have substantial delays in tPA administration, and some patient groups, hospitals, and regions have particularly high rates of inappropriate delays.[14,15]

Given the similarities in the emergent treatment of AIS and STEMI, there is a lot that can be learned from the STEMI experience in efforts to improve AIS care delivery.[16] Additionally, given the overlap in physical space and staff involved in care, organizational behavior patterns may carry over between the care of STEMI and AIS. However, the degree to which hospital performance on STEMI care correlates with performance on emergent ischemic stroke care is unknown, and factors that may influence overlaps in hospital performance have not been described. Our aims are to examine the correlation between hospital performance on D2B time for STEMI and DTN time for AIS and determine whether a hospital's performance on D2B time for STEMI predicts performance on DTN time for AIS after controlling for patient case-mix differences.

Methods

Data Source

We use data from GWTG-Stroke and GWTG-Coronary Artery Disease (CAD) for the primary analysis. GWTG-Stroke is an ongoing, voluntary, continuous registry, and performance improvement initiative that collects patient-level data on characteristics, diagnostic testing, treatments, adherence to quality measures, and in-hospital outcomes in patients hospitalized with stroke, including ischemic stroke, intracerebral hemorrhage, and subarachnoid hemorrhage, and patients with transient ischemic attack (limited to those presenting with symptoms at time of arrival). GWTG-CAD enrolled patients hospitalized with coronary artery disease including patients with STEMI. Details of the design and conduct of the GWTG-Stroke and GWTG-CAD Program have been previously described.[17,18]

Both registries capture data using a web-based, patient management system with embedded decision support and real-time online reporting features. The data coordinating center for GWTG is Quintiles Real-World & Late Phase Research (Cambridge, MA), and the Duke

Clinical Research Institute serves as the statistical analytic center. The Duke University Medical Center Institutional Review Board approved all related analyses.

The GWTG-CAD program started in 2001 and the GWTG-Stroke Program was made available in April 2003 to any hospital in the United States. Each participating hospital received either human research approval to enroll cases without individual patient consent under the common rule or a waiver of authorization and exemption from subsequent review by their institutional review board.

Trained hospital personnel were instructed to ascertain consecutive patients admitted with AIS by prospective clinical identification, retrospective identification using *International Classification of Disease, Ninth Revision*, discharge codes, or a combination. *International Classification of Disease, Ninth Revision*, codes used to identify ischemic stroke hospitalizations included 433.x, 434.x, and 436. Methods used for prospective identification varied but included regular surveillance of ED records (ie, presenting symptoms and chief complaints), ward census logs, and neurological consultations. The eligibility of each acute stroke or transient ischemic attack admission was confirmed at chart review before abstraction. Patient data were abstracted by trained hospital personnel. These included demographics, medical history, initial head computerized tomographic findings, in-hospital treatment and events, discharge treatment and counseling, mortality, and discharge destination. The data abstraction tool included predefined logic features and user alerts to identify potentially invalid format or values entry such as DTN time beyond plausible duration. Sites received individual data quality reports to promote data completeness and accuracy. GWTG-CAD also collects data on patient demographics, medical history, symptoms on arrival, in-hospital treatment and events, discharge treatment and counseling, and patient disposition for consecutive eligible patients presenting to participating hospitals.[19] Additional descriptions of the case ascertainment, data collection, and quality-auditing methods have been previously published.[9,18]

Study Population

For this 2-level analysis, we included patients presenting to hospitals participating in both the GWTG-Stroke and GWTG-CAD registries from 2006 to 2009. We limited the study period to these years because the GWTG-CAD registry merged into ACTION-GWTG Registry in 2009. We then limited our study population to AIS patients arriving within 2 hours of symptom onset, who were eligible for tPA, who were not transferred out, and who were not missing DTN time. We excluded patients presenting to sites with fewer than 10 patients treated during the study period. This resulted in a final study population of 1976 ischemic stroke patients treated at 43 hospitals from 2006 to 2009 (Figure 1A). To determine hospitals' DTN times, we included AIS patients treated with intravenous tPA. We excluded patients with in-hospital stroke, enrolled in a clinical trial, admitted for elective carotid intervention, and with DTN time >24 hours. To determine hospitals' D2B times, we included patients with STEMI (ie, STEMI or STEMI/non–ST-segment–elevation myocardial infarction unspecified), with a first ECG diagnostic for ST-segment elevation or left bundle branch block, who underwent percutaneous coronary intervention. We excluded patients transferred in, transferred from another ED, who received thrombolytic therapy, with a reason for delay in percutaneous coronary intervention and with a D2B time >24 hours.

Because GWTG-CAD merged into ACTION-GWTG Registry in 2009, we conducted a secondary analysis using STEMI data from Hospital Compare between October 2013 and September 2014 to have the most up-to-date analysis. Data from the Hospital Compare data sets are the official data used by CMS comparing care at >4000 Medicare-certified hospitals in the US Data are freely available at data.medicare.gov. Using the hospital ID, we linked the hospital-level D2B time for STEMI with DTN time for AIS and determined whether the site-level proportion of eligible patients with D2B times within 90 minutes for STEMI correlated with the site-level proportion of eligible patients with DTN times within 60 minutes for STEMI. The AIS study population included tPA-treated patients who arrived within 2 hours of symptom onset, were not transferred out, and were without missing DTN time. We further excluded sites with fewer than 10 AIS
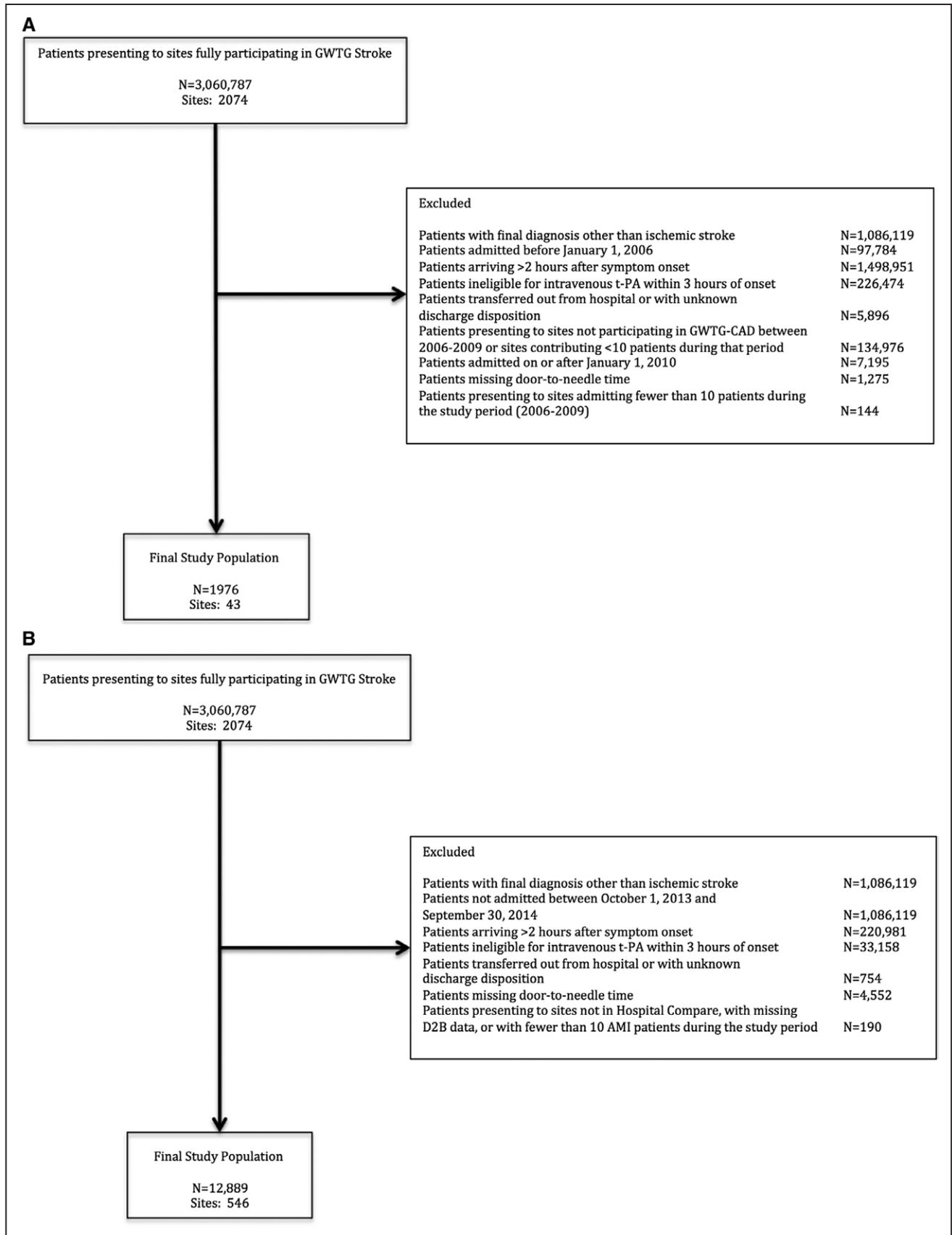
A

Patients presenting to sites fully participating in GWTG Stroke

N=3,060,787
Sites: 2074

Excluded

Patients with final diagnosis other than ischemic stroke	N=1,086,119
Patients admitted before January 1, 2006	N=97,784
Patients arriving >2 hours after symptom onset	N=1,498,951
Patients ineligible for intravenous t-PA within 3 hours of onset	N=226,474
Patients transferred out from hospital or with unknown discharge disposition	N=5,896
Patients presenting to sites not participating in GWTG-CAD between 2006-2009 or sites contributing <10 patients during that period	N=134,976
Patients admitted on or after January 1, 2010	N=7,195
Patients missing door-to-needle time	N=1,275
Patients presenting to sites admitting fewer than 10 patients during the study period (2006-2009)	N=144

Final Study Population

N=1976
Sites: 43

B

Patients presenting to sites fully participating in GWTG Stroke

N=3,060,787
Sites: 2074

Excluded

Patients with final diagnosis other than ischemic stroke	N=1,086,119
Patients not admitted between October 1, 2013 and September 30, 2014	N=1,086,119
Patients arriving >2 hours after symptom onset	N=220,981
Patients ineligible for intravenous t-PA within 3 hours of onset	N=33,158
Patients transferred out from hospital or with unknown discharge disposition	N=754
Patients missing door-to-needle time	N=4,552
Patients presenting to sites not in Hospital Compare, with missing D2B data, or with fewer than 10 AMI patients during the study period	N=190

Final Study Population

N=12,889
Sites: 546

Figure 1. A, Primary study population flow diagram. **B**, Secondary study population flow diagram. CAD indicates coronary artery disease; GWTG, Get With The Guidelines; and tPA, tissue-type plasminogen activator.

patients treated during the study period. This resulted in a final study population of 12 889 AIS patients treated at 546 hospitals between October 2013 and September 2014 (Figure 1B).

Outcomes

D2B Time
We calculated mean and median observed D2B time at the hospital level using the GWTG-CAD data set. We used the same inclusions and exclusions as above to calculate the proportion of eligible patients with D2B time within 90 minutes at the hospital level. The denominator included all eligible patients, including those who did not receive percutaneous coronary intervention.

Finally, we used the same inclusions and exclusions as above and calculated each hospital's risk-adjusted mean D2B time using adjusted hierarchical linear mixed models. Patient characteristics included in the model were age, sex, race, medical history of chronic obstructive pulmonary disease or asthma, diabetes mellitus, heart failure, hypertension, hyperlipidemia, previous myocardial infarction, peripheral vascular disease, renal insufficiency, stroke, transient ischemic attack, smoking, body mass index, and systolic blood pressure at admission. Hospital characteristics in the model were: region, hospital type, and number of beds.

DTN Time
We calculated mean and median observed DTN time between 2006 and 2009 at the hospital level using the GWTG-Stroke data set. We used the same inclusions and exclusions as above to calculate the proportion of eligible patients with DTN time within 60 minutes at the hospital level. The denominator included all eligible patients, including those who were not treated with intravenous tPA.

Finally, we used the same inclusions and exclusions as above and calculated each hospital's risk-adjusted mean DTN time using adjusted hierarchical linear mixed models. Patient characteristics included in the model were age, sex, race, medical history of atrial fibrillation or atrial flutter, previous stroke or transient ischemic attack, coronary artery disease or previous myocardial infarction, carotid stenosis, diabetes mellitus, peripheral vascular disease, hypertension, dyslipidemia, smoking, arrival on versus off hours, and stroke severity (National Institutes of Health Stroke Scale score). Hospital characteristics included were region, hospital type, number of beds, annual ischemic stroke volume, annual intravenous tPA volume, rural location, and primary stroke center status.

Statistical Analysis
Patient and hospital characteristics are described using proportions for categorical variables and means with SDs and medians with 25th and 75th percentiles for continuous variables.

The degree of correlation between observed hospital performance on D2B time for STEMI and DTN time for ischemic stroke is described using Spearman rank correlation coefficients. The degree of correlation between risk-adjusted performance on D2B time and DTN time was calculated using hierarchical linear regression modeling with the variables outlined above. First, site-level risk-adjusted mean D2B time and DTN time were calculated as follows. A predicted/expected ratio was calculated using the following modifications: (1) instead of the observed average D2B/DTN time, the numerator is the predicted mean time (D2B/DTN) by the hierarchical model among a hospital's patients using the hospital-specific random-effect estimate and (2) the denominator is the expected average D2B/DTN time among the hospital's patients given the average of all hospital-specific effects overall. Then, the ratio of the numerator and denominator are multiplied by the observed mean D2B/DTN time across all hospitals and patients. This method is similar to that used by CMS to derive risk-standardized mortality rates.[20]

To determine the degree to which hospital-level D2B time explains the variation in DTN time when controlling for patient factors, we used linear mixed models with a random site effect to determine intraclass correlation coefficient (ICC) in DTN times. First, an unadjusted model was fit with a random intercept for each hospital, and the

ICC was calculated (ICC_A). Next, patient-level factors were added to the model as fixed effects, and the ICC was calculated (ICC_B). Then, hospital-level risk-adjusted mean D2B time was added to the model as fixed effects giving ICC_C. Finally, other hospital-level factors were added to the model as fixed effects giving ICC_D.

Next, to determine whether a hospital's performance on D2B time for STEMI is associated with performance on DTN time when controlling for patient case-mix differences, we used hierarchical linear regression modeling to calculate site-level D2B and DTN times. Hospital-level D2B times were calculated using the adjusted model described above. DTN times were then calculated using the above adjusted models and controlling for site-level D2B times.

Missing rates were minimal—most were <1% missing, except for arrival via EMS, which had a missing rate of 5.8% and National Institutes of Health Stroke Scale score, which had a missing rate of 11.4%. Multiple imputation was used to reduce missingness in all models; however, all medical history variables were imputed to no. The final estimate is the average of estimates computed on each of 25 imputed data sets. Finally, for our most contemporary analysis using GWTG-Stroke and Hospital Compare data, we used Hospital Compare data to determine the site-level proportion of eligible patients with D2B times within 90 minutes. We then used Spearman rank correlation coefficients to calculate the correlation between hospitals' D2B time within 90 minutes and DTN time within 60 minutes.

Results

Patient and Hospital Characteristics
Patient and hospital characteristics are presented in Table 1. Ischemic stroke patients were slightly older and more often women than STEMI patients and more often presented to academic/teaching hospitals. There were 61 799 patients from 43 hospitals included in the primary analysis (GWTG-Stroke and GWTG-CAD, 2006–2009) and 12 889 patients from 546 hospitals included in the secondary analysis (GWTG-Stroke and Hospital Compare, 2013–2014).

Correlation in Hospital Performance

Observed Performance
During the 2006 to 2009 study period, the median D2B time for STEMI patients was 72 minutes (interquartile range 62–80.5) and median DTN time for AIS was 84.5 minutes (interquartile range 77–90). There was no correlation in unadjusted mean or median hospital-level performance on DTN and D2B times (Spearman rank correlation coefficients r_s=−0.07 [P=0.65] and r_s=−0.09 [P=0.55], respectively; Figure 2). Similarly, there was no correlation in hospital performance on the proportion of eligible patients with D2B time within 90 minutes and DTN time within 60 minutes (r_s=−0.14; P=0.36; Figure 3).

Risk-Adjusted Performance
There was also no correlation in hospital-level risk-adjusted mean DTN and D2B times (r_s=0.19; P=0.21; Figure 4).

Of the unadjusted variation in DTN time, 17.2% was attributable to hospitals (ICC=0.172; Table 2). After including patient-level factors, the variation attributable to hospitals changed minimally (ICC=0.177). Including hospital-level risk-adjusted D2B time did not explain any of the hospital-level variation in DTN time (ICC=0.181). Finally, adding hospital-level characteristics (region, hospital type, bed number, annual stroke volume, annual tPA volume, rural location, and primary stroke center status) explained 24.3% of hospitals' variation in DTN time (ICC in fully adjusted model 0.137).

Table 1.   Characteristics of Patients and Hospitals in Primary Analysis

	Ischemic Stroke (N=1976)	Acute Myocardial Infarction (N=59 823)
Demographics		
Age, mean (SD), y	69.5 (15.0)	65.8 (13.9)
Female sex, n (%)	1000 (50.6)	22 411 (37.5)
Race/ethnicity, n (%)		
White	1388 (70.2)	45 633 (78.8)
Black	281 (14.2)	5346 (9.2)
Hispanic (any race)	79 (4.0)	3412 (5.9)
Asian	35 (1.7)	1785 (3.1)
Other	193 (9.8)	1745 (3.0)
Missing	0	1902 (3.2)
Medical history, n (%)		
Atrial fibrillation/flutter	437 (22.2)	4703 (8.2)
Prosthetic heart valve	20 (1.0)	…
Previous stroke/TIA	467 (23.7)	5305 (9.2)
CAD/previous MI	542 (27.5)	2467 (43.0)
Carotid stenosis	69 (3.5)	…
Diabetes mellitus	439 (22.3)	18 565 (32.4)
Peripheral vascular disease	58 (2.9)	5026 (8.8)
Hypertension	1395 (70.7)	39 784 (69.3)
Dyslipidemia	692 (35.1)	31 591 (55.0)
Heart failure	111 (5.6)	8546 (14.9)
COPD or asthma	*	83 234 (14.5)
Previous PCI	*	3995 (7.0)
Previous CABG	*	2713 (4.7)
Pacemaker/ICD	*	2328 (3.9)
Anemia	*	2475 (4.3)
Renal insufficiency	*	4764 (8.3)
Valvular heart disease	*	553 (1.0)
Smoker	366 (18.6)	17 651 (30.1)
Medical history missing	3 (0.2)	2431 (4.1)
Medications before admission, n (%)		
Antiplatelets	305 (43.7)	20 161 (55.5)
Anticoagulants	54 (7.8)	2496 (6.9)
Antihypertensives	1269 (65.5)	23 759 (65.4)
Cholesterol reducer	695 (35.2)	18 584 (51.2)
Patient presentation		
Arrival by EMS, n (%)	1615 (86.8)	*
Off-hour arrival†, n (%)	1026 (51.9)	28 172 (47.1)
Onset-to-arrival time (min), median (IQR)	52 (35–73)	*
Systolic blood pressure, median (IQR)	154 (136–177)	135 (118–154)

(Continued)

Table 1.   Continued

	Ischemic Stroke (N=1976)	Acute Myocardial Infarction (N=59 823)
NIHSS documented, n (%)	1750 (88.6)	*
NIHSS, median (IQR)	12 (7–18)	*
Hospital characteristics		
Academic/teaching hospital, n (%)	1480 (74.9)	42 136 (70.4)
Rural location, n (%)	0	791 (1.3)
Region, n (%)		
Northeast	355 (18.0)	7262 (12.1)
Midwest	461 (23.3)	22 799 (38.1)
South	761 (38.5)	16 008 (26.8)
West	399 (20.2)	13 754 (23.0)
Number of beds, median (IQR)	475 (331–806)	475 (325–599)
TJC primary stroke center, n (%)	1252 (63.4)	39 406 (65.9)
Annual stroke volume, median (IQR)	265 (211–343)	249 (183–299)
Annual tPA volume, median (IQR)	20 (13.3–31.8)	15.3 (8.5–20.5)
Percentage of patients with door-to-balloon time within 90 min, median (IQR)	60.3 (50.0–77.2)	68.2 (62.1–78.6)
Percentage of patients with door-to-needle time within 60 min, median (IQR)	20.8 (11.1–29.8)	14.3 (9.2–22.0)

CABG indicates coronary artery bypass grafting; CAD, coronary artery disease; COPD, chronic obstructive pulmonary disease; EMS, emergency medical services; ICD, implantable cardioverter-defibrillator; IQR, interquartile range; MI, myocardial infarction; NIHSS, National Institutes of Health Stroke Scale; PCI, percutaneous coronary intervention; TIA, transient ischemic attack; TJC, The Joint Commission; and tPA, tissue-type plasminogen activator.

*Data not collected or not applicable.

†Patients arriving during nonregular hours (regular hours: 7:00 AM to 6:00 PM Monday through Friday).

Contemporary Analysis

We then used data from Hospital Compare 2013 to 2014 and GWTG-Stroke to determine whether the relationship in hospital DTN time and D2B time has changed since our 2006 to 2009 primary study period. We found no correlation between hospital performance on the proportion of eligible patients with D2B time within 90 minutes and DTN time within 60 minutes (r_s=−0.05; P=0.22; Figure 5).

Discussion

In this hospital-level analysis, we found no correlation in hospitals' performance on emergent reperfusion for AIS and STEMI. This finding held in both observed and risk-adjusted performance on door-to-needle time for AIS and D2B time for STEMI.

Although no previous studies have specifically focused on emergency care processes between conditions, similar work has examined whether hospital performance is correlated
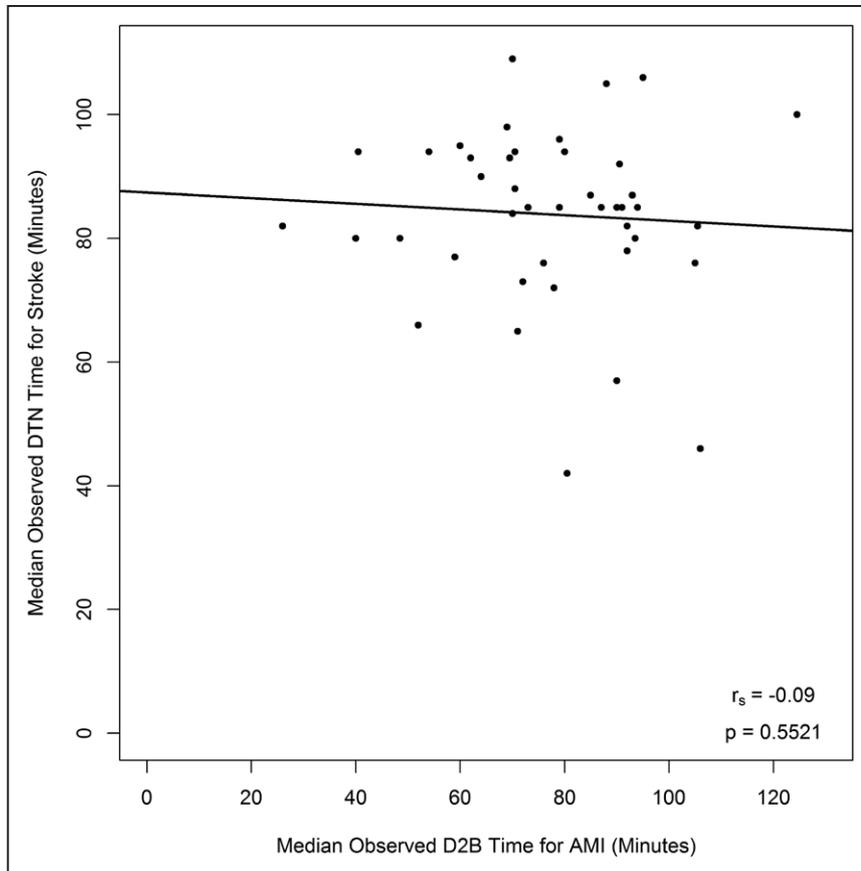
Figure 2. Scatterplot of hospital-level median observed door-to-needle (DTN) and door-to-balloon (D2B) times.

across conditions. One study examined performance on heart failure and STEMI process measures and found modest correlation in hospital-level performance between the conditions.[21] Another study by Heidenreich et al[22] found that hospitals with performance recognition awards for cardiovascular care (stroke, STEMI, and heart failure) were more likely to have high performance on CMS heart failure and coronary artery disease measures but did not necessarily have high performance on CMS pneumonia or surgical infection performance measures. Thus, although there may be spillover in hospital performance on related cardiovascular conditions, this does not seem to reflect an overall higher level of care delivery across all conditions.

Just as previous work demonstrated spillover between performance on cardiovascular conditions, we also expected to find spillover in hospitals' performance on emergency reperfusion therapy for stroke and STEMI. Both processes are based in the ED, relying on rapid recognition, multidisciplinary team activation, and timely diagnostic evaluation and decision making. Yet we did not find evidence for such a spillover effect occurring between the conditions. This may be driven by differences in the emergency evaluation and care processes. For example, there is variability in patient presentation (chest pain versus various neurological complaints); the conditions have different diagnostic evaluation processes (ECG versus detailed neurological examination and brain imaging usually head computerized tomographic scan); and the conditions have different team leadership (cardiology versus neurology). Furthermore, this team leadership manifests differently

between the conditions. A STEMI patient has a brief ED stay; STEMI recognition by the ED team is rapidly followed by patient transport to the intervention suite by the cardiology team. In contrast, after identification of a patient with a possible stroke, the neurological evaluation continues in the ED and is largely led by the stroke team. Given that obtaining an electrocardiogram and a head computerized tomography are often streamlined processes in an ED, the period from diagnostic evaluation to initiation of therapy may be where greater variation in process and performance occurs.[23] Thus, rather than D2B and DTN times, we might consider whether ischemic stroke picture-to-puncture time for endovascular therapy is the more appropriate time period to compare to D2B time.

This lack of correlation between emergency STEMI and ischemic stroke care may also reflect the different degrees of investment that have been made in process and quality improvement for the 2 conditions over time.[10] As illustrated in Figure 5, performance on D2B time for STEMI is high overall—all hospitals achieved D2B time within 90 minutes in at least 60% of patients. In contrast, DTN time performance for AIS leaves much more room for improvement, with a lower and wider range of hospital performance. It is also possible that we did not find a correlation in performance on reperfusion for stroke and STEMI because the correlation is time shifted. For example, if there is a phase delay between quality improvement interventions and performance improvement, then this analysis may have missed the correlation. Finally, the lack of correlation in hospital performance on D2B time for STEMI and DTN times for AIS may reflect that different
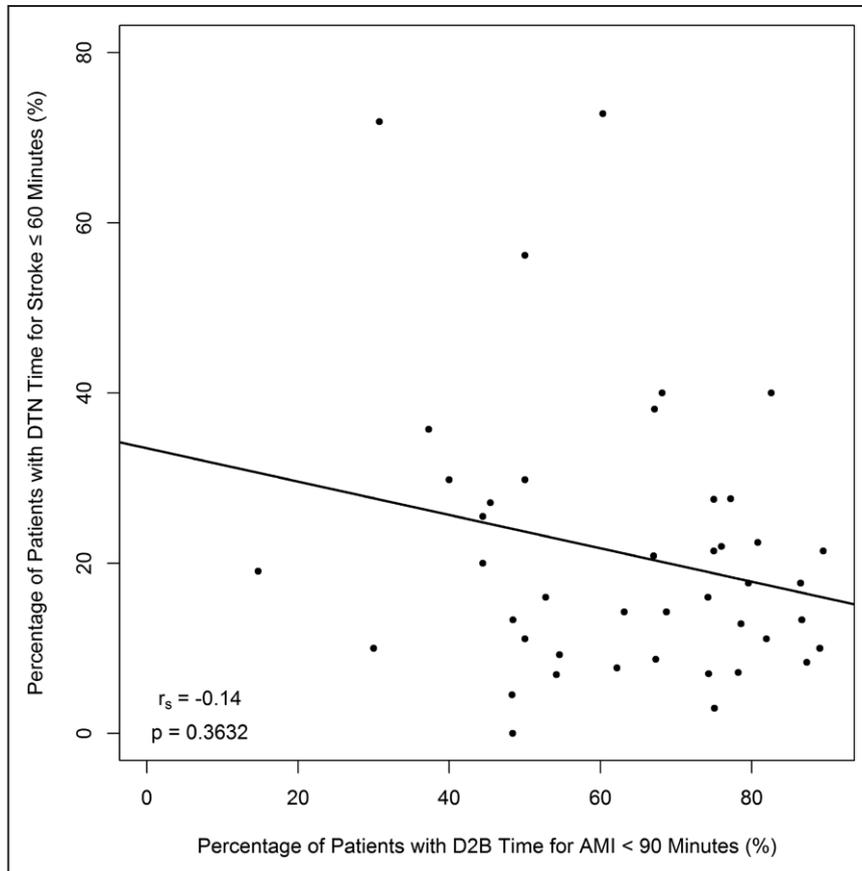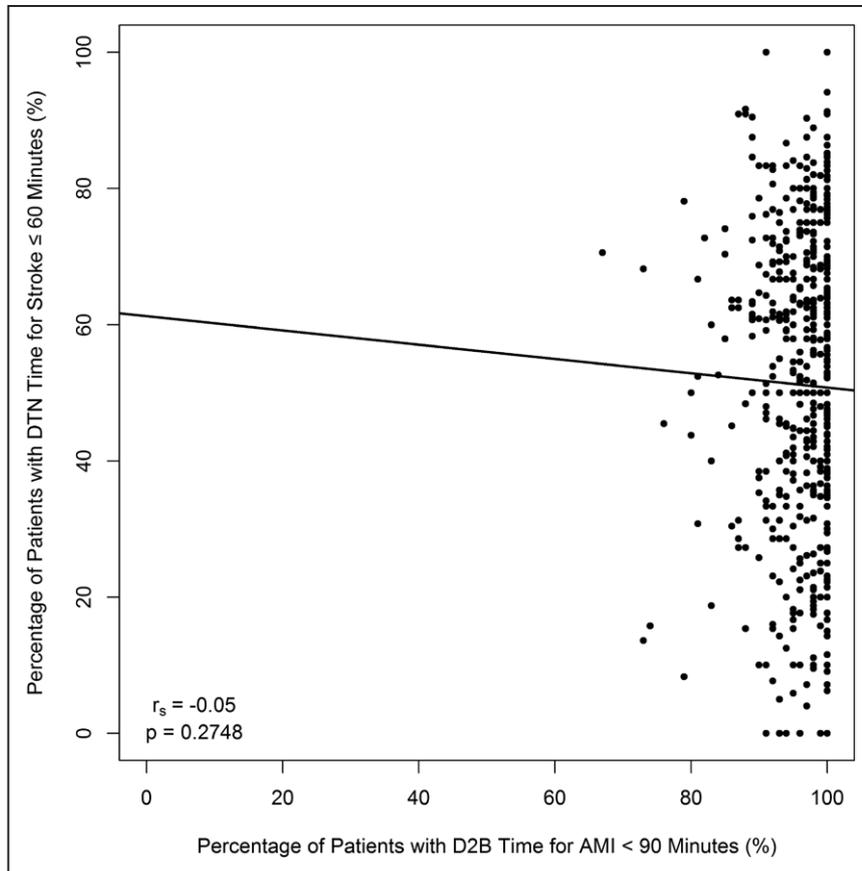
Figure 3. Scatterplot of hospital-level proportion of eligible patients with door-to-needle (DTN) times within 60 min and door-to-balloon (D2B) times within 90 min.

hospitals have different priorities. This may signal that few hospitals prioritized quality improvement efforts for both conditions.

Given this lack of correlation between hospital performance on timely reperfusion for ischemic stroke and STEMI, it will be necessary to understand the distinct drivers for ischemic stroke care. Future work may focus on exploring characteristics of hospitals with high versus low performance to better inform future quality improvement efforts for ischemic stroke.

Yet, beyond condition-specific quality improvement efforts, it is equally important to consider how to implement quality improvement processes that will raise all ships. For example, within organizations, performance improvement tends to be siloed by discipline or by department, and it may be that more interdisciplinary performance improvement work is needed. Rather than focusing on a specific condition, how can we incorporate more interprogram collaborations? When considering emergency care of stroke and STEMI, we might focus on using the prehospital and ED settings to catalyze cross-fertilization of knowledge and process improvement protocols. Although acute stroke and STEMI teams rarely interact as a whole, they do share common ED space and staff. Prehospital notification and system activation protocols for STEMI may inform approaches for AIS. Lessons learned in trauma systems may inform both. ED triage nurses and emergency physicians may facilitate interprogram collaborations, enabling stroke processes to benefit from the best practices and process improvements that have already been realized for

STEMI or trauma systems. Both hospitals and patients would benefit from such improved collaboration and streamlined, synergistic approaches.

Outside of the ED, we may also consider overall hospital structural and cultural changes that will lead to improved quality of care delivery. Wang et al[21] found that hospitals with high performance on both STEMI and heart failure measures had lower risk-adjusted mortality. Thus, there may be global, hospital-level commitments to quality that are manifested in improved quality of care delivery and lead to better patient outcomes. Hospitals achieving such outcomes may have differences in infrastructure, information technology, leadership commitment, mechanisms for feedback and accountability, or other yet-unidentified processes that elevate institutional quality globally. This will be a fruitful area for future quality improvement research.

Our study does have several limitations. First, our primary analysis focuses on hospital performance from over 5 years ago. Although this was an inherent limitation of our data, our secondary analysis confirmed similar findings in a more up-to-date analysis. Second, measurement error related to the use of summary statistics for hospital performance may have attenuated our ability to find a correlation; however, it is unlikely that our findings are because of this alone. Finally, the number of hospitals participating in both GWTG-Stroke and GWTG-CAD is small (43 hospitals, relative to the >2000 hospitals in GWTG-Stroke), and this may be a biased representation of hospitals given that our primary analysis was limited to hospitals choosing to participate in quality improvement registries
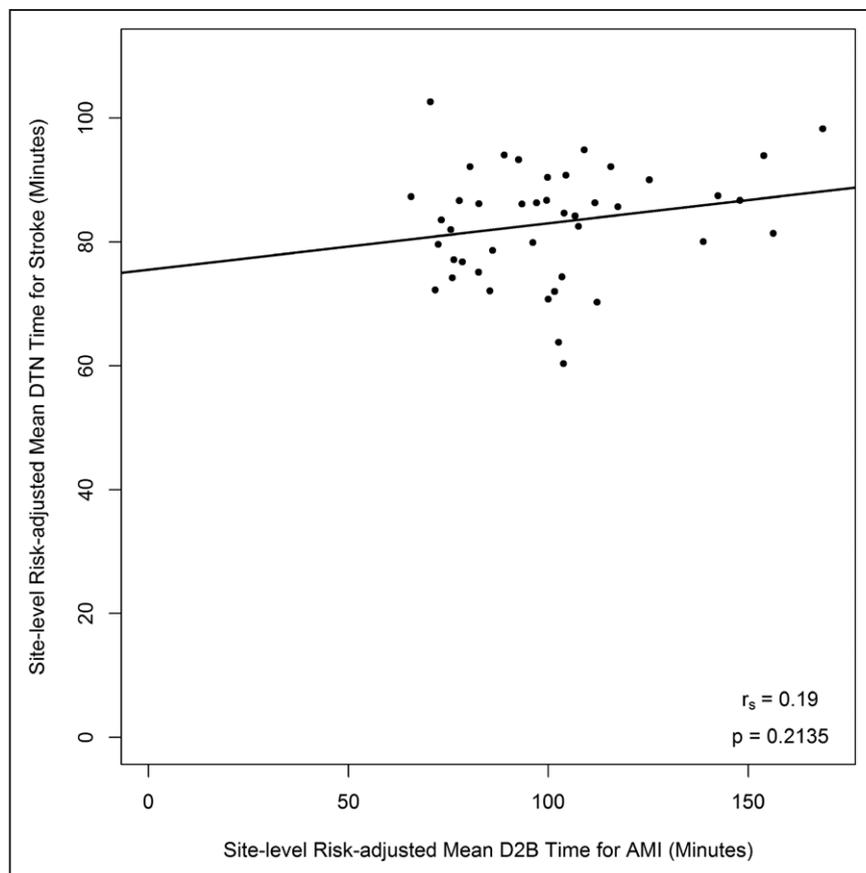
Figure 4. Scatterplot of hospital-level risk-adjusted mean door-to-needle (DTN) and door-to-balloon (D2B) times.

for both conditions. However, we would expect that this selection bias would lead to more correlation in performance between conditions given hospitals' commitment to registry participation for both conditions rather than the lack of correlation that we found.

Table 2.   Attributable Variation in Hospitals' DTN Times

Model	Proportion of Variation in DTN Attributable to Differences Between Hospitals, n (%)	Proportion of Hospital-Level Variation Explained by Addition of Underlined Factors to the Model, n (%)
A: Adjusted only for clustering by hospital	17.2	N/A
B: Adjusted for clustering by hospital and for patient characteristics	17.7	−2.9
C: Adjusted for clustering by hospital, for patient characteristics, and for hospital risk-adjusted D2B time	18.1	−2.3
D: Adjusted for clustering by hospital, for patient characteristics, for hospital risk-adjusted D2B time, and for hospital characteristics	13.7	24.3

D2B indicates door-to-balloon time for acute myocardial infarction; DTN, door-to-needle time; and N/A, not applicable.

Despite these limitations, our findings have important implications. This analysis adds to the existing literature that there is not a significant spillover in hospital performance on different conditions and adds to the imperative for more system-wide approaches to quality improvement. Rather than singularly focusing on process improvement for individual conditions, there may be value in efforts to improve timely care for multiple acute disease states with more coordinated efforts. There is the potential for synergy between AIS and STEMI process improvement to implement more widespread, broad-reaching system-level changes.

Conclusions

We found no significant correlation between hospitals' performance on D2B time for STEMI and DTN time for ischemic stroke. Future research should consider how to implement synergistic quality improvement strategies across conditions.

Sources of Funding

Figure 5. Scatterplot of hospital-level proportion of eligible patients with door-to-needle (DTN) time within 60 min and door-to-balloon (D2B) time within 90 min.

References

1. McNamara RL, Wang Y, Herrin J, Curtis JP, Bradley EH, Magid DJ, Peterson ED, Blaney M, Frederick PD, Krumholz HM, NRMI Investigators. Effect of door-to-balloon time on mortality in patients with ST-segment elevation myocardial infarction. *J Am Coll Cardiol*. 2006;47:2180–2186.
2. Berger PB, Ellis SG, Holmes DR Jr, Granger CB, Criger DA, Betriu A, Topol EJ, Califf RM. Relationship between delay in performing direct coronary angioplasty and early clinical outcome in patients with acute myocardial infarction: results from the global use of strategies to open occluded arteries in Acute Coronary Syndromes (GUSTO-IIb) trial. *Circulation*. 1999;100:14–20.
3. De Luca G, Suryapranata H, Ottervanger JP, Antman EM. Time delay to treatment and mortality in primary angioplasty for acute myocardial infarction: every minute of delay counts. *Circulation*. 2004;109:1223–1225. doi: 10.1161/01.CIR.0000121424.76486.20.

4. Marler JR, Tilley BC, Lu M, Brott TG, Lyden PC, Grotta JC, Broderick JP, Levine SR, Frankel MP, Horowitz SH, Haley EC Jr, Lewandowski CA, Kwiatkowski TP. Early stroke treatment associated with better outcome: the NINDS rt-PA stroke study. *Neurology*. 2000;55:1649–1655.

5. Hacke W, Donnan G, Fieschi C, Kaste M, von Kummer R, Broderick JP, Brott T, Frankel M, Grotta JC, Haley EC Jr, Kwiatkowski T, Levine SR, Lewandowski C, Lu M, Lyden P, Marler JR, Patel S, Tilley BC, Albers G, Bluhmki E, Wilhelm M, Hamilton S; ATLANTIS Trials Investigators; ECASS Trials Investigators; NINDS rt-PA Study Group Investigators. Association of outcome with early stroke treatment: pooled analysis of ATLANTIS, ECASS, and NINDS rt-PA stroke trials. *Lancet*. 2004;363:768–774. doi: 10.1016/S0140-6736(04)15692-4.

6. Saver JL, Smith EE, Fonarow GC, Reeves MJ, Zhao X, Olson DM, Schwamm LH; GWTG-Stroke Steering Committee and Investigators. The "golden hour" and acute brain ischemia: presenting features and lytic therapy in >30,000 patients arriving within 60 minutes of stroke onset. *Stroke*. 2010;41:1431–1439. doi: 10.1161/STROKEAHA.110.583815.

7. Saver JL, Fonarow GC, Smith EE, Reeves MJ, Grau-Sepulveda MV, Pan W, Olson DM, Hernandez AF, Peterson ED, Schwamm LH. Time to treatment with intravenous tissue plasminogen activator and outcome from acute ischemic stroke. *J Am Med Assoc*. 2013;309:2480–2488.

8. Lees KR, Bluhmki E, von Kummer R, Brott TG, Toni D, Grotta JC, Albers GW, Kaste M, Marler JR, Hamilton SA, Tilley BC, Davis SM, Donnan GA, Hacke W, Allen K, Mau J, Meier D, del Zoppo G, De Silva DA, Butcher KS, Parsons MW, Barber PA, Levi C, Bladin C, Byrnes G; ECASS, ATLANTIS, NINDS and EPITHET rt-PA Study Group. Time to treatment with intravenous alteplase and outcome in stroke: an updated pooled analysis of ECASS, ATLANTIS, NINDS, and EPITHET trials. *Lancet*. 2010;375:1695–1703. doi: 10.1016/S0140-6736(10)60491-6.

9. Hong Y, LaBresh KA. Overview of the American Heart Association "Get with the Guidelines" programs: coronary heart disease, stroke, and heart failure. *Crit Pathw Cardiol*. 2006;5:179–186. doi: 10.1097/01.hpc.0000243588.00012.79.

10. Krumholz HM, Herrin J, Miller LE, Drye EE, Ling SM, Han LF, Rapp MT, Bradley EH, Nallamothu BK, Nsa W, Bratzler DW, Curtis JP. Improvements in door-to-balloon time in the United States, 2005 to 2010. *Circulation*. 2011;124:1038–1045. doi: 10.1161/CIRCULATIONAHA.111.044107.

11. Jauch EC, Saver JL, Adams HP Jr, Bruno A, Connors JJ, Demaerschalk BM, Khatri P, McMullan PW Jr, Qureshi AI, Rosenfield K, Scott PA, Summers DR, Wang DZ, Wintermark M, Yonas H; American Heart Association Stroke Council; Council on Cardiovascular Nursing; Council on Peripheral Vascular Disease; Council on Clinical Cardiology. Guidelines for the early management of patients with acute ischemic stroke: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke*. 2013;44:870–947. doi: 10.1161/STR.0b013e318284056a.

12. 2013 Physician Quality Reporting System (PQRS) Claims/Registry Measure Specification Manual [Internet]. 2012 [cited December 26, 2013]. http://www.acr.org/~/media/ACR/Documents/P4P/Resources/2013/2013_PQRS_MeasureSpecManual.pdf.

13. Fonarow GC, Zhao X, Smith EE, Saver JL, Reeves MJ, Bhatt DL, Xian Y, Hernandez AF, Peterson ED, Schwamm LH. Door-to-needle times for tissue plasminogen activator administration and clinical outcomes in acute ischemic stroke before and after a quality improvement initiative. *JAMA*. 2014;311:1632–1640. doi: 10.1001/jama.2014.3203.

14. Nasr DM, Brinjikji W, Cloft HJ, Rabinstein AA. Racial and ethnic disparities in the use of intravenous recombinant tissue plasminogen activator and outcomes for acute ischemic stroke. *J Stroke Cerebrovasc Dis*. 2013;22:154–160. doi: 10.1016/j.jstrokecerebrovasdis.2011.07.003.

15. Kleindorfer D, Xu Y, Moomaw CJ, Khatri P, Adeoye O, Hornung R. US geographic distribution of rt-PA utilization by hospital for acute ischemic stroke. *Stroke*. 2009;40:3580–3584. doi: 10.1161/STROKEAHA.109.554626.

16. Sun CH, Bhatt DL, Nogueira RG, Gupta R. Endovascular therapy for stroke: getting to the "heart" of the matter. *Circulation*. 2014;129:1152–1160. doi: 10.1161/CIRCULATIONAHA.113.003703.

17. Smaha LA; American Heart Association. The American Heart Association Get With The Guidelines program. *Am Heart J*. 2004;148(suppl 5):S46–S48. doi: 10.1016/j.ahj.2004.09.015.

18. Schwamm LH, Fonarow GC, Reeves MJ, Pan W, Frankel MR, Smith EE, Ellrodt G, Cannon CP, Liang L, Peterson E, Labresh KA. Get With the Guidelines-Stroke is associated with sustained improvement in care for patients hospitalized with acute stroke or transient ischemic attack. *Circulation*. 2009;119:107–115. doi: 10.1161/CIRCULATIONAHA.108.783688.

19. Xian Y, Pan W, Peterson ED, Heidenreich PA, Cannon CP, Hernandez AF, Friedman B, Holloway RG, Fonarow GC. Are quality improvements associated with the Get With the Guidelines-Coronary Artery Disease (GWTG-CAD) program sustained over time? *Am Heart J*. 2010;159:207–214.

20. Implementation and Maintenance of CMS Mortality Measures for AMI & HF: Frequently Asked Questions [Internet]. 2007 [cited September 25, 2015]. http://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/HospitalQualityInits/downloads/HospitalMortalityAboutAMI_HF.pdf.

21. Wang TY, Dai D, Hernandez AF, Bhatt DL, Heidenreich PA, Fonarow GC, Peterson ED. The importance of consistent, high-quality acute myocardial infarction and heart failure care. *J Am Coll Cardiol*. 2011;58:637–644.

22. Heidenreich PA, Lewis WR, LaBresh KA, Schwamm LH, Fonarow GC. Hospital performance recognition with the Get With The Guidelines Program and mortality for acute myocardial infarction and heart failure. *Am Heart J*. 2009;158:546–553. doi: 10.1016/j.ahj.2009.07.031.

23. Sauser K, Levine DA, Nickles AV, Reeves MJ. Hospital variation in thrombolysis times among patients with acute ischemic stroke: the contributions of door-to-imaging time and imaging-to-needle time. *JAMA Neurol*. 2014;71:1155–1161. doi: 10.1001/jamaneurol.2014.1528.

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Timely Reperfusion in Stroke and Myocardial Infarction Is Not Correlated: An Opportunity for Better Coordination of Acute Care

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