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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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Abstract

Background—Timely reperfusion is critical in acute ischemic stroke (AIS) and ST Segment Elevation acute myocardial infarction (STEMI). The degree to which hospital performance is correlated on emergent STEMI and AIS care is unknown. Primary objective: to determine whether there was a positive correlation between hospital performance on door-to-balloon time (D2B) for STEMI and door-to-needle time (DTN) 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 (GWTG)-Stroke and GWTG-Coronary Artery Disease from 2006–2009 and treating 10 patients. We compared hospital-level DTN and D2B using Spearman's 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 < 60 minutes: 21% [IQR, 11–30]; median D2B < 90 minutes: 68% [IQR, 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 and D2B data from 2013–14 using GWTG (DTN) and Hospital Compare (D2B). From 2013–14, hospitals' DTN performance in GWTG was not correlated with D2B 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.

Keywords

stroke care; myocardial infarction; tissue-type plasminogen activator; emergency department; door-to-balloon time

Subject Terms

Ischemic Stroke; Myocardial Infarction; Health Services; Quality and Outcomes

Introduction

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 pre-hospital, triage, and Emergency

Department (ED) setting; both require an urgent diagnostic test in the ED prior to evaluation for time-sensitive therapeutic intervention; and both require expedient mobilization of staff and resources in order 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 & Medicaid Services (CMS) focused on improving timely treatment with fibrinolysis or percutaneous coronary intervention (PCI).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 time, D2B).¹⁰

Likewise, emergent treatment with intravenous tissue plasminogen activator (t-PA) for AIS patients has more recently become a focus for quality improvement efforts. Guidelines recommend door-to-needle time (DTN) for t-PA within 60 minutes,¹¹ and CMS requires reporting on t-PA 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 t-PA 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 acute ischemic stroke. 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 for STEMI and DTN for acute ischemic stroke and determine whether a hospital's performance on D2B for STEMI predicts performance on DTN for acute ischemic stroke after controlling for patient case-mix differences.

Methods

Data Source

We use data from GWTG-Stroke and GWTG-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, as well as 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 acute ischemic stroke by prospective clinical identification, retrospective identification using International Classification of Disease (ICD)-9 discharge codes, or a combination. ICD-9 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 emergency department records (i.e., presenting symptoms and chief complaints), ward census logs, and/or neurological consultations. The eligibility of each acute stroke or TIA admission was confirmed at chart review before abstraction. Patient data were abstracted by trained hospital personnel. These included demographics, medical history, initial head computerized tomography (CT) 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 door to needle times 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 two-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 t-PA, 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 2006–2009 (Figure 1a). To determine hospitals' DTN times, we included AIS patients treated with intravenous t-PA. We excluded patients with in-hospital stroke, enrolled in a clinical trial, admitted for elective carotid intervention, and with DTN time greater than 24 hours. To determine hospitals' D2B times, we included patients with an STEMI (ST elevation MI [STEMI]) or STEMI/non-ST elevation

MI [NSTEMI] unspecified) with a first ECG diagnostic for ST segment elevation or left bundle branch block who underwent PCI. We excluded patients transferred in, transferred from another ED, who received thrombolytic therapy, with a reason for delay in PCI, and with a D2B time greater than 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 datasets are the official data used by CMS comparing care at over 4,000 Medicare-certified hospitals in the U.S. Data are freely available at data.medicare.gov. Using the hospital ID, we linked the hospital-level D2B for STEMI with DTN 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, not transferred out, and without missing DTN time. We further excluded sites with fewer than 10 AIS 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–September 2014 (Figure 1b).

Outcomes

Door-to-Balloon Time (D2B)—We calculated mean and median observed D2B time at the hospital level using the GWTG-CAD dataset. 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 PCI.

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 COPD or asthma, diabetes, 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.

Door-to-Needle Time (DTN)—We calculated mean and median observed DTN time between 2006–2009 at the hospital level using the GWTG-Stroke dataset. 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 iv t-PA.

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, gender, 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, peripheral vascular disease, hypertension, dyslipidemia, smoking, arrival on versus off hours, and stroke severity

(National Institutes of Health Stroke Scale score, NIHSS). Hospital characteristics included were: region, hospital type, number of beds, annual ischemic stroke volume, annual intravenous t-PA volume, rural location, and primary stroke center status.

Statistical Analysis

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

The degree of correlation between observed hospital performance on D2B for STEMI and DTN for ischemic stroke is described using Spearman's rank correlation coefficients. The degree of correlation between risk-adjusted performance on D2B and DTN was calculated using hierarchical linear regression modeling with the variables outlined above. First, site-level risk-adjusted mean D2B and DTN 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; 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

In order to determine the degree to which hospital-level D2B explains the variation in DTN 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 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, in order to determine whether a hospital's performance on D2B for STEMI is associated with performance on DTN 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 less than 1% missing, except for arrival via EMS, which had a missing rate of 5.8% and NIHSS 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 datasets. 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's rank correlation coefficients to calculate the correlation between hospitals' D2B within 90 minutes and DTN 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 female 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, 2006–09), and 12,889 patients from 546 hospitals included in the secondary analysis (GWTG-Stroke and Hospital Compare, 2013–14).

Correlation in Hospital Performance

Observed Performance—During the 2006–2009 study period, the median D2B for STEMI patients was 72 minutes (IQR 62–80.5) and median DTN for AIS was 84.5 minutes (IQR 77–90). There was no correlation in unadjusted mean or median hospital-level performance on DTN and D2B times (Spearman's 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 (intraclass correlation coefficient, $ICC=0.172$) (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 ($ICC=0.181$). Finally, adding hospital-level characteristics (region, hospital type, bed number, annual stroke volume, annual t-PA volume, rural location, and primary stroke center status) explained 24.3% of hospitals' variation in DTN (ICC in fully adjusted model 0.137).

Contemporary Analysis—We then used data from Hospital Compare 2013–2014 and GWTG-Stroke to determine whether the relationship in hospital DTN and D2B has changed since our 2006–2009 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 acute ischemic stroke and STEMI. This finding held in both observed and risk-adjusted performance on door-to-needle time for acute ischemic stroke and door-to-balloon time for STEMI.

While no previous studies have specifically focused on emergency care processes between conditions, similar work has examined whether hospital performance is correlated 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 and colleagues found that hospitals with performance recognition awards for cardiovascular care (stroke, STEMI, and/or 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.²² Thus, while 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 (electrocardiogram versus detailed neurological exam and brain imaging usually head CT 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 very 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 EKG and a head CT 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.

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 two conditions over time.¹⁰ As illustrated in Figure 5, performance on door-to-balloon time for STEMI is very high overall – all hospitals achieved D2B time within 90 minutes in at least 60% of patients. In contrast, DTN performance for acute ischemic stroke 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 for STEMI and DTN times for AIS may reflect that different 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 inter-program collaborations? When considering emergency care of stroke and STEMI, we might focus on utilizing the pre-hospital and ED settings to catalyze cross-fertilization of knowledge and process improvement protocols. While acute stroke and STEMI teams rarely interact as a whole, they do share common ED space and staff. Pre-hospital 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 inter-program 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 and colleagues found that hospitals with high performance on both STEMI and heart failure measures had lower risk-adjusted mortality.²¹ 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 five years ago. While this was an inherent limitation of our data, our secondary analysis confirmed similar findings in a more up-to-date analysis. Secondly, 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 due to this alone. Finally, the number of hospitals participating in both GWTG-Stroke and GWTG-CAD is small (43 hospitals, relative to the more than 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 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.

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 in order to implement more widespread, broad-reaching system-level changes.

Conclusions

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

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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 appears to be spillover between performance on cardiovascular conditions within hospitals.

What the Study Adds

- This study found no correlation between hospital performance on door-to-balloon time (D2B) for STEMI and door-to-needle time (DTN) for acute ischemic stroke.
- This held in observed as well as risk-adjusted analyses.
- These results suggest that future research should consider how to implement synergistic quality improvement strategies across conditions.

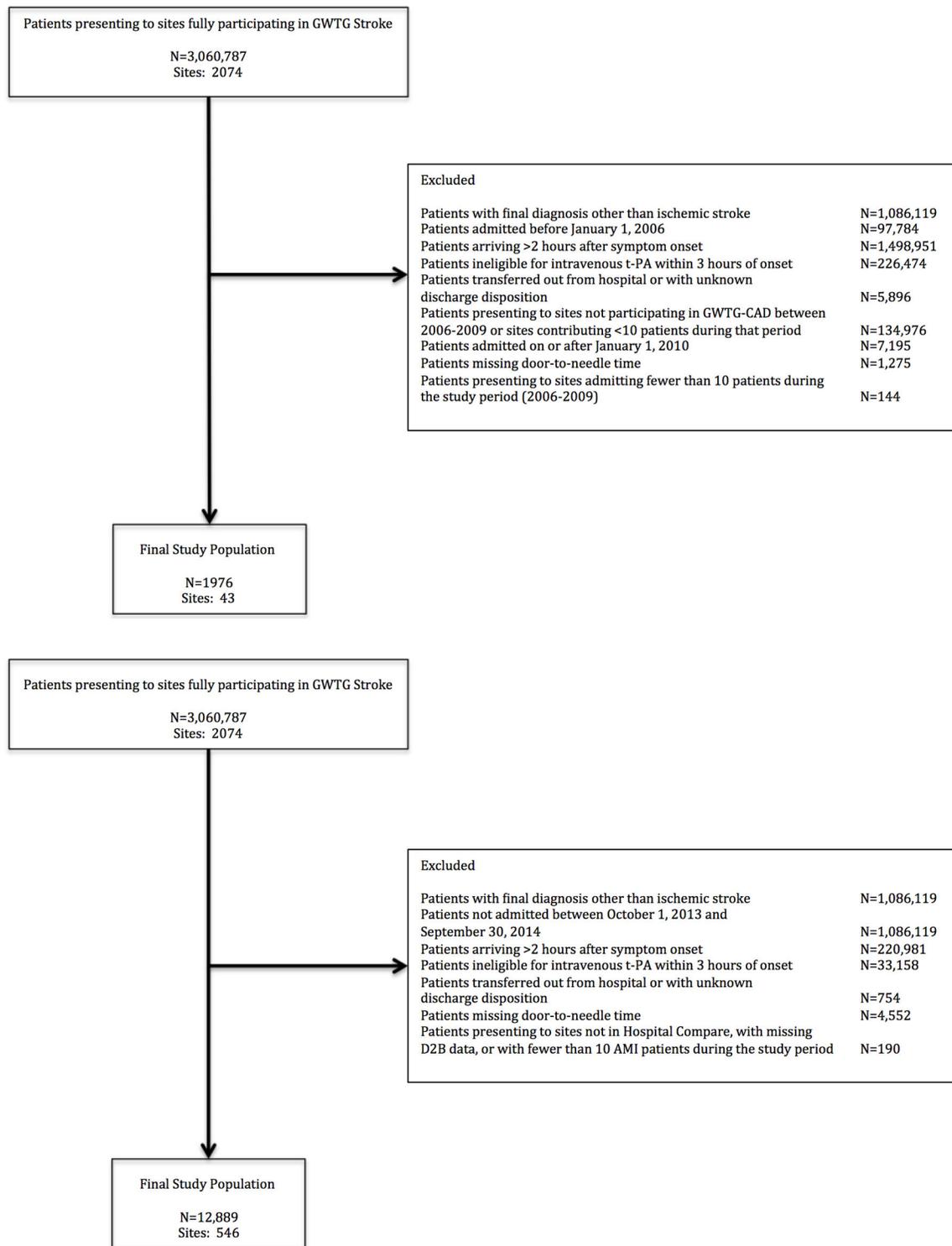


Figure 1.
A, Primary Study Population Flow Diagram. B, Secondary Study Population Flow Diagram.

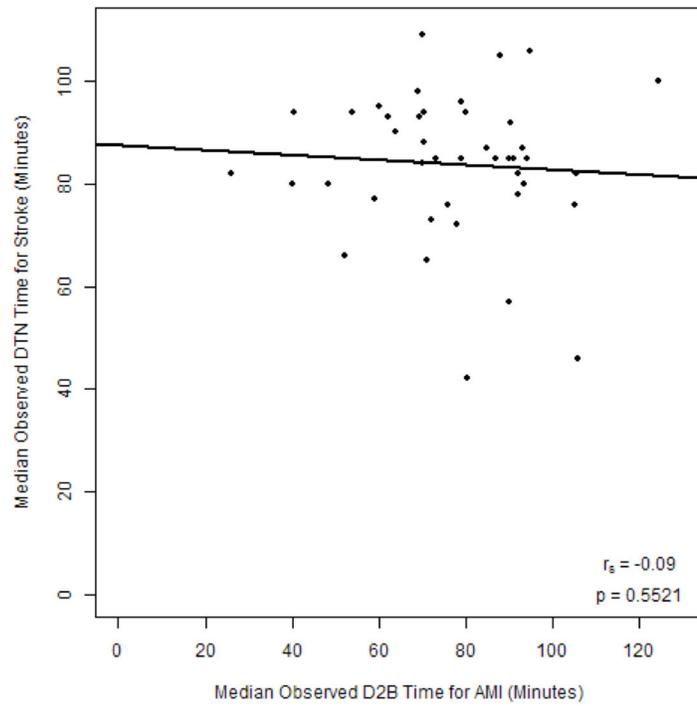


Figure 2. Scatterplot of Hospital-level Median Observed DTN and D2B times. DTN: Door-to-Needle for acute ischemic stroke patients; D2B: door-to-balloon for acute myocardial infarction patients.

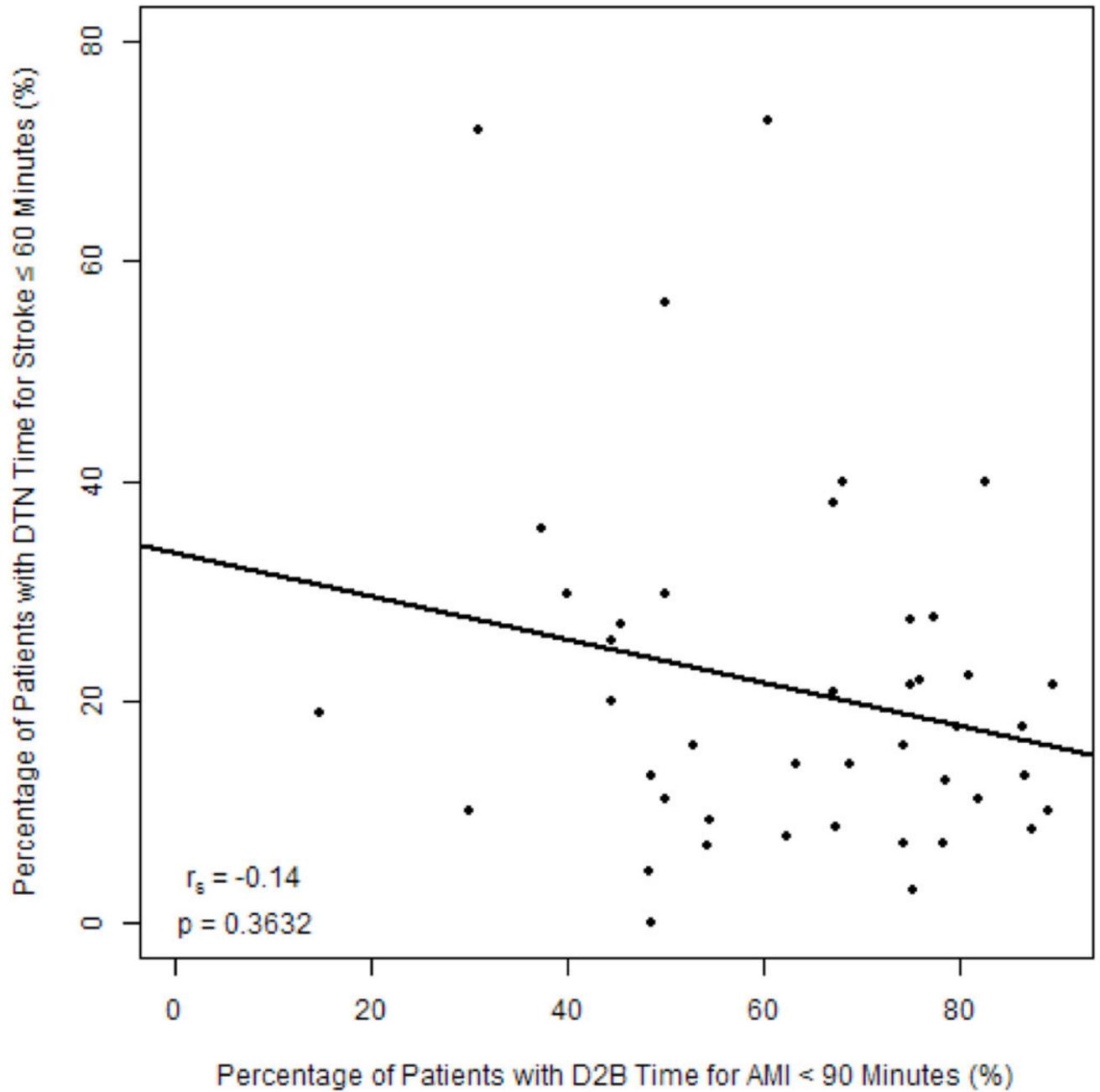


Figure 3. Scatterplot of Hospital-level Proportion of Eligible Patients with DTN times within 60 minutes and D2B times within 90 minutes. Door-to-Needle for acute ischemic stroke patients; D2B: door-to-balloon for acute myocardial infarction patients

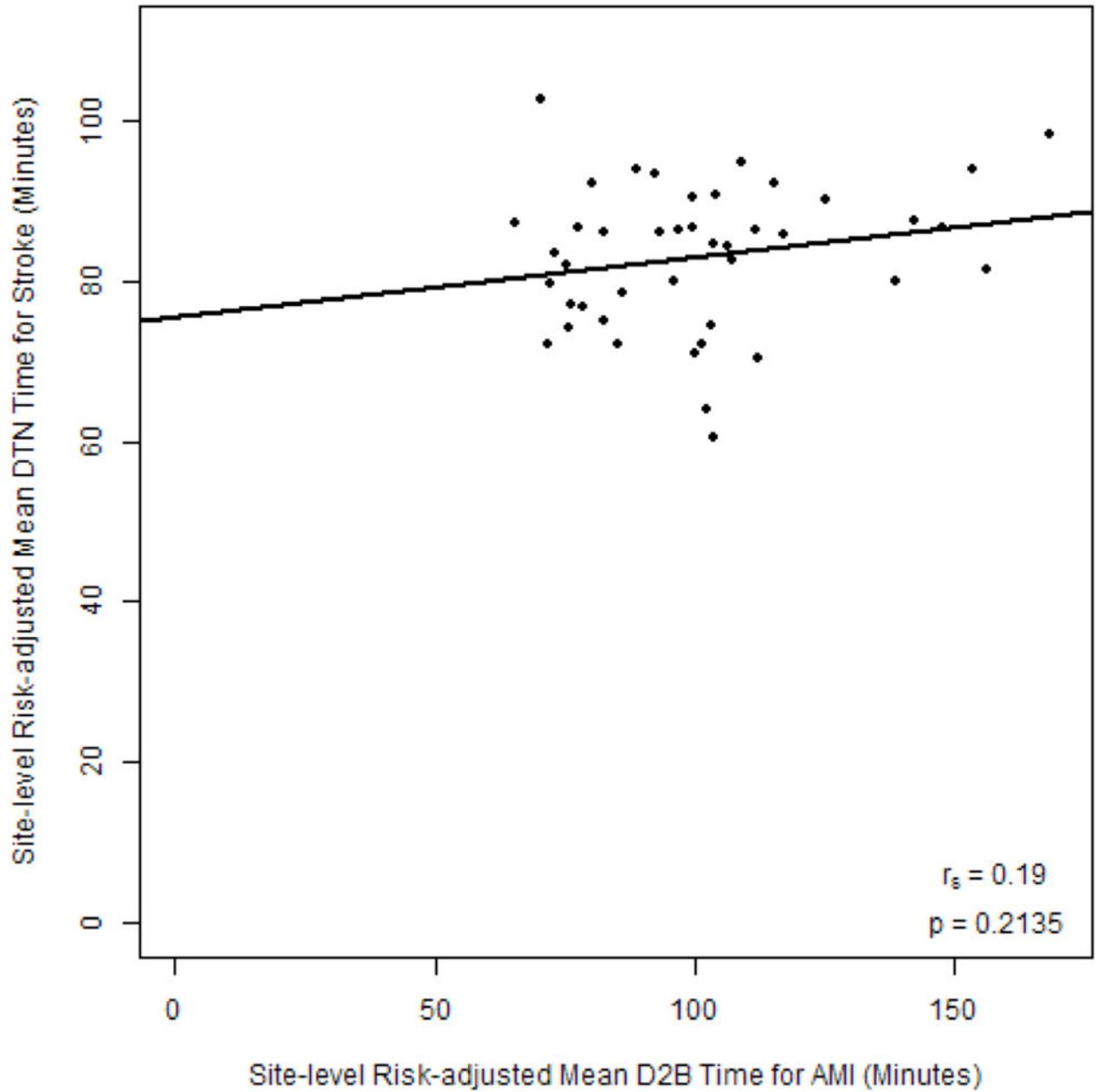


Figure 4. Scatterplot of Hospital-level Risk-adjusted Mean DTN and D2B times. Door-to-Needle for acute ischemic stroke patients; D2B: door-to-balloon for acute myocardial infarction patients

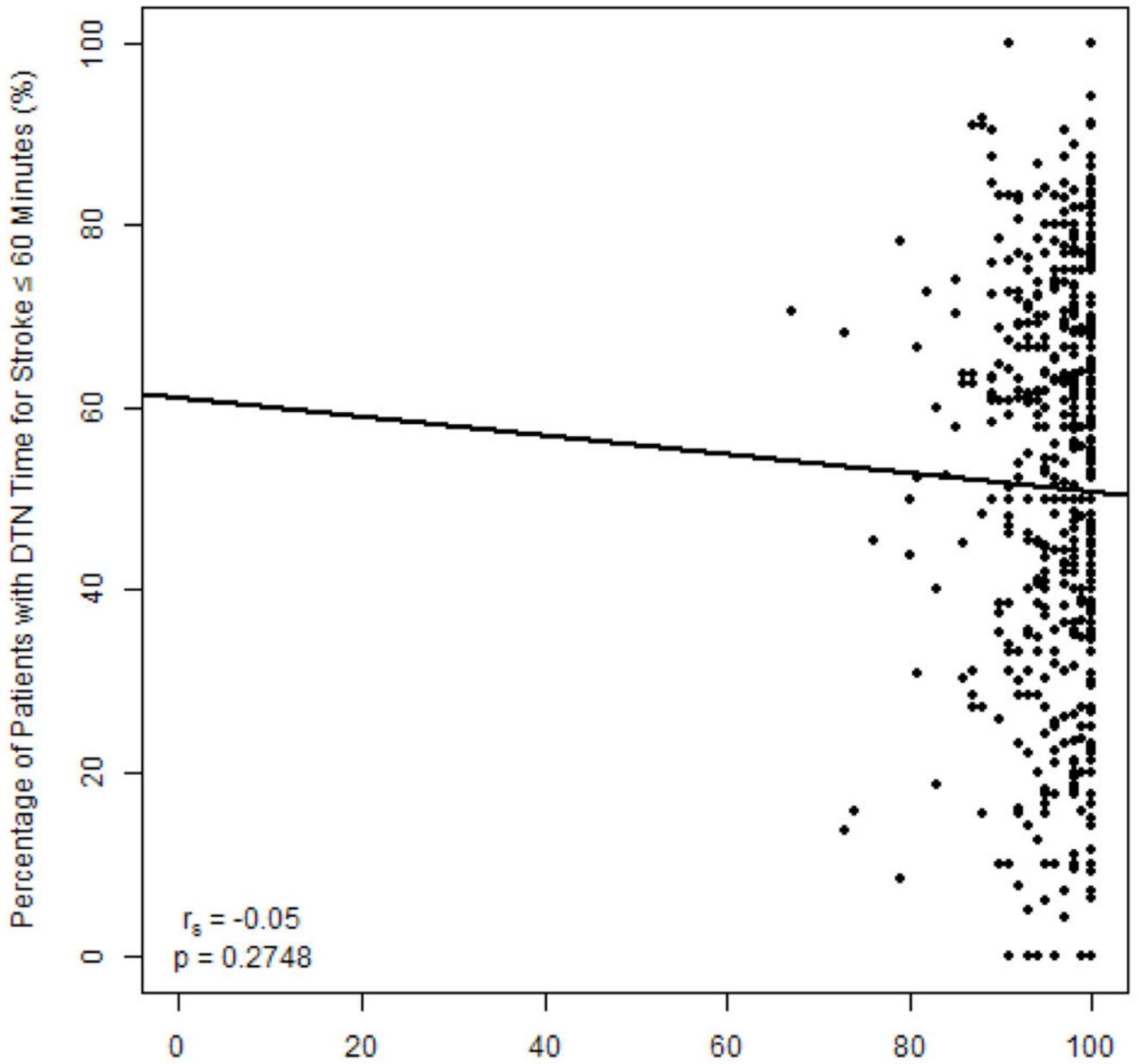


Figure 5. Scatterplot of Hospital-level Proportion of Eligible Patients with DTN time within 60 minutes and D2B time within 90 minutes. Door-to-Needle for acute ischemic stroke patients; D2B: door-to-balloon for acute myocardial infarction patients

Table 1

Characteristics of Patients and Hospitals in Primary Analysis

	Ischemic Stroke N=1976	Acute Myocardial Infarction, N=59,823
Demographics		
Age, mean (SD)	69.5 (15.0)	65.8 (13.9)
Female gender, n (%)	1000 (50.6%)	22411 (37.5%)
Race/ethnicity, n (%)		
White	1388 (70.2%)	45633 (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/Prior MI	542 (27.5%)	2467 (43.0%)
Carotid stenosis	69 (3.5%)	
Diabetes Mellitus	439 (22.3%)	18565 (32.4%)
Peripheral Vascular Disease	58 (2.9%)	5026 (8.8%)
Hypertension	1395 (70.7%)	39784 (69.3%)
Dyslipidemia	692 (35.1%)	31591 (55.0%)
Heart failure	111 (5.6%)	8546 (14.9%)
COPD or asthma	*	83234 (14.5%)
Prior PCI	*	3995 (7.0%)
Prior CABG	*	2713 (4.7%)
Pacemaker/ICD	*	2328 (3.9%)
Anemia	*	2475 (4.3%)
Renal Insufficiency	*	4764 (8.3%)
Valvular heart disease	*	553 (1.0%)

	Ischemic Stroke N=1976	Acute Myocardial Infarction, N=59,823
Smoker	366 (18.6%)	17651 (30.1%)
Medical history missing	3 (0.2%)	2431 (4.1%)
Medications Prior to Admission		
Antiplatelets	305 (43.7%)	20161 (55.5%)
Anticoagulants	54 (7.8%)	2496 (6.9%)
Antihypertensives	1269 (65.5%)	23759 (65.4%)
Cholesterol-reducer	695 (35.2%)	18584 (51.2%)
Patient Presentation		
Arrival by EMS	1615 (86.8%)	*
Off-hours arrival [†]	1026 (51.9%)	28172 (47.1%)
Onset-to-arrival time (min), median (IQR)	52 (35–73)	*
Systolic blood pressure, median (IQR)	154 (136–177)	135 (118–154)
NIHSS documented	1750 (88.6%)	*
NIHSS, median (IQR)	12 (7–18)	*
Hospital Characteristics		
Academic/teaching hospital	1480 (74.9%)	42136 (70.4%)
Rural location	0	791 (1.3%)
Region		
Northeast	355 (18.0%)	7262 (12.1%)
Midwest	461 (23.3%)	22799 (38.1%)
South	761 (38.5%)	16008 (26.8%)
West	399 (20.2%)	13754 (23.0%)
Number of beds, median (IQR)	475 (331–806)	475 (325–599)
TJC Primary Stroke Center	1252 (63.4%)	39406 (65.9%)
Annual Stroke Volume, median (IQR)	265 (211–343)	249 (183–299)
Annual t-PA Volume, median (IQR)	20 (13.3–31.8)	15.3 (8.5–20.5)
Percentage of patients with Door-to-balloon time within 90 minutes, median (IQR)	60.3 (50.0–77.2)	68.2 (62.1–78.6)

	Ischemic Stroke N=1976	Acute Myocardial Infarction, N=59,823
Percentage of patients with Door-to-needle time within 60 minutes, median (IQR)	20.8 (11.1–29.8)	14.3 (9.2–22.0)

* Data not collected or not applicable;

† Patients arriving during non-regular hours (regular hours: 7am–6pm Monday through Friday)

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Table 2

Attributable Variation in Hospitals' Door-to-Needle (DTN) Times

Model	Proportion of Variation in DTN Attributable to Differences between Hospitals	Proportion of Hospital-level variation explained by addition of underlined factors to the model
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 time: door-to-balloon time for acute myocardial infarction

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