# Hospital 30-Day, All-Cause, Risk-Standardized Mortality Rate (RSMR) Following Acute Ischemic Stroke Hospitalization with Claims-Based Risk Adjustment for Stroke Severity Technical Report (Version 1.0)

**Submitted By**

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**Prepared For:**

Centers for Medicare & Medicaid Services (CMS)

**March 2016**

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**ACKNOWLEDGEMENTS**

This work is a collaborative effort and the authors gratefully acknowledge and thank our many colleagues and collaborators for their thoughtful and instructive input.

Specifically, we would like to acknowledge the American Heart Association and American Stroke Association (AHA/ASA) for their contribution of data, our colleagues affiliated with the AHA/ASA, and those affiliated with the Yale School of Medicine for their insights and work on developing the stroke mortality measures. Without their continued support, this project would not have been possible:

Gregg Fonarow, MD
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We appreciate the ongoing contributions to this work from our consultants and colleagues at CORE. These individuals include:

Kanchana Bhat, M.P.H.
Jacqueline Grady, M.S.
Jessica Brewer, M.P.H.
Lori Schroeder, LL.M., J.D.

Finally, we would like to thank our Contracting Officer Representative at the Centers for Medicare & Medicaid Services, Dr. Lein Han, for her continued support of our work.

## 1. EXECUTIVE SUMMARY

The Centers for Medicare & Medicaid Services (CMS) publicly report a 30-day hospital-level stroke mortality measure as part of the Inpatient Quality Reporting (IQR) program. CMS contracted with Yale New Haven Services Corporation, Center for Outcomes Research and Evaluation (CORE) to develop an updated stroke mortality measure that includes an assessment of stroke severity in the risk-adjustment model. This work was initiated in response to stakeholder feedback about the publicly reported measure and grows out of CMS's commitment to continually improve on quality measures, as well as to seek opportunities to develop measures with clinical data. This updated measure work became possible in part due to changes in clinical guidelines and hospital practices that allow for more standard collection of stroke severity.

CORE collaborated with the American Heart Association/American Stroke Association (AHA/ASA) to complete this work. Based on a review of the literature, community feedback, and current clinical guidelines for stroke care, we selected the National Institutes of Health Stroke Scale (NIHSS) as the stroke severity assessment to be incorporated into the measure. Scheduled for October 2016, codes for the NIHSS will be added to the International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10) and could be incorporated into an administrative claims-based measure. Alternatively, the NIHSS could be extracted from the electronic health record (EHR) to develop a measure that uses both administrative claims data and EHR data (hybrid measure). Therefore, a measure could be developed using NIHSS scores obtained from Medicare administrative claims or from the EHR in the future.

The cohort and outcome of this measure is aligned with CMS's publicly reported stroke mortality measure. We developed the updated mortality measure using a linked dataset consisting of Medicare fee-for-service (FFS) claims and AHA/ASA Get With The Guidelines® (GWTG)-Stroke registry data. GWTG-Stroke registry data were used because at the time of measure development (2015), it was the largest database that included the NIHSS. For this measure, the registry data served as a proxy for NIHSS codes that will be captured in administrative claims in the future.

This report presents an updated claims model that includes 19 claims data-derived variables and the NIHSS. This measure accounts for stroke severity, has a modestly higher c-statistic, and is more parsimonious than the publicly reported stroke mortality measure.

# 2. INTRODUCTION

## 2.1 Overview

The Centers for Medicare & Medicaid Services (CMS) publicly report a 30-day hospital-level stroke mortality measure on *Hospital Compare* as part of the Inpatient Quality Reporting (IQR) program. This measure is calculated using administrative claims data. CMS contracted with Yale New Haven Services Corporation, Center for Outcomes Research and Evaluation (CORE) to develop an updated stroke mortality measure that includes an assessment of stroke severity in the risk-adjustment model. This work was initiated in response to stakeholder feedback about the publicly reported measure, a commitment to seek opportunities to develop measures with richer clinical data, changes in clinical guidelines and hospital practices that allow for more standard collection of stroke severity, and in an effort to continually improve on existing quality measures.

CORE collaborated with the American Heart Association/American Stroke Association (AHA/ASA) to form a working group to determine how best to incorporate an assessment of a patient's stroke severity into hospital-level outcome measures. The AHA/ASA is one of the nation's preeminent non-profit public health organizations with a long history of work in this area. They possess and supplied CORE with Get With The Guidelines® (GWTG)-Stroke registry data that were used in the development of the measure.

Based on a review of the literature and current clinical guidelines for stroke care, the National Institutes of Health Stroke Scale (NIHSS) was selected as the stroke severity assessment to be incorporated in the measure. Clinical guidelines recommend the collection of the NIHSS on most stroke patients. Furthermore, early in the measure development process, we determined that a measure could be developed using NIHSS scores obtained from Medicare administrative claims. Scheduled for October 2016, codes for the NIHSS will be added to the International Statistical Classification of Diseases and Related Health Problems 10th Revision (ICD-10) and could be incorporated into an administrative claims-based measure.

The updated stroke mortality measure was developed using a linked dataset consisting of Medicare fee-for-service (FFS): administrative claims data and AHA/ASA Get With The Guidelines® (GWTG)-Stroke registry data abstracted from medical records. Data from this registry were used to develop the measure because at the time of measure development, the GWTG-Stroke registry was the largest database that included the NIHSS. However, the intent of this measure is to be implemented in a national dataset and calculated using only claims data. This measure can be implemented once the NIHSS is collected consistently through ICD-10 codes.

In alignment with the publicly reported stroke mortality measure, the updated measure estimates the hospital-level, risk-standardized mortality rate (RSMR) for patients discharged from the hospital with a principal discharge diagnosis of acute ischemic stroke. The outcome is all-cause 30-day mortality, defined as death from any cause within 30 days of the index admission date, whether in-hospital or not.

## 2.2 Importance of Stroke Mortality Measures

Stroke is the fourth most common cause of death in the United States, affecting approximately 795,000 people annually, and has a 30-day mortality rate that varies by age from 9% in patients 65 to 74 years of age, 13.1% in those 74 to 84 years of age, and 23% in those ≥85 years of age.[1-3] Mortality following

stroke is an important adverse outcome that can be measured reliably and objectively and is influenced by the quality of care provided to patients during their initial hospitalization; therefore, mortality is an appropriate measure of quality of care following stroke hospitalization.[4,5] Specifically, post-stroke mortality rates have been shown to be influenced by critical aspects of care such as response to complications, speediness of delivery of care, organization of care, and appropriate imaging.[6-9] This work demonstrates the relationship between hospital organizational factors and performance on the stroke mortality measure and supports the ability of hospitals to impact these rates.

Measurement of patient mortality allows for a broad view of quality of care that encompasses more than what can be captured by individual process-of-care measures. The goal of outcome measurement is to identify institutions whose performance is better or worse than would be expected based on their patient case mix, by risk adjusting for patients' conditions at the time of hospital admission. The goal of reporting a stroke outcome measure is to improve patient outcomes by providing patients, physicians, and hospitals with information about hospital-level RSMRs following hospitalization for acute ischemic stroke.

### 2.3 Rationale for Updated Stroke Mortality Measure

Clinicians and stakeholders, including the AHA/ASA and other professional organizations, highlight the importance of including an assessment of stroke severity in risk-adjustment models of stroke mortality. The publicly reported stroke mortality measure uses only administrative claims data for risk adjustment and does not include an assessment of stroke severity. Therefore, this updated measure seeks to satisfy stakeholders' and CMS's preferences by incorporating an assessment of stroke severity into the risk-adjustment model.

Several studies have demonstrated that the initial stroke severity score is one of the strongest predictors of mortality in ischemic stroke patients.[10-12] The NIHSS, which was created in 1989 and is widely used in routine stroke care, is collected in the GWTG-Stroke registry, which has over 1,700 hospitals throughout the U.S.[13] The NIHSS is a 15-item neurologic examination stroke scale used to provide a quantitative measure of stroke-related neurologic deficit. The NIHSS evaluates the effect of acute ischemic stroke on a patient's level of consciousness, language, neglect, visual-field loss, extra-ocular movement, motor strength, ataxia, dysarthria, and sensory loss. The NIHSS was designed to be a simple, valid, and reliable tool that can be administered at the bedside consistently by neurologists, physicians, nurses, or therapists. The use of the NIHSS to measure stroke severity in acute ischemic stroke patient presentation is Class I recommended in the AHA/ASA guidelines. [14]

We are now able to incorporate an assessment of stroke severity into this measure due to a recent increase in the collection and ability to obtain these assessments, which is likely due in part to the AHA/ASA guidelines that recommend administering a stroke severity scale – specifically, the NIHSS – on all stroke patients.[14] The current project is timely, as the NIHSS will soon be included in claims data for ICD-10, thereby allowing hospitals to incorporate this stroke severity assessment and report through claims data.

In summary, in response to stakeholder feedback and in an effort to continually improve on existing quality measures, we aimed to develop an updated stroke mortality measure that incorporates stroke severity, and that could be implemented using claims data.

# 3. METHODOLOGY

## 3.1 Overview

This section provides details about the development of the hospital risk-standardized stroke mortality measure, including the identification of relevant data sources, the cohort definition, variable selection for the risk-adjustment model, and model testing. In developing this measure, we followed the standards set forth in the development of prior outcome performance measures, specifically using guidance from the National Quality Forum, the CMS Measures Management System,[15] and the AHA's scientific statement, "Standards for Statistical Models Used for Public Reporting of Health Outcomes."[16]

## 3.2 Approach to Development

We developed an updated stroke mortality measure with a risk-adjustment model using AHA/ASA's GWTG-Stroke registry data linked with Medicare administrative claims data. In this updated model, registry data was used solely as a source for NIHSS scores for the purposes of measure development. However, NIHSS scores will be included in ICD-10 coding system and obtainable from claims data scheduled to begin in October 2016. We reviewed and largely retained the cohort and outcome definitions of the publicly reported stroke mortality measure, focusing on updating and improving the risk-adjustment strategy.

### 3.2.1 CORE and AHA/ASA Working Group and Expert Input

Development of the updated stroke mortality measure involved input from a number of experts, including a working group convened by CORE and the AHA/ASA that consisted of clinical and methodological experts with extensive experience in both performance measure development and stroke. The group included stroke neurologists, members of the AHA/ASA, health sciences researchers, and other professionals with expertise in biostatistics, measure methodology, and quality improvement. The working group provided regular key input on all measure decisions, including cohort derivation, model development, and model testing. Working group meetings were typically held twice per month and addressed key issues to ensure the measures would be meaningful, useful, and well-designed. For a list of working group members, please see Appendix C.

## 3.3 Data Sources

For model development purposes only, we used two data sources: Medicare administrative claims and the AHA/ASA GWTG-Stroke Registry. Both data sources were linked to create the dataset used for measure development. Registry data were used to obtain the NIHSS.

### 3.3.1 Medicare Administrative Datasets

Administrative claims data for patients with an inpatient admission for ischemic stroke between July 2011 and June 2014 were obtained from Medicare Inpatient/Outpatient Claims Databases, Physician's Carrier Claims Database, as well as Medicare's Enrollment Database (EDB), containing Medicare beneficiary demographic (including age, gender, and birth date), benefit/coverage, and vital status information (such as whether the patient was dead or alive and date of death).

### 3.3.2 AHA/ASA GWTG-Stroke Registry Data

Because stroke severity is not yet recorded in administrative claims data, we used data collected for

patients with stroke between July 2011 and June 2014 in the AHA/ASA's GWTG-Stroke registry as a source of NIHSS data on patients and linked this data to claims data for model development and validation. Hospitals across the United States voluntarily participate in the registry, which includes information on stroke patients collected using the GWTG-Stroke Patient Management Tool™. It includes patient characteristics such as age and sex; arrival and admission information; medical history such as atrial fibrillation/flutter, previous stroke/transient ischemic attack (TIA), previous myocardial infarction, diabetes mellitus, hypertension and heart failure; clinical diagnoses; medications prior to admission; measurements such as total cholesterol, triglycerides, high-density lipoprotein (HDL), low-density lipoprotein (LDL), blood glucose, serum creatinine, international normalized ratio (INR), heart rate, blood pressure and weight; and the NIHSS score, a 15-item neurological examination that is used to evaluate the effect of acute ischemic stroke on the levels of sensory loss, dysarthria, ataxia, motor strength, extraocular movement, visual field loss, neglect, language, and consciousness. In order to most accurately risk adjust based upon the patient status at presentation for care, the model includes the first NIHSS score captured on patients.

A wide spectrum of hospitals across the country participates in the GWTG-Stroke registry. We compared the characteristics of hospitals that participated in the GWTG-Stroke registry with those that did not participate in the registry. When performing this comparison, we included hospitals with at least one ischemic stroke patient between July 2011 and June 2014 and that participated in the 2013 American Hospital Association Survey. Compared with hospitals that did not participate in GWTG-Stroke, hospitals that did participate were larger (had a greater number of beds), more likely to be teaching hospitals, and less likely to be safety-net hospitals. They were also more likely to be not-for-profit rather than government or for-profit hospitals, and to be located in metropolitan rather than rural areas (Table 3.3.1). Hospitals that participated in the GWTG-Stroke registry were not fully representative of all hospitals in the United States, but the diversity among them generates a valid dataset for measure development.

The AHA employs a number of strategies to ensure that data submitted to GWTG-Stroke are complete, consistent, and accurate. To optimize data quality, the GWTG-Stroke Program includes detailed training of site chart abstractors, standardized case definitions and coding instructions, predefined logic and range checks on data fields at data entry, audit trails, and regular data quality reports for all sites. Source documentation quality audits at the individual state and site levels are performed and have shown high data quality.

In Table 3.3.1, "safety-net hospitals" are defined as government hospitals or non-government hospitals with high Medicaid caseloads; a designation of "Yes" signifies to a high Medicaid caseload. Additionally, core-based statistical areas are defined on the basis of the population contained within them:

- Division: >2.5 million inhabitants
- Metro: 50,000 – 2.5 million inhabitants
- Micro: 10,000 – 50,000 inhabitants
- Rural: <10,000 inhabitants

**Table 3.3.1. Comparison of hospitals that participated and hospitals that did not participate in GWTG-Stroke registry**

| Description | Hospitals in GWTG-Stroke (N=1,555) % | Hospitals not in GWTG-Stroke (N=2,845) % |
|---|---|---|
| **Number of beds** | | |
| <100 | 15.8 | 66.4 |
| 100 to 300 | 47.4 | 26.7 |
| >300 | 36.8 | 6.8 |
| Mean (SD) | 284.4 (220.3) | 108.0 (148.2) |
| **Ownership** | | |
| Government | 11.3 | 28.5 |
| Not-for-profit | 73.1 | 54.4 |
| For-profit | 15.6 | 17.0 |
| **Region** | | |
| Associated area | 0.5 | 1.5 |
| New England | 5.5 | 3.1 |
| Middle Atlantic | 14.2 | 5.5 |
| South Atlantic | 19.6 | 12.0 |
| East North Central | 16.5 | 15.0 |
| East South Central | 4.9 | 10.4 |
| West North Central | 8.0 | 17.9 |
| West South Central | 10.5 | 15.8 |
| Mountain | 6.4 | 9.1 |
| Pacific | 13.9 | 9.7 |
| **Teaching status** | | |
| Council of Teaching Hospitals | 12.8 | 2.0 |
| Other teaching | 24.8 | 7.4 |
| Non-teaching | 62.4 | 90.6 |
| **Core-based statistical area** | | |
| Division | 24.0 | 8.4 |
| Metro | 60.1 | 32.7 |
| Micro | 10.4 | 23.0 |
| Rural | 5.5 | 36.0 |
| **Safety-net hospital** | | |
| No | 82.1 | 63.8 |
| Yes | 17.9 | 36.2 |

### 3.4 Cohort Derivation

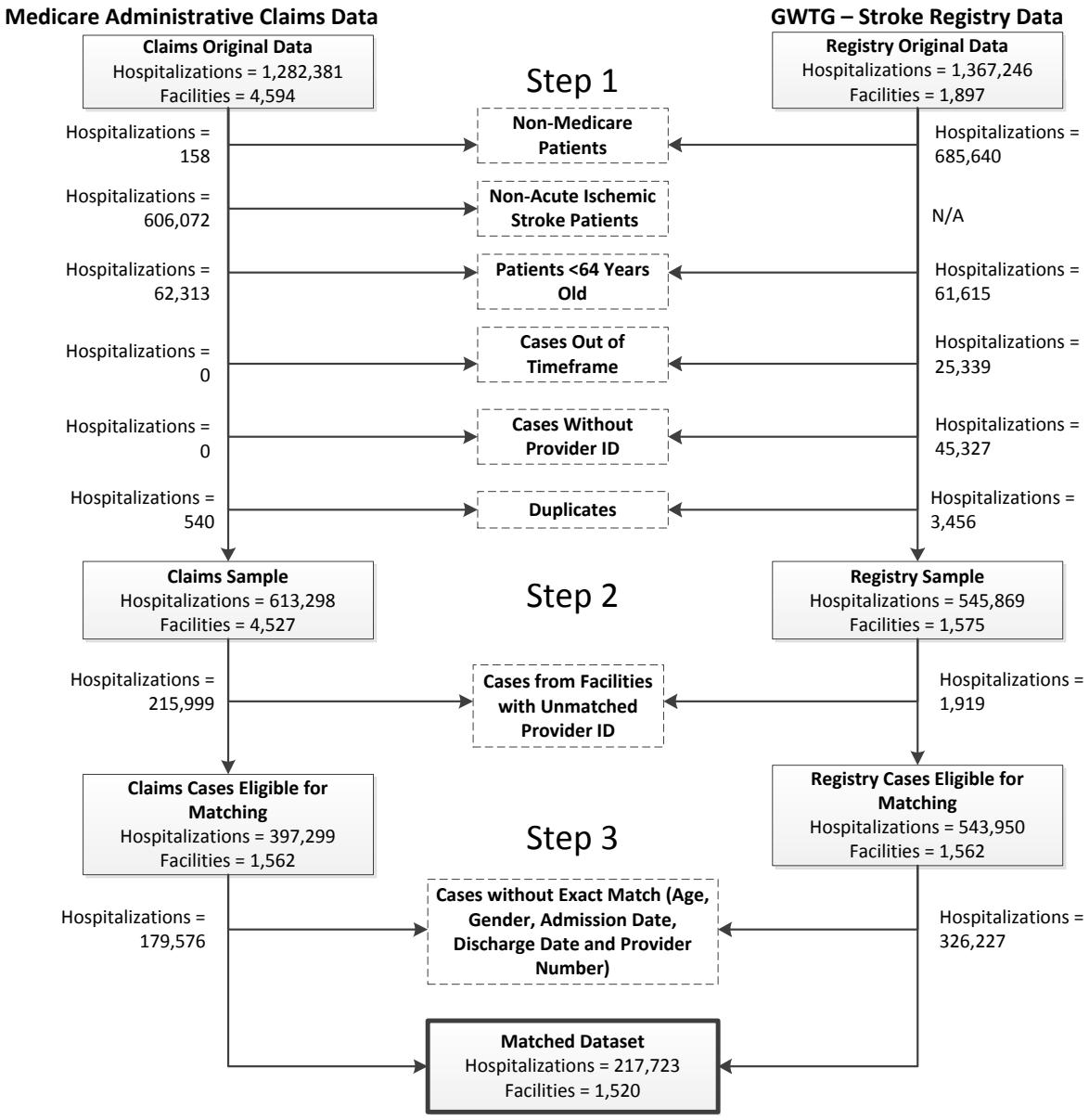
To build the dataset used in the development of the model, we used discharges for stroke included in the GWTG-Stroke and Medicare claims datasets from July 1, 2011 through June 31, 2014. Both claims and registry data include indicators of ischemic stroke. In the claims dataset, we identified discharges with ischemic stroke by International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) principal discharge diagnosis codes 433.01, 433.11, 433.21, 433.31, 433.81, 433.91, 434.01, 434.11, 434.91, and 436 (see Table A 1 in Appendix A). In the GWTG-Stroke dataset, ischemic stroke was identified clinically. The paper-based GWTG-Stroke Patient Management Tool™ provides a list of

the following options for the final clinical diagnosis related to stroke: ischemic stroke, transient ischemic attack, subarachnoid hemorrhage, intracerebral hemorrhage, stoke not otherwise specified, no stroke-related diagnosis, or elective carotid interventions only. This data, which was abstracted from the Patient Management Tool and submitted to the GTWG-Stroke registry, was used to identify ischemic stroke patients.

### 3.4.1 Deterministic Matching of GWTG-Stroke and Medicare Claims Datasets

In order to obtain a comparable cohort of stroke hospitalizations in each dataset (GWTG-Stroke and Medicare claims data) in preparation for deterministic matching, we applied several exclusion criteria to each dataset and then deterministically matched the remaining hospitalizations using a hospital ID number, patient age (within one year), sex, admission date, and discharge date as the linking fields. Admissions that did not match based on all five linking fields were excluded. Figure 3.4.1 depicts the steps followed to derive the matched Medicare-GWTG-Stroke cohort, followed by a detailed description of each step.

**Figure 3.4.1. Deterministic matching to derive cohort for model development**



Steps 1 and 2: Preparation of Datasets for Deterministic Matching

In order to obtain a comparable cohort of hospitalizations within each dataset (GWTG-Stroke and Medicare claims data) in preparation for deterministic matching, we applied the following exclusion criteria to one or both datasets:

- **Non-Medicare patients (applied only to the GWTG-Stroke dataset)**

  Rationale: Non-Medicare patients in the GWTG-Stroke dataset would not be included in the Medicare dataset, and therefore could not be matched.

- **Patients without a principal discharge diagnosis of ischemic stroke (only in the Medicare claims dataset)**

  Rationale: Ischemic stroke is the condition targeted for measurement. The outcome of this measure is mortality from any cause within 30 days of the index admission date for patients hospitalized with ischemic stroke. In the claims dataset, we identified discharges with ischemic stroke by ICD-9-CM principal discharge diagnosis codes 433.01, 433.11, 433.21, 433.31, 433.81, 433.91, 434.01, 434.11, 434.91, and 436 (see Table A 1 in Appendix A).

- **Age <64 years (Medicare claims and GWTG-Stroke data)**

  Rationale: Admissions for patients aged <64 years at the time of admission were excluded, as these patients may be in the Medicare dataset but are not targeted for measurement.

- **Cases out of timeframe (applied only to the GWTG-Stroke dataset)**

  Rationale: Cases in the GWTG-Stroke dataset with admission date outside of the timeframe from July 1, 2011 through June 31, 2014 were excluded because these cases would not be included in the Medicare dataset, and therefore could not be matched.

- **Index admissions missing a provider ID**

  Rationale: Provider ID was necessary in order to match datasets.

- **Duplicate admissions within each separate dataset (Medicare claims and GWTG-Stroke data)**

  Rationale: Admissions for patients who have identical information in a single dataset indicated for age, sex, admission date, discharge date, and MPN are excluded to avoid making matching errors upon merging of the two datasets.

- **Cases from facilities with unmatched provider ID**

  Rationale: Cases from facilities with unmatched provider IDs are not included, as provider IDs must be matched in order to perform hospital-level analyses.

Step 3: Deterministic Match of GWTG-Stroke and Medicare Claims Datasets

The remaining hospitalizations in both datasets were then matched using a hospital ID number, patient age (within one year), sex, admission date, and discharge date as the linking fields. Admissions that did not match based on all five linking fields were excluded.

Among admissions eligible for matching within the Medicare claims dataset, 55% were successfully matched to GWTG-Stroke data; Table 3.4.1 compares matched and unmatched admissions. Admissions in the claims dataset that matched to the GWTG-stroke data as compared with patients in the unmatched cohort were older; slightly less likely to be male; less likely to have comorbidities including

cerebral hemorrhage, previous ischemic or unspecified stroke, precerebral arterial occlusion and transient cerebral ischemia, cerebral atherosclerosis and aneurysm, and hemiplegia/hemiparesis; and more likely to have previous valvular and rheumatic heart disease, congenital cardiac/circulatory defects, and heart arrhythmias (all $p<0.05$). Possible explanations for mismatch include differences in selection criteria for the two databases; failure to include an eligible patient in GWTG-Stroke; the use of sampling, as some GWTG-Stroke hospitals use sampling techniques consistent with The Joint Commission/CMS standards for sampling;[17] inaccuracies within the Medicare claims or GWTG-Stroke data for linking fields (e.g., substituting age for date of birth); and differences in coding of principal discharge diagnosis between the two datasets.

Among admissions eligible for matching in the GWTG-Stroke registry, 40% were successfully matched to Medicare claims data. As shown in Table 3.4.2, the observed characteristics of admissions in GWTG-stroke that matched to claims admissions were similar to admissions that did not match, including similar age, cholesterol, and medical history. Possible explanations for the failure of 60% of the admissions to match include differences in selection criteria for the two databases – specifically, the inclusion of non-ischemic strokes in the GWTG-Stroke dataset; differences in coding of principal discharge diagnosis between the two datasets; admissions for patients ineligible for Medicare (e.g., non-U.S. citizens); admissions for patients in Medicare Advantage (not in Medicare FFS) or with non-governmental insurance; or inaccuracies within the Medicare claims or GWTG-Stroke data for linking fields.

**Table 3.4.1. Selected patient characteristics and outcomes in Medicare claims data for patients matched and unmatched to GWTG-Stroke data**

| Description | Matched (N=217,723) % | Unmatched (N=179,576) % |
|---|---|---|
| Transfer from another ED | 10.27 | 9.63 |
| **Demographic** | | |
| Age (continuous): Mean (SD) | 79.47 (8.55) | 78.98 (8.65) |
| Male | 43.39 | 43.75 |
| **Cardiovascular/Cerebrovascular** | | |
| Congestive heart failure | 23.88 | 23.69 |
| Valvular and rheumatic heart disease | 26.04 | 24.81 |
| Congenital cardiac/circulatory defects | 2.86 | 2.62 |
| Hypertensive heart disease | 5.01 | 5.11 |
| Specified heart arrhythmias | 30.70 | 29.44 |
| Cerebral hemorrhage | 2.25 | 2.41 |
| Ischemic or unspecified stroke | 23.40 | 27.79 |
| Precerebral arterial occlusion and transient cerebral ischemia | 22.52 | 24.93 |
| Cerebral atherosclerosis and aneurysm | 12.22 | 13.02 |
| Hemiplegia/hemiparesis | 6.27 | 7.04 |
| **Comorbidities** | | |
| History of infection | 27.24 | 25.86 |
| Metastatic cancer and acute leukemia and other major cancers | 3.93 | 3.98 |

| Description | Matched (N=217,723) % | Unmatched (N=179,576) % |
|---|---|---|
| Lymphatic, head and neck, brain, breast, colorectal and other major cancers | 23.99 | 23.23 |
| Protein-calorie malnutrition | 6.54 | 6.83 |
| Other significant endocrine and metabolic disorders | 87.44 | 86.70 |
| Other gastrointestinal disorders | 48.92 | 49.35 |
| Disorders of the vertebrae and spinal discs | 19.48 | 19.47 |
| Osteoarthritis of hip or knee | 11.28 | 11.13 |
| Other musculoskeletal and connective tissue disorders | 68.01 | 67.66 |
| Iron deficiency and other/unspecified anemia and blood disease | 36.73 | 37.39 |
| Dementia or senility | 29.92 | 30.72 |
| Major psychiatric disorders | 9.86 | 10.40 |
| Quadriplegia, other extensive paralysis | 1.49 | 1.61 |
| Multiple sclerosis | 13.01 | 13.22 |
| Seizure disorders and convulsions | 7.61 | 8.29 |
| Hypertension | 92.05 | 92.07 |
| Peripheral vascular disease | 24.10 | 23.78 |
| Chronic obstructive pulmonary disease | 21.44 | 22.13 |
| Pneumonia | 15.22 | 15.71 |
| Pleural effusion/pneumothorax | 7.50 | 7.39 |
| Other eye disorders | 19.69 | 19.37 |
| Other ear, nose, throat, and mouth disorders | 27.40 | 27.61 |
| Dialysis status | 1.63 | 1.79 |
| Renal failure | 20.42 | 20.90 |
| Urinary tract infection | 20.42 | 20.75 |
| Male genital disorders | 14.44 | 14.25 |
| Decubitus ulcer of skin | 2.57 | 2.61 |
| Chronic ulcer of skin, except decubitus | 5.28 | 5.10 |
| Other dermatological disorders | 30.96 | 29.81 |
| **Outcomes** | | |
| In-hospital mortality | 5.12 | 5.27 |
| 30-day mortality | 14.13 | 14.58 |
| 90-day mortality | 19.46 | 20.02 |

**Table 3.4.2. Selected patient characteristics and outcomes in GWTG-Stroke Registry data for patients matched and unmatched to CMS data**

| Description | Matched (N=217,723) % | Unmatched (N=326,227) % |
|---|---|---|
| **Demographics** | | |
| Age (continuous): Mean (SD) | 79.47 (8.55) | 78.61 (8.24) |
| Female | 56.61 | 55.81 |
| Race – White | 83.47 | 81.82 |
| Race – Black | 10.95 | 11.30 |
| Race – Other | 5.58 | 6.88 |
| **Medical history** | | |
| Atrial Fib/Flutter | 26.11 | 21.53 |
| Prosthetic Heart Valve | 1.48 | 1.61 |
| CAD/prior MI | 29.96 | 29.23 |
| Carotid Stenosis | 4.29 | 6.69 |
| Diabetes Mellitus | 31.63 | 31.28 |
| PVD | 5.58 | 5.75 |
| Hypertension | 80.28 | 77.70 |
| Smoker | 10.01 | 8.76 |
| Dyslipidemia | 48.08 | 48.81 |
| HF | 11.23 | 9.74 |
| Sickle Cell | 0.02 | 0.02 |
| Previous Stroke | 27.06 | 24.82 |
| Previous TIA | 10.56 | 12.50 |
| Drugs/Alcohol Abuse | 1.46 | 1.29 |
| Family History of Stroke | 3.59 | 3.36 |
| HRT | 0.26 | 0.26 |
| Migraine | 0.64 | 0.71 |
| Obesity/Overweight | 6.55 | 7.09 |
| Renal insufficiency - chronic | 4.48 | 4.51 |
| Sleep Apnea | 0.29 | 0.32 |
| Depression | 1.07 | 1.20 |
| **Diagnosis and Evaluation** | | |
| Stroke symptoms resolved at time of presentation | 7.37 | 16.14 |
| First NIHSS score: Mean (SD) | 7.58 (8.14) | 6.08 (8.13) |
| **Measurements**: Mean (SD) | | |
| Total Cholesterol | 164.83 (52.36) | 163.5 (255.48) |
| Triglycerides | 123.87 (93.81) | 123.73 (315.15) |
| HDL | 45.91 (16.90) | 46.78 (17.67) |
| LDL | 95.25 (62.71) | 92.98 (75.04) |
| A1C | 7.52 (24.53) | 7.43 (23.53) |

| Description | Matched (N=217,723) % | Unmatched (N=326,227) % |
|---|---|---|
| Blood glucose (mg/dL) | 136.61 (60.94) | 136.70 (65.36) |
| Serum Creatinine | 1.58 (7.52) | 1.58 (8.33) |
| Initial Platelet Count at Hospital Arrival | 251.03 (80.35) | 234.22 (108.33) |
| INR | 1.18 (0.70) | 1.26 (1.09) |
| Vital Signs - Heart Rate | 79.62 (18.29) | 79.07 (210.60) |
| Vital Signs - Blood Pressure Systolic | 158.16 (69.17) | 156.86 (30.79) |
| Vital Signs - Blood Pressure Diastolic | 80.84 (17.89) | 79.79 (18.06) |
| Height (cm) | 167.14 (18.97) | 166.83 (14.73) |
| Weight (kg) | 76.31 (47.73) | 76.48 (49.29) |
| Waist Circumference (cm) | 102.48 (46.74) | 99.21 (45.08) |
| BMI | 27.72 (113.55) | 27.69 (28.00) |
| **In-Hospital Death** | 5.12 | 7.64 |

Inclusion and Exclusion Criteria Applied to Matched Dataset

After performing the deterministic match, as shown in Figure 3.4.1, we applied inclusion and exclusion criteria to derive the final cohort of patients for building the risk-adjustment model. These criteria are very similar to those in the publicly reported claims-based stroke mortality measure[18]. Figure 3.4.2 illustrates the steps followed to apply the inclusion and exclusion criteria to derive the final study cohort.

In addition to the principal discharge diagnosis of ischemic stroke and Medicare FFS enrollment criteria applied when matching the Medicare claims and GWTG-Stroke data, we also included index hospital admissions for patients who:

1. **Are aged 65 years or older**

   Rationale: Medicare patients younger than 65 usually qualify for the program due to severe disability. They were not included in the measure because they are considered to be too clinically distinct from Medicare patients 65 and over. The characteristics and outcomes of these patients may not be representative of the larger population of stroke patients.

2. **Were not transferred following an admission to another acute care facility**

   Rationale: Death is attributed to the hospital where the patient was initially admitted. Transferred patients were included in the measure cohort, but it is the initial hospitalization, rather than the "transfer-in" hospitalization that was included as an index admission.

3. **Were enrolled in Part A and Part B Medicare for the 12 months prior to the date of admission, and enrolled in Part A during the index admission***

   Rationale: The 12-month prior enrollment criterion ensures that patients are Medicare FFS beneficiaries and that their comorbidities were captured from claims for risk adjustment. Medicare Part A is required during the index admission to ensure that no Medicare Advantage patients were included in the measures.

   *This inclusion criterion could be removed in the future for implementation of a measure that

uses only EHR data for risk adjustment.

The measure excludes index hospital admissions for patients who (Figure 3.4.2):

1. **Have inconsistent or unknown vital status or other unreliable data**

   Rationale: We did not include stays for patients where the age is greater than 115, where the gender was neither male nor female, where the admission date was after the date of death in the Medicare Enrollment Database, or where the date of death occurred before the date of discharge but the patient was discharged alive.

2. **Enrolled in the Medicare hospice program any time in the 12 months prior to the index admission, including the first day of the index admission**

   Rationale: These patients are likely continuing to seek comfort measures only; thus, mortality is not necessarily an adverse outcome or signal of poor quality care for these patients.

3. **Discharged against medical advice (AMA)**

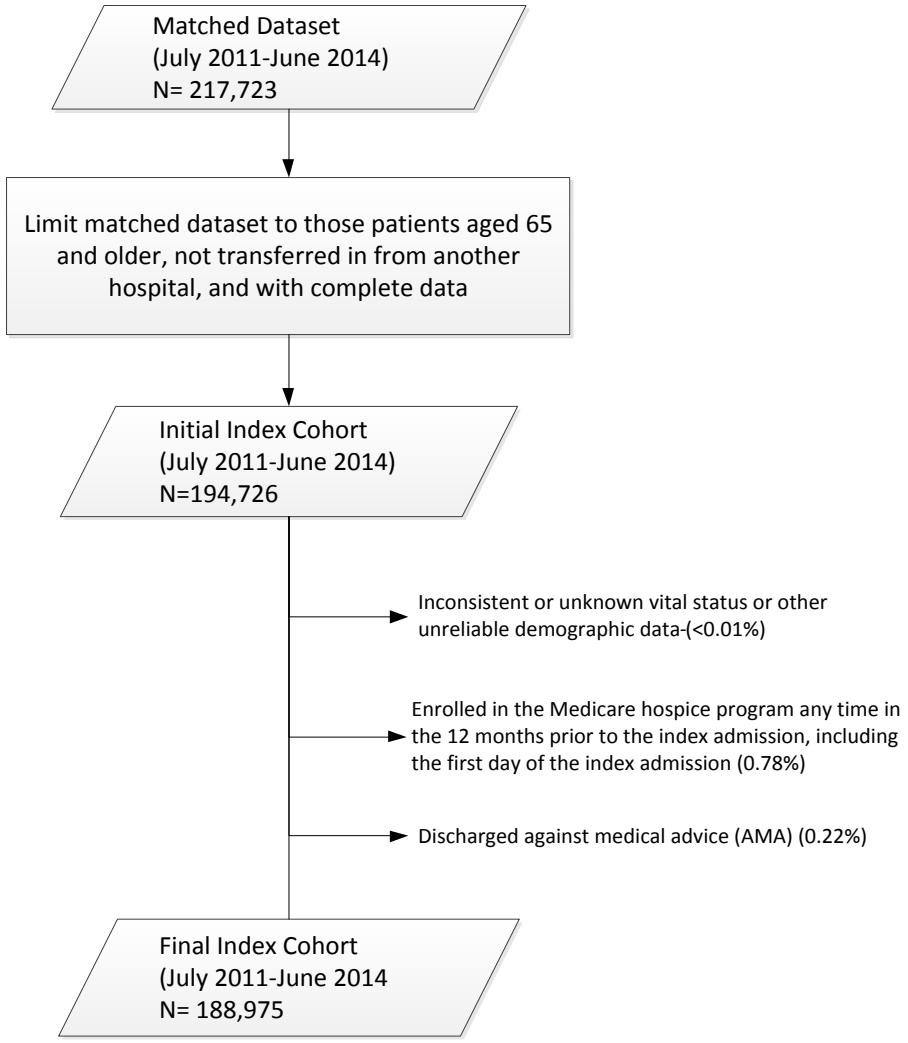
   Rationale: Providers did not have the opportunity to deliver full care and prepare the patient for discharge.

For patients with more than one admission for stroke in a given year between July of the current year and June of the following year, only one index admission was randomly selected for inclusion in the cohort.

As a part of claims data processing prior to the measure calculation, records are removed for non-short-term acute care facilities such as psychiatric facilities, rehabilitation facilities, or long-term care hospitals. Additional data cleaning steps include removing claims with stays longer than one year, claims with overlapping dates, and stays for patients not listed in the Medicare enrollment database as well as records for providers with invalid provider IDs.

Finally, for index admissions that occur during the transition between measure years, June and July of each year for the development data, the measure includes admissions only if they were the first to occur in the 30 days prior to a patient's death; additional admissions in that 30-day period are excluded. This exclusion criterion is applied after one admission per patient per year is randomly selected to avoid assigning a single death to two admissions in two separate reporting periods. For example, consider a patient who is admitted on June 18, 2012, readmitted on July 2, 2012, and subsequently dies on July 15, 2012. If both admissions are randomly selected for inclusion (one for the July 2011-June 2012 time period and the other for the July 2012-June 2013 time period), the measure will exclude the July 2, 2012 admission to avoid assigning the death to two admissions.

**Figure 3.4.2: Exclusions applied to the July 2011-June 2014 matched dataset**




### 3.4.2 Transfers between Hospitals

The updated stroke mortality measure uses the same methodology as the current publicly reported stroke mortality measure to define transfers and to attribute mortality outcomes. For patients whose index admission includes one or more transfers between hospitals, the mortality outcome is attributed to the hospital where the patient was first admitted for stroke. For patients seen in the emergency department of one hospital and who are then admitted to another hospital, the measure assigns them to the admitting hospital.

### 3.4.3 Development and Validation Samples

In order to develop and test the updated stroke mortality measure, we randomly split the final index cohort (N=188,975) into two samples. The first sample – the development sample (N=94,466) – was

used to develop the risk-adjusted model, and the second sample – the validation sample (N=94,509) – was used to validate the model.

### 3.5 Outcome Assessment

The approach to assessment of the mortality outcome is identical to the currently publicly reported stroke mortality measure methodology. The outcome is 30-day all-cause mortality, defined as death from any cause within 30 days of the index admission date. We identify deaths for Medicare FFS patients in the Medicare Enrollment Database (EDB).

#### 3.5.1 All-Cause Mortality

There are a number of reasons for counting all deaths in this measure. First, from a patient perspective, death from any cause is an adverse event. In addition, making inferences about quality issues and accountability based solely on the documented cause of death is difficult. For example, a patient with stroke who develops a hospital-acquired infection may ultimately die of sepsis and multi-organ failure. In this context, considering the patient's death to be unrelated to the care the patient received for stroke during the index admission would be inappropriate.

#### 3.5.2 30-Day Time Period

The updated measure assesses mortality within a 30-day period from the date of the index admission. This standard time period is necessary so that the outcome for each patient is measured uniformly. The updated measure uses a 30-day time frame because outcomes occurring within 30 days of admission can be influenced by hospital care and the early transition to the outpatient setting. The use of the 30-day time frame is a clinically meaningful period for hospitals to collaborate with their communities in an effort to reduce mortality.[19]

### 3.6 Approach to Risk Adjustment

For the current project, we aimed to identify risk factors for the model that are clinically relevant and have strong relationships with the mortality outcome. For this measure, risk-adjustment variables were obtained from inpatient, outpatient, and physician carrier Medicare claims data extending 12 months prior to, and including, the index admission. The NIHSS was obtained from the GWTG-Stroke registry for measure development.

The updated measure aligns with other CMS hospital-level outcome measures, which seek to adjust for case mix differences among hospitals based on the clinical status of the patient at the time of the index admission. Accordingly, only comorbidities that convey information about the patient at the time of admission or in the 12 months prior, and not complications that arise during the course of the index hospitalization, are considered as risk-variables.

### 3.6.1 Candidate Risk-Adjustment Variables

We sought to develop a risk-adjustment model that included the NIHSS and other key variables that are clinically relevant that demonstrate a strong statistical association with 30-day mortality.

To select candidate variables from claims, we considered those 42 risk-adjustment variables in the currently publicly reported claims-based measure as candidate variables. The only data element from the registry that was additionally included as a candidate risk-adjustment variable was the NIHSS (Table B 1).

### 3.6.2 Handling of Missing Data for Measure Development

Hospitals may not always collect and record the NIHSS on all patients. Therefore, we must address missing data during measure development. For this model, only the NIHSS had missing values. Because only final action claims are included in the dataset and records with unreliable data are excluded before CORE receives the data from CMS, all other variables in the claims dataset are complete. The missing NIHSS values were imputed using the standard statistical method of multiple imputation based on the claims data, and full conditional specification (FCS) with a multi-logit regression model was used for the imputation. Five copies of imputation datasets were produced for the analyses. The results based on these data were aggregated according to the standard statistical methods for presentation of the results and for the measure score calculation.[20]

In multiple imputation, missing variable values are predicted using available related patient variables. The predicted values are substituted for the missing values, which results in a full dataset without any missing variables (the imputed dataset). By repeating this process multiple times, we get multiple imputed datasets with which we conduct analyses and from which we obtain results. The results based on multiple datasets are combined to produce the overall final results. In general, multiple imputation is used to preserve the important characteristics of the underlying dataset and the inherent relationships among the variables in the dataset. This approach allows us to make use of all possible available information to generate a range of plausible values to use in place of the missing values. The multiple imputation represents a random sample of the missing values according to the association of the non-missing values of all the variables considered, and the resulting inferences of multiple imputation are statistically valid, which reflect uncertainty due to missing values. [21,22]

## 3.7 Model Specification, Measure Score Calculation, and Validation

For model development we used a logistic regression model, with outcome $Y_i$ for the $i^{th}$ patient equal to 1 if the patient died within 30 days of admission and 0 otherwise. To develop the updated claims-only model, we used the claims model variables from the publicly reported outcome measure and the NIHSS as the candidate predictors for 30-day mortality. We selected the best model using the logistic regression model with the stepwise selection method based on 1,000 bootstrapping samples for each copy of the multiple imputed (MI) data. Variable selection rate for all the variables selected into the best model was calculated for each copy of the MI data, and variables were included into the final model if the minimum variable selection rate among the 5 copies of MI was 90% or more.

### 3.7.1 Measure Score Calculation

After identifying the appropriate model to use in the logistic regression model above, we estimated the hospital-specific RSMRs using hierarchical generalized linear models (hierarchical model) in each copy of the imputed data. This strategy accounts for within-hospital correlation of the observed outcome

and accommodates the assumption that underlying differences in quality across hospitals lead to systematic differences in outcomes. We model the probability of mortality as a function of patient age and clinically relevant comorbidities with an intercept for the hospital-specific random effect.

We used the following strategy to calculate the hospital-specific RSMRs in each copy of the imputed data, which we calculated as the ratio of a hospital's "predicted" mortality to "expected" mortality multiplied by the national observed mortality rate. The expected mortality for each hospital was estimated using its patient mix and the average hospital-specific (i.e., the average intercept among all hospitals in the sample). The predicted mortality for each hospital was estimated given the same patient mix but an estimated hospital-specific intercept. Operationally, the expected mortality for each hospital was obtained by summing the expected probabilities of mortality for all patients in the hospital. The expected probability of mortality for each patient was calculated via the hierarchical model, which applies the estimated regression coefficients to the observed patient characteristics and adds the average of the hospital-specific intercept. The predicted mortality for each hospital was calculated by summing the predicted probabilities for all patients in the hospital. The predicted probability for each patient was calculated through the hierarchical model, which applies the estimated regression coefficients to the patient characteristics observed and adds the hospital-specific intercept.

More specifically, we used a hierarchical logistic regression model to account for the natural clustering of observations within hospitals. The model employs a logit link function to link the risk factors to the outcome with a hospital-specific random effect:

Let $Y_{ij}$ denote the outcome (equal to 1 if patient *i* dies within 30 days, zero otherwise) for patient i at hospital *j*; $\mathbf{Z_{ij}}$ denotes a set of risk factors. We assume the outcome is related linearly to the covariates via a logit function with dispersion:

$$\text{logit}(\text{Prob}(Y_{ij} = 1)) = \alpha_j + \boldsymbol{\beta}^{*}\mathbf{Z_{ij}} + \varepsilon_{ii} \qquad (1)$$

$$\alpha_j = \mu + \omega_j \; ; \; \omega_j \sim N(0,\tau^2)$$

where $Y_{ij}$ denotes the outcome (equal to 1 if patient *i* dies within 30 days, zero otherwise) for patient i at hospital *j*; $\mathbf{Z_{ij}} = (Z_1, Z_2, \ldots Z_k)$ is a set of *k* patient-level covariates; $\alpha_j$ represents the hospital-specific intercept; $\mu$ is the adjusted average hospital intercept over all hospitals; $\tau^2$ is the between-hospital variance component; and $\varepsilon \sim N(0,\sigma^2)$ captures any over- or under-dispersion. This model separates within-hospital variation from between-hospital variation. The hierarchical logistic regression model was estimated using the SAS software system (GLIMMIX procedure).

With the hospital-specific RSMRs in all copies of the imputed data, we take the average of these RSMRs of each hospital to get the final hospital-specific RSMR as the measure score.

### 3.7.2 Hospital Performance Assessment

We used the results of each hierarchical logistic regression model to calculate the predicted number of deaths and the expected number of deaths at each hospital. The predicted number of mortalities was calculated using the hierarchical logistic regression model, as the sum of the predicted probability of mortality for each patient, including the hospital-specific effect. The expected number of mortalities for each hospital was similarly calculated as the sum of the predicted probability of mortality for each patient, ignoring the hospital-specific effect.

### 3.7.3 Model Performance Assessment

Assessment of the stroke mortality measures' performance included model calibration (to assess over-fitting), discrimination in terms of predictive ability (the range of observed mortality rates across deciles of predicted rates), and distribution of model residuals. These analyses were done in the development and validation samples.

## 3.8 Measure Reliability

To determine the extent to which the assessments of a hospital using different but randomly selected subsets of patients produces similar measures of hospital performance, we calculated the RSMRs based on the development and validation cohorts. Thus, we obtain two RSMRs per hospital using an entirely distinct set of patients from the same time period. To the extent that the calculated measures of these two subsets agree, we have evidence that the measure is assessing an attribute of the hospital, not of the patients. As a metric of agreement, we calculated the intra-class correlation as defined by ICC (2,1) by Shrout and Fleiss (1979).[23,24] For the hospital event rates based on patient binomial outcomes like mortality (Yes/No), an ICC value of 0-0.2 indicates poor agreement; 0.3-0.4 indicates fair agreement; 0.5-0.6 indicates moderate agreement; 0.7-0.8 indicates strong agreement; and >0.8 indicates almost perfect agreement.[23]

# 4. RESULTS

## 4.1 Cohort

The inclusion and exclusion criteria that were applied to the matched dataset are presented in Section 3.4; specifically, Figure 3.4.2 displays the percentage of patients meeting each exclusion criterion in the three-year dataset (July 2011 to June 2014). The final index cohort consisted of 188,975 hospital admissions at 1,511 hospitals; the development and validation samples consisted of 94,466 and 94,509 hospital admissions, respectively.

## 4.2 Outcome

### 4.2.1 Assessment of the 30-Day All-Cause Mortality Outcome

We created a risk-adjustment model that assesses 30-day all-cause mortality as the outcome. It was developed in a 50% sample of the full 2011-2014 dataset and validated using the remaining 50% of the dataset. The crude mortality rates in the final index cohort, the development sample, and the validation sample were 14.43%, 14.28%, and 14.58%, respectively. Therefore, the development sample had a slightly lower rate than the validation sample.

### 4.2.2 Distribution of 30-Day Mortality Rate

The hospital-level unadjusted 30-day mortality rate in the July 2011-June 2014 data for the final index cohort ranged from 0.00% to 100.00% across 1,511 hospitals with a median (interquartile range) of 14.40% (11.93%, 16.48%).

## 4.3 Final Model with Risk Adjustment

Following the bootstrapping simulation method for variable selection, those candidate claims risk-adjustment variables that were included more than 90% of the time for all the copies of the imputed data were retained in the final model. The final model included 19 claims-based risk-adjustment variables and the NIHSS, listed in Table 4.3.1 below.

**Table 4.3.1. Final updated stroke mortality model variables**

| Category | ICD-9/CC | Description |
|---|---|---|
| **Demographic** | N/A | Age-65 (continuous, per 5 years) |
| **Arrival Information** | N/A | Transfer from another ED |
| **Evaluation** | N/A | NIHSS score (continuous, per 5 units) |
| **Cardiovascular/ Cerebrovascular** | CC 80 | Congestive heart failure |
| **Cardiovascular/ Cerebrovascular** | CC 87-88 | Congenital cardiac/circulatory defects |
| **Cardiovascular/ Cerebrovascular** | CC 92 | Specified heart arrhythmias |
| **Cardiovascular/ Cerebrovascular** | CC 98 | Cerebral atherosclerosis and aneurysm |
| **Comorbidities** | CC 7-8 | Metastatic cancer and acute leukemia and other major cancers |
| **Comorbidities** | CC 21 | Protein-calorie malnutrition |

| Category | ICD-9/CC | Description |
|---|---|---|
| **Comorbidities** | CC 22-24 | Other significant endocrine and metabolic disorders |
| **Comorbidities** | CC 36 | Other gastrointestinal disorders |
| **Comorbidities** | CC 39 | Disorders of the vertebrae and spinal discs |
| **Comorbidities** | CC 40 | Osteoarthritis of hip or knee |
| **Comorbidities** | CC 43 | Other musculoskeletal and connective tissue disorders |
| **Comorbidities** | CC 47 | Iron deficiency and other/unspecified anemia and blood disease |
| **Comorbidities** | CC 49-50 | Dementia or other specified brain disorders |
| **Comorbidities** | CC 72, 76 | Multiple sclerosis |
| **Comorbidities** | CC 74 | Seizure disorders and convulsions |
| **Comorbidities** | CC 111-113 | Pneumonia |
| **Comorbidities** | CC 131 | Renal failure |

### 4.3.1 Logistic Regression

The final logistic regression model performed very well, with a mean C-statistic of 0.812 and an adjusted R-squared of 0.268. The variable descriptions, estimates, and standard errors for the logistic regression model using the final model variables are shown in Table 4.3.2 below.

**Table 4.3.2. Final updated model: logistic regression results (N=94,466 patients in development cohort)**

| Description | Estimate | Standard Error | T | OR | 95% CI |
|---|---|---|---|---|---|
| Intercept | -3.7613 | 0.0437 | -86.11 | - | - |
| Age-65 (continuous, per 5 years) | 0.2899 | 0.0071 | 40.72 | 1.34 | 1.32, 1.36 |
| Transfer from another ED | 0.2993 | 0.0328 | 9.13 | 1.35 | 1.26, 1.44 |
| NIHSS (continuous, per 5 units) | 0.4637 | 0.0068 | 68.03 | 1.59 | 1.57, 1.61 |
| Congestive heart failure | 0.2115 | 0.0263 | 8.03 | 1.24 | 1.17, 1.3 |
| Congenital cardiac/circulatory defects | -0.4088 | 0.0783 | -5.22 | 0.66 | 0.57, 0.77 |
| Specified heart arrhythmias | 0.3011 | 0.0232 | 12.99 | 1.35 | 1.29, 1.41 |
| Cerebral atherosclerosis and aneurysm | -0.2115 | 0.0340 | -6.22 | 0.81 | 0.76, 0.87 |
| Metastatic cancer and acute leukemia and other major cancers | 1.0597 | 0.0471 | 22.51 | 2.89 | 2.63, 3.16 |
| Protein-calorie malnutrition | 0.4771 | 0.0349 | 13.66 | 1.61 | 1.5, 1.73 |
| Other significant endocrine and metabolic disorders | -0.3601 | 0.0311 | -11.59 | 0.70 | 0.66, 0.74 |
| Other gastrointestinal disorders | -0.1038 | 0.0225 | -4.61 | 0.90 | 0.86, 0.94 |
| Disorders of the vertebrae and spinal discs | -0.1271 | 0.0289 | -4.39 | 0.88 | 0.83, 0.93 |
| Osteoarthritis of hip or knee | -0.1407 | 0.0347 | -4.05 | 0.87 | 0.81, 0.93 |
| Other musculoskeletal and connective tissue disorders | -0.1092 | 0.0246 | -4.43 | 0.90 | 0.85, 0.94 |
| Iron deficiency and other/unspecified anemia and blood disease | 0.1767 | 0.0236 | 7.49 | 1.19 | 1.14, 1.25 |
| Dementia or other specified brain | 0.2296 | 0.0230 | 9.97 | 1.26 | 1.2, 1.32 |

| Description | Estimate | Standard Error | T | OR | 95% CI |
|---|---|---|---|---|---|
| disorders | | | | | |
| Multiple sclerosis | -0.1409 | 0.0337 | -4.18 | 0.87 | 0.81, 0.93 |
| Seizure disorders and convulsions | 0.2077 | 0.0372 | 5.58 | 1.23 | 1.14, 1.32 |
| Pneumonia | 0.2670 | 0.0273 | 9.77 | 1.31 | 1.24, 1.38 |
| Renal failure | 0.1324 | 0.0263 | 5.03 | 1.14 | 1.08, 1.2 |

### 4.3.2 Hierarchical Logistic Regression Model

In the final hierarchical logistic regression model, the estimated mean between-hospital variance in the log-odds of mortality was 0.0420 (mean standard error=0.0072). This result implies that the odds of mortality for a high-mortality hospital (+1 standard deviation) were 1.51 times those for a low-mortality hospital (-1 standard deviation). Model variable descriptions, estimates, standard errors, and odds ratios are shown in Table 4.3.3 below. 1,473 hospitals with between-hospital variance=0.0420, standard error=0.0072.

**Table 4.3.3. Final updated model: hierarchical logistic regression results (N=94,466 patients in development cohort)**

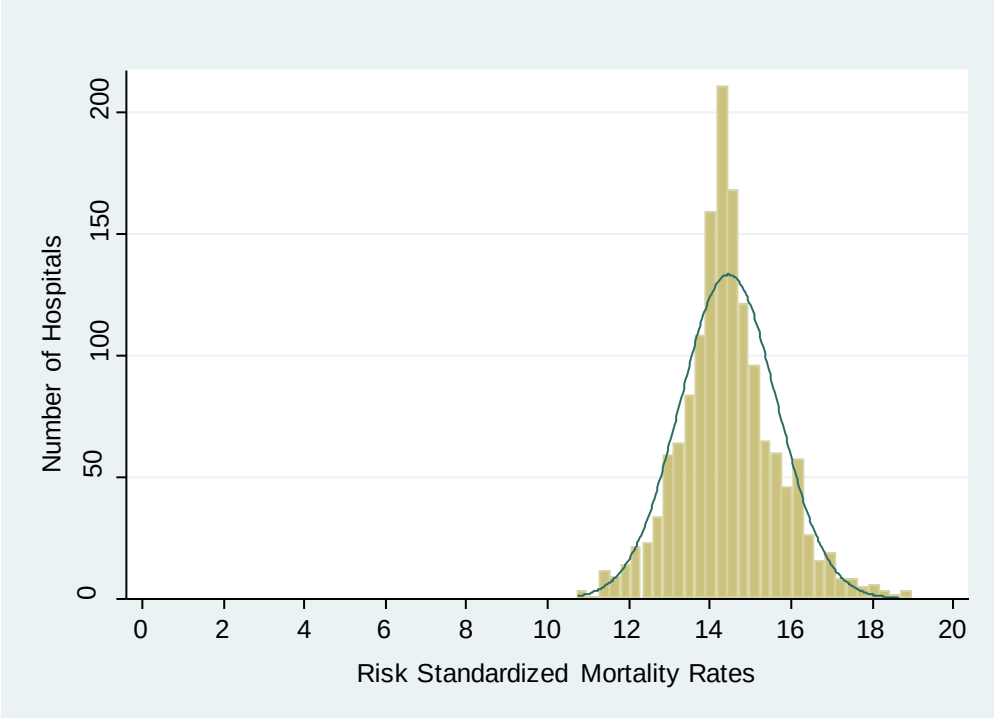
| Description | Estimate | Standard Error | T | OR | 95% CI |
|---|---|---|---|---|---|
| Intercept | -3.7748 | 0.0445 | -84.86 | - | - |
| Age-65 (continuous, per 5 years) | 0.2916 | 0.0072 | 40.72 | 1.34 | 1.32, 1.36 |
| Transfer from another ED | 0.2764 | 0.0343 | 8.07 | 1.32 | 1.23, 1.41 |
| NIHSS (continuous, per 5 units) | 0.4650 | 0.0069 | 68.03 | 1.59 | 1.57, 1.61 |
| Congestive heart failure | 0.2120 | 0.0265 | 8.01 | 1.24 | 1.17, 1.3 |
| Congenital cardiac/circulatory defects | -0.4093 | 0.0784 | -5.22 | 0.66 | 0.57, 0.77 |
| Specified heart arrhythmias | 0.2981 | 0.0233 | 12.81 | 1.35 | 1.29, 1.41 |
| Cerebral atherosclerosis and aneurysm | -0.2114 | 0.0342 | -6.18 | 0.81 | 0.76, 0.87 |
| Metastatic cancer and acute leukemia and other major cancers | 1.0686 | 0.0472 | 22.63 | 2.91 | 2.65, 3.19 |
| Protein-calorie malnutrition | 0.4813 | 0.0352 | 13.67 | 1.62 | 1.51, 1.73 |
| Other significant endocrine and metabolic disorders | -0.3606 | 0.0312 | -11.56 | 0.70 | 0.66, 0.74 |
| Other gastrointestinal disorders | -0.1064 | 0.0226 | -4.71 | 0.90 | 0.86, 0.94 |
| Disorders of the vertebrae and spinal discs | -0.1262 | 0.0291 | -4.34 | 0.88 | 0.83, 0.93 |
| Osteoarthritis of hip or knee | -0.1390 | 0.0348 | -4.00 | 0.87 | 0.81, 0.93 |
| Other musculoskeletal and connective tissue disorders | -0.1083 | 0.0248 | -4.37 | 0.90 | 0.85, 0.94 |
| Iron deficiency and other/unspecified anemia and blood disease | 0.1826 | 0.0237 | 7.70 | 1.20 | 1.15, 1.26 |
| Dementia or other specified brain disorders | 0.2343 | 0.0232 | 10.12 | 1.26 | 1.21, 1.32 |
| Multiple sclerosis | -0.1419 | 0.0338 | -4.20 | 0.87 | 0.81, 0.93 |
| Seizure disorders and convulsions | 0.2062 | 0.0374 | 5.51 | 1.23 | 1.14, 1.32 |

| Description | Estimate | Standard Error | T | OR | 95% CI |
|---|---|---|---|---|---|
| Pneumonia | 0.2673 | 0.0274 | 9.75 | 1.31 | 1.24, 1.38 |
| Renal failure | 0.1310 | 0.0264 | 4.96 | 1.14 | 1.08, 1.20 |

### 4.3.3 Distribution of 30-Day Mortality Rate

After adjusting for patient characteristics and clustering within hospitals, RSMRs at the hospital level were normally distributed, ranging from 11.75% to 18.98%. The median (interquartile range) RSMR was 14.48% (13.52%, 15.56%) (Figure 4.3.1).

**Figure 4.3.1. Distribution of hospital risk-standardized mortality rates for the updated model (July 2011 – June 2014)**




### 4.3.4 Validation of Final Model

We computed five summary statistics for assessing model performance: over-fitting indices, predictive ability, area under the receiver operating characteristic (ROC) curve, distribution of residuals, and model chi-square. Model performance was similar in each dataset, with strong model discrimination and fit. Predictive ability was also similar across datasets. The C-statistic (area under the ROC curve) was 0.81 and 0.82 for the development and validation datasets, respectively (Table 4.3.4).

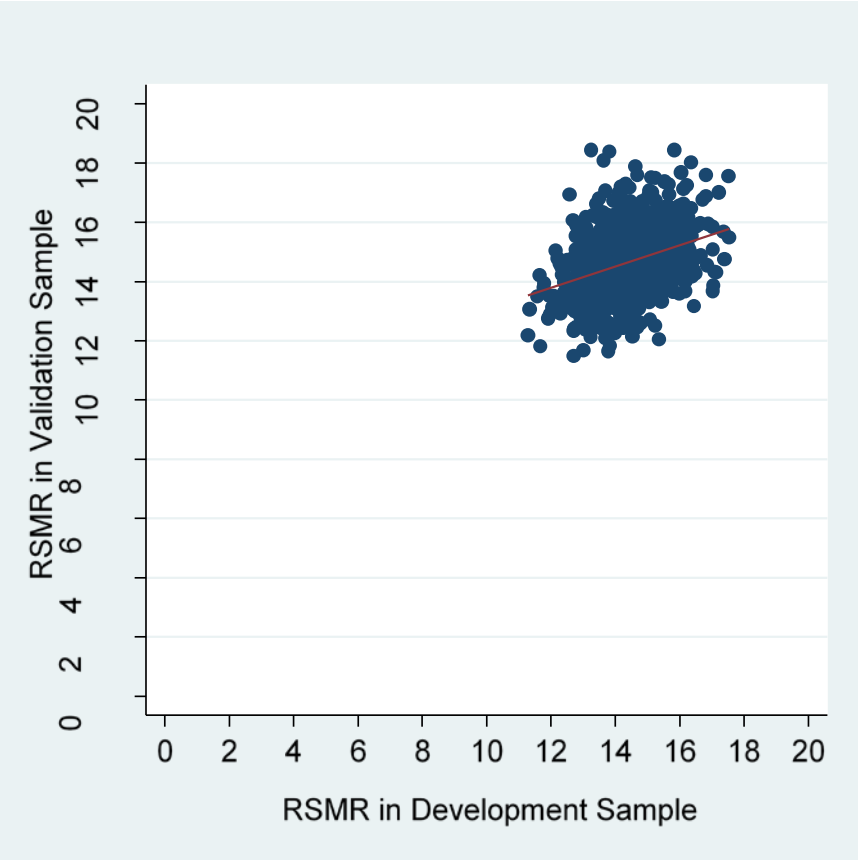
**Table 4.3.4. Updated model performance results based on logistic regression**

| Indices | Development Sample | Validation Sample |
|---|---|---|
| **Number of Admissions** | 94,466 | 94,509 |
| **Mortality Rate** | 14.3 | 14.6 |
| **Calibration (γ0, γ1)** | 0.00, 1.00 | 0.00, 1.00 |
| **Discrimination: Adjusted R-square** | 0.2681 | 0.2764 |
| **Discrimination: C-statistic** | 0.81 | 0.82 |
| **Predictive Ability, % (lowest decile, highest decile)** | 1.3, 50.0 | 1.3, 51.6 |
| **Residuals Lack of Fit (Pearson Residual Fall %)** | - | - |
| **<-2** | 0.15 | 0.17 |
| **[-2, 0)** | 85.57 | 85.3 |
| **[0, 2)** | 8.63 | 8.99 |
| **[2+** | 5.65 | 5.58 |
| **Model χ2 (number of covariates)** | 12201.90 (20) | 12584.62 (20) |

### 4.3.5 Measure Testing – Reliability of Measure Results

When comparing the hospitals' RSMRs in the development and validation samples for the updated stroke mortality measure, hospital-level RSMRs were moderately correlated (correlation coefficient = 0.336), as shown in Figure 4.3.2. The reliability (ICC) for the full three years of data was 0.556, indicating moderate agreement between the development and validation samples.

**Figure 4.3.2. Correlation of RSMRs in development and validation samples for the updated stroke mortality model for hospitals with ≥ 12 cases**



## 5. SUMMARY

This technical report describes the methodology used to develop an updated measure of 30-day, hospital-level stroke mortality that includes an assessment of stroke severity in the risk model. This work was aligned with clinical guidelines to collect the NIHSS on patients admitted to the hospital with ischemic stroke. It was also responsive to stakeholder preference to include a stroke severity score in the risk model to improve predictive ability and face validity.

The updated measure is designed to be implemented using comorbidity variables and the NIHSS, once available, from administrative claims. In addition to a modestly higher C-statistic, the updated measure has a more parsimonious risk model than the publicly reported stroke mortality measure. Calculation of this measure would require three years of NIHSS claims data. We anticipate that the NIHSS will be assigned ICD-10 codes in October 2016, and data collection could begin shortly thereafter.

## 6. GLOSSARY OF TERMS

- *Administrative claims data:* An electronic system in which hospitals capture data to submit claims to insurance providers for payment. These databases allow providers to complete the Universal Bill required to submit Medicare claims and contain patient data, such as dates of birth, names, national and unique medical record identification numbers, dates of admission, dates of discharge, principal discharge diagnoses, and all hospital charges that might be included in a bill for care provided.
- *Case mix:* The particular illness severity and age characteristics of patients with index admissions at a given hospital.
- *Cohort:* The index admissions used to calculate the measure after inclusion and exclusion criteria have been applied.
- *Complications:* Medical conditions that are acquired during the index admission and might be a consequence of care rendered during hospitalization.
- *Comorbidities:* Medical conditions that the patient had in addition to his/her primary reason for admission to the hospital.
- *Electronic health records (EHR)*: A record in digital format that allows for systematic collection of electronic health information about individual patients or populations. It theoretically allows for sharing of information across different health care settings.
- *Expected mortality:* The number of deaths expected based on average hospital performance with a given hospital's case mix.
- *Hierarchical model:* A widely accepted statistical method that enables fair evaluation of relative hospital performance by accounting for patient risk factors, as well as the number of patients a hospital treats. This statistical model accounts for the structure of the data (patients clustered within hospitals) and calculates (1) how much variation in hospital mortality rates overall is accounted for by patients' individual risk factors (such as age and other medical conditions); and (2) how much variation is accounted for by hospital contribution to mortality risk.
- *Hospital-specific [effect]:* A measure of the hospital quality of care calculated based on the hospital's actual mortality rate relative to hospitals with similar patients, considering how many patients it served, its patients' risk factors, and how many died. The hospital-specific effect will be negative for a better-than-average hospital, positive for a worse-than-average hospital, and close to zero for an average hospital. The hospital-specific effect is used in the numerator to calculate "predicted" mortality.
- *Hybrid measure:* Quality measure that utilizes more than one source of data, such as patient electronic clinical data captured in the EHR and CMS administrative claims data.
- *Index admission:* Any admission included in the measure calculation as the initial admission for an episode of care to which the outcome is attributed.
- *Medicare fee-for-service (FFS):* Original Medicare plan in which providers receive a fee or payment for each individual service provided directly from Medicare. All services rendered are unbundled and paid for separately. Only beneficiaries in Medicare FFS, not in managed care (Medicare Advantage), are included in the measure.
- *NIHSS:* National Institutes of Health Stroke Scale. This is a 15-item neurologic examination used to evaluate the effect of acute cerebral infarction on the levels of consciousness, language, neglect,

visual-field loss, extraocular movement, motor strength, ataxia, dysarthria, and sensory loss.

- *Outcome:* The result of a broad set of healthcare activities that affect patients' well-being. For these measures, the outcome is mortality within 30 days of discharge.
- *Predicted mortality:* The number of deaths within 30 days predicted based on the hospital's performance with its observed case mix.
- *Risk adjustment:* Patient demographics and comorbidities used to standardize rates for differences in case mix across hospitals.

## 7. REFERENCES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# 8. APPENDICES

## Appendix A. Cohort Definition

**Table A 1. ICD-9-CM codes for stroke cohort**

| ICD-9-CM Codes | Description |
|---|---|
| **433.01** | Occlusion and stenosis of basilar artery with cerebral infarction |
| **433.11** | Occlusion and stenosis of carotid artery with cerebral infarction |
| **433.21** | Occlusion and stenosis of vertebral artery with cerebral infarction |
| **433.31** | Occlusion and stenosis of multiple and bilateral precerebral arteries with cerebral infarction |
| **433.81** | Occlusion and stenosis of other specified precerebral artery with cerebral infarction |
| **433.91** | Occlusion and stenosis of unspecified precerebral artery with cerebral infarction |
| **434.01** | Cerebral thrombosis with cerebral infarction |
| **434.11** | Cerebral embolism with cerebral infarction |
| **434.91** | Cerebral artery occlusion, unspecified with cerebral infarction |
| **436** | Acute, but ill-defined, cerebrovascular disease |

**Outcome**

1. **30-day time frame**
   Rationale: Outcomes occurring within 30 days of discharge can be influenced by hospital care and the early transition to outpatient settings. The use of the 30-day time frame is a clinically meaningful period for hospitals to collaborate with their communities to reduce mortality.
2. **All-cause mortality**
   Rationale: From a patient perspective, death from any cause is an adverse event.

## Appendix B. Candidate Variables

**Table B 1. Candidate variables for the updated claims-only risk adjustment model**

| Variable | Description |
|---|---|
| **n/a** | Age minus 65 (years above 65, continuous) |
| **n/a** | Male |
| **n/a** | NIHSS (continuous) |
| **n/a** | Transfer from ED |
| **CC 80** | Congestive heart failure |
| **CC 86** | Valvular or rheumatic heart disease |
| **CC 87-88** | Congenital cardiac/circulatory defects |
| **CC 90** | Hypertensive heart disease |
| **CC 92** | Specified arrhythmias |
| **CC 95** | Cerebral hemorrhage |
| **CC 96** | Ischemic or unspecified stroke |
| **CC 97** | Precerebral arterial occlusion and transient cerebral ischemia |
| **CC 98** | Cerebral atherosclerosis and aneurysm |
| **CC 100** | Hemiplegia/hemiparesis |
| **CC 1, 3-6** | History of infection |
| **CC 7-8** | Metastatic cancer, acute leukemia and other severe cancers |
| **CC 9-13** | Lymphatic, head and neck, brain, and other major cancers; breast, colorectal and other major cancers |
| **CC 21** | Protein-calorie malnutrition |
| **CC 22-24** | Other significant endocrine and metabolic disorders |
| **CC 36** | Other gastrointestinal disorders |
| **CC 39** | Disorders of the vertebrae and spinal discs |
| **CC 40** | Osteoarthritis of hip or knee |
| **CC 43** | Other musculoskeletal and connective tissue disorders |
| **CC 47** | Iron deficiency or other unspecified anemias and blood disease |
| **CC 49-50** | Dementia or other specified brain disorders |
| **CC 54-56** | Major psychiatric disorders |
| **CC 67-69** | Quadriplegia, other extensive paralysis |
| **CC 72, 76** | Multiple sclerosis |
| **CC 74** | Seizure disorders and convulsions |
| **CC 89, 91** | Hypertension |
| **CC 104-105** | Vascular disease and complications |
| **CC 108** | Chronic obstructive pulmonary disease (COPD) |
| **CC 111-113** | Pneumonia |
| **CC 114** | Pleural effusion/pneumothorax |
| **CC 124** | Other eye disorders |
| **CC 127** | Other ear, nose, throat, and mouth disorders |

| Variable | Description |
|---|---|
| **CC 130** | Dialysis status |
| **CC 131** | Renal failure |
| **CC 135** | Urinary tract infection |
| **CC 140** | Male genital disorders |
| **CC 148** | Decubitus ulcer of skin |
| **CC 149** | Chronic ulcer of skin, except decubitus |
| **CC 153** | Other dermatological disorders |

## Appendix C. Working Group Members

**Table E 1. List of measure development working group members and affiliations**

| Name | Organization/Affiliation |
|---|---|
| **Gregg Fonarow, MD** | • Professor of Medicine, David Geffen School of Medicine at UCLA<br>• Director, Ahmanson-UCLA Cardiomyopathy Center<br>• Co-Director, UCLA Preventative Cardiology Program<br>• Associate Chief, UCLA Division of Cardiology<br>• The Eliot Corday Chair in Cardiovascular Medicine and Science |
| **Lee Schwamm, MD** | • Professor of Neurology, Harvard Medical School<br>• Vice Chairman, Department of Neurology, Massachusetts General Hospital<br>• Director, TeleStroke & Acute Stroke Services |
| **Kevin Sheth, MD** | • Associate Professor of Neurology and of Neurosurgery<br>• Division Chief, Neurocritical Care and Emergency Neurology<br>• Director, Neuroscience ICU<br>• Chief, Clinical Research, Department of Neurology |
| **Jason Sico, MD** | • Assistant Professor of Neurology<br>• Assistant Professor Internal Medicine (Section of General Medicine)<br>• Director, Stroke Care VA Connecticut Healthcare System |