There are important parallels between the emergent care of acute ischemic stroke (AIS) and ST-segment–elevation myocardial infarction (STEMI). The central tenet of emergent care is the same: timely reperfusion is critical and is associated with better patient outcomes.1–4 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.

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 pre-defined 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.

Additional descriptions of the case ascertainment, data collection, and quality-auditing methods have been previously published.

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 176 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
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-Stroke 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 (ICCa). Next, patient-level factors were added to the model as fixed effects, and the ICC was calculated (ICCb). Then, hospital-level risk-adjusted mean D2B time was added to the model as fixed effects giving ICCc. Finally, other hospital-level factors were added to the model as fixed effects giving ICCd.

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 rs=−0.07 [P=0.65] and rs=−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 (rs=−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 (rs=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).
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
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 2. Scatterplot of hospital-level median observed door-to-needle (DTN) and door-to-balloon (D2B) times.
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. 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-identified 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.
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 to implement more widespread, broad-reaching system-level changes.

**Table 2. Attributable Variation in Hospitals’ DTN Times**

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

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**

The investigation was funded by a GWTG Young Investigator Database Research Seed Grant. The GWTG-Stroke program is provided by the American Heart Association (AHA)/American Stroke Association and is currently sponsored by Medtronic. GWTG-Stroke has been funded in the past through support from Boeringher-Ingelheim, Merck, Bristol-Myers Squib/Sanofi Pharmaceutical Partnership, Janseen Pharmaceutical Companies of Johnson & Johnson and the AHA Pharmaceutical Roundtable; none of these companies participated in the design, analysis, article preparation, or approval.
Disclosures

Dr Levine reports receiving funding from National Institutes of Health/National Institute on Aging (K23AG040278); receiving consulting fees from AstraZeneca and the National Institute of Neurological Disorders and Stroke for work on clinical trials; receiving a grant from the Michigan Alzheimer’s Disease Center; and serving as a member of the program advisory committee for the Kaiser Permanente Northern California-University of California, San Francisco, Stroke Prevention/Intervention Research Program. Dr Fonarow reports being steering committee member of American Heart Association (AHA) GWTG and research support from the Patient-Centered Outcomes Research Institute (PCORI). Dr Bhatt discloses the following relationships—Advisory Board: Cardax, Elsevier Practice Update Cardiology, Medscape Cardiology, and Regado Biosciences; Board of Directors: Boston VA Research Institute and Society of Cardiovascular Patient Care; Chair: AHA Quality Oversight Committee; Data Monitoring Committees: Duke Clinical Research Institute, Harvard Clinical Research Institute, Mayo Clinic, and Population Health Research Institute; Honoraria: American College of Cardiology (Senior Associate Editor, Clinical Trials and News, ACC.org), Belvoir Publications (Editor in Chief, Harvard Heart Letter), Duke Clinical Research Institute (clinical trial steering committees), Harvard Clinical Research Institute (clinical trial steering committees), HMP Communications (Editor in Chief, Journal of Invasive Cardiology), Journal of the American College of Cardiology (Guest Editor; Associate Editor), Population Health Research Institute (clinical trial steering committee), Slack Publications (Chief Medical Editor, Cardiology Today’s Intervention), Society of Cardiovascular Patient Care (Secretary/Treasurer), WebMD (CME steering committees); Other: Clinical Cardiology (Deputy Editor), NCDR-ACTION Registry Steering Committee (Chair), VA CART Research and Publications Committee (Chair); Research Funding: Amarin, Amgen, AstraZeneca, Bristol-Myers Squibb, Eisai, Ethicon, Forest Laboratories, Ischemix, Medtronic, Pfizer, Roche, Sanofi Aventis, and The Medicines Company; Royalties: Elsevier (Editor, Cardiovascular Intervention: A Companion to Braunwald’s Heart Disease); Site Co-Investigator: Biotronik, Boston Scientific, and St. Jude Medical; Trustee: American College of Cardiology; Unfunded Research: FlowCo, Plx Pharma, and Takeda. Dr Smith reports being a member of the Steering Committee of AHA GWTG. Dr Schwamm serves as a volunteer for the AHA as chair of the stroke clinical workgroup for GWTG-Stroke. He serves as the PI of an NINDS-funded SPOTRIAS network trial, MR WITNESS, which is a phase 2 safety study of alteplase delivered in an extended time window with MR-guided patient selection (NCT01262242). The study is funded primarily by NINDS, and alteplase is provided by Genentech to MGH for distribution to sites and for modest per-patient supplemental site payments. Genentech has no control over study design, analysis, or publication. Dr Schwamm reports receiving significant research support from the PCORI; serving as a stroke systems consultant to the Massachusetts Department of Public Health; and serving as a scientific consultant regarding trial design and conduct to Lundbeck (international steering committee, DIA3, 4 trial), Medtronic (steering committees REACT-AF, STROKE-AF), and Penumbra (data and safety monitoring committee, Separator 3D trial).

References


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.


Timely Reperfusion in Stroke and Myocardial Infarction Is Not Correlated: An Opportunity for Better Coordination of Acute Care
Kori Sauser Zachrison, Deborah A. Levine, Gregg C. Fonarow, Deepak L. Bhatt, Margueritte Cox, Phillip Schulte, Eric E. Smith, Robert E. Suter, Ying Xian and Lee H. Schwamm

Circulation: Cardiovascular Quality and Outcomes is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 1941-7705. Online ISSN: 1941-7713

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