Excess Days in Acute Care after Hospitalization for Acute Myocardial Infarction (AMI) (Version 1.0)

Final Measure Methodology Report

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Center for Outcomes Research & Evaluation (CORE) Project Team

Report Authors:

Leora I. Horwitz, M.D., M.H.S.* – Project Lead
Changqin Wang, M.D., M.S. – Lead Analyst
Faseeha K. Altaf, M.P.H. – Project Coordinator
Chi K. Ngo, M.P.H. – Research Associate
Jeph Herrin, Ph.D.** – Statistical Consultant
Yongfei Wang, M.S. – Supporting Analyst
Jacqueline N. Grady, M.S. – Supporting Analyst
Shuling Liu, Ph.D. – Statistical Consultant
Zhenqiu Lin, Ph.D. – Analytics Director
Sharon-Lise T. Normand, Ph.D.*** – Statistical Consultant
Nihar Desai, M.D., M.P.H.** – Clinical Consultant
Arjun K. Venkatesh, M.D., M.B.A. – Clinicial Consultant
Harlan M. Krumholz, M.D., S.M.** – Principal Investigator
Susannah M. Bernheim, M.D., M.H.S. – Project Director

*New York University School of Medicine
**Yale School of Medicine
***Harvard Medical School, Harvard T.H. Chan School of Public Health

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David Engler, PhD - Senior Vice President for Leadership and Innovation, America's Essential Hospitals

Timothy Farrell, MD - Assistant Professor of Medicine, Adjunct Professor of Family Medicine, Physician Investigator; University of Utah School of Medicine

Karen Farris, PhD - Charles R. Walgreen III Professor of Pharmacy Administration, Director of the Social and Administrative Pharmacy Graduate Program; University of Michigan College of Pharmacy

Maura C. Feldman, MSW - Director for Hospital Performance Measurement and Improvement, Blue Cross Blue Shield of Massachusetts

Jay A. Gold, MD, JD, MPH - Senior Vice President and Chief Medical Officer, MetaStar

Sally Hinkle, DNP, MPA, RN - Director of Performance Improvement and Clinical Value, Temple University Hospital

Amy J. H. Kind, MD, PhD - Assistant Professor of Geriatrics, University of Wisconsin School of Medicine and Public Health; Attending Physician, William S. Middleton VA Hospital

Marjorie King, MD, FACC, MAACVPR - Director of Cardiac Services, Helen Hayes Hospital

Eugene Kroch, PhD - Vice President and Chief Scientist, Premier

Keith D. Lind, JD, MS, BSN - Senior Policy Advisor, American Association of Retired Persons (AARP) Public Policy Institute

Grace McConnell, PhD - Patient Representative

Michael A. Ross, MD, FACEP - Medical Director, Professor of Emergency Medicine; Emory University School of Medicine

Mark L. Sanz, MD - Interventional Cardiologist, International Heart Institute of Montana

Paul Takahashi, MD - Associate Professor of Medicine, Mayo Clinic College of Medicine

Anonymous Patient - Patient Representative

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Jeremiah Brown, MS, PhD - Assistant Professor of Health Policy and Clinical Practice, The Dartmouth Institute for Health Policy and Clinical Practice

Grant Ritter, PhD, MS, MA - Senior Scientist, Schneider Institute for Health Policy & Heller Graduate School

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Executive Summary

This technical report describes the excess days in acute care (EDAC) measure for acute myocardial infarction (AMI) developed by Yale New Haven Health Services Corporation – Center for Outcomes Research & Evaluation (CORE) under contract with the Center for Medicare & Medicaid Services (CMS). The outcome of this measure is the number of risk-adjusted days a hospital's patients spend in an emergency department (ED), a hospital observation unit, or a hospital inpatient unit ("days in acute care") during the 30 days following a hospitalization for AMI. The measure reports, for each hospital, the difference ("excess") between each hospital's average days in acute care ("predicted days"), and the number of days in acute care that each hospital's patients would have been expected to spend if discharged from an average performing hospital ("expected days").

Existing measures publicly report readmission and mortality rates following hospitalization for AMI. These measures do not include all post-discharge outcomes that matter to patients, such as having to return to the ED or spend time in the hospital under observation. Moreover, the increasing use of observation care may be replacing some readmissions.[1] Hospitals with high rates of observation stays in the post-discharge period may therefore have lower readmission rates that do not fully reflect their quality of care. In addition, current measures report only readmissions as a binary outcome (i.e., any versus no readmission). However, some readmissions reflect severe deterioration requiring prolonged hospitalization while others involve only a brief, less acute hospitalization. Some patients have multiple visits in 30 days. Existing measures do not distinguish among these outcomes. In addition, binary metrics do not account for each patient's opportunity for readmission: in those measures, patients who die post-discharge have less opportunity for readmission, but are counted as being at the same risk for readmission as those who survive the full measurement period. The EDAC measure addresses all of these gaps by including other outcomes (that is, ED visits and observation stays), by capturing the total amount of time patients spend in acute care, and by accounting for time at risk of an event (that is, survival time). We anticipate that the measure will support hospital efforts to further optimize quality of care for patients with AMI, particularly the quality of transitional care, by providing a more comprehensive picture of post-discharge events. It will also provide more detailed information to consumers on what to expect following discharge.

The outcome is risk-adjusted, meaning it takes into account patients' age, sex, and comorbidities in profiling hospitals. The risk-adjustment model also takes into account post-discharge deaths by scaling patient risk for acute care use and the available days for acute care to account for the time patients are alive. In addition, the model adjusts separately for the risk of having at least one event and for the duration of any event, and assumes hospitals may have differing performance for each of these. We risk standardize the measure by reporting the

difference between the predicted risk-adjusted days in acute care and the expected risk-adjusted days in acute care for each hospital. Each visit to the ED is counted as one half-day in acute care. Observation care is counted according to the hours spent in observation care, rounded up to the nearest half day. Readmissions are counted as the days spent in the hospital. Planned readmissions are not counted as outcomes. The measure reports the EDAC per 100 discharges in order to be analogous with existing readmission measures, which report the number of patients with any readmission per 100 discharges.

Overall, we find that the mean expected hospital-level days in acute care for hospitals with at least 25 discharges is 105.95 days per 100 discharges from 2010 to 2013. The mean hospital-level risk-standardized EDAC for hospitals with at least 25 discharges is 9.27 days per 100 discharges, with a minimum of -54.82 and maximum of 170.44 days per 100 discharges. The measure has a good three-year reliability using the current model specifications.

1. Introduction

1.1 Background

In July 2009, the Center for Medicare & Medicaid Services (CMS) began publicly reporting hospital 30-day risk-standardized readmission rates (RSRRs) for acute myocardial infarction (AMI). AMI was the tenth most common principal discharge diagnosis among patients with Medicare in 2012.[2] AMI also accounts for a large fraction of hospitalization costs and it was the sixth most expensive condition billed to Medicare, accounting for 4.8% of Medicare's hospital bill, in 2011.[3]

Patients admitted for AMI have disproportionately high readmission rates. Readmission rates following discharge for AMI are highly variable across hospitals in the United States (U.S.).[4,5] For the time period between July 2012 and June 2013, hospitals' 30-day RSRRs for AMI ranged from 14.1% to 20.6%.[6]

Patients, however, are not only at risk of requiring rehospitalization in the post-discharge period. Emergency department (ED) visits represent a significant proportion of post-discharge acute care utilization. Two recent studies conducted in patients of all ages have shown that 9.5% of patients return to the ED within 30 days of hospital discharge and that about 12.0% of these patients are discharged from the ED and are not captured by the current CMS 30-day AMI readmission measure.[7,8]

Additionally, over the past decade, the use of observation stays has rapidly increased. Between 2001 and 2008, the use of observation services increased nearly three-fold,[9] and significant variation has been demonstrated in the use of observation services for conditions such as chest pain.[10] These rising rates of observation stays among Medicare beneficiaries have gained the attention of patients, providers, and policymakers.[1,7,8] A report from the Office of the Inspector General (OIG) noted that in 2012, Medicare beneficiaries had 1.5 million observation stays. Many of these observation stays lasted longer than the intended one day. The OIG report also noted the potential relationship between hospital use of observation stays as an alternative to short-stay inpatient hospitalizations as a response to changing hospital payment incentives.[11]

Thus, in the context of the publicly reported CMS 30-day AMI readmission measure, the increasing use of ED visits and observation stays has raised concerns that the current CMS 30-day AMI readmission measure does not capture the full range of unplanned acute care in the post-discharge period. In particular, there exists concern that high use of observation stays could in some cases replace readmissions, and hospitals with high rates of observation stays in the post-discharge period may therefore have low readmission rates that do not accurately

reflect the quality of care.[12] In response to these concerns, we have built a measure for AMI that incorporates the full range of post-discharge use of acute care.

1.2 Importance of Post-Discharge Outcomes

The goal of this measure is to improve patient care by providing patients, physicians, and hospitals with information about hospital-level, risk-standardized acute care use following hospitalization for AMI. Measurement of patient outcomes allows for a broad view of quality of care that cannot be captured entirely by individual process-of-care measures. Safely transitioning patients from hospital to home requires a complex series of tasks which would be cumbersome to capture individually as process measures: timely and effective communication between providers, prevention of and response to complications, patient education about post-discharge care and self-management, timely follow-up, and more. Suboptimal transitions contribute to a variety of adverse outcomes post-discharge, including ED evaluation, need for observation, and readmission. Measures of unplanned readmission already exist, but there are no current measures for ED and observation stay utilization. It is thus difficult for providers and consumers to gain a complete picture of post-discharge outcomes. Moreover, separately reporting each outcome encourages "gaming," such as recategorizing readmissions as observation stays to avoid a readmission outcome. By capturing a range of outcomes that are important to patients, we can produce a more complete picture of post-discharge outcomes that better informs consumers about care quality and incentivizes global improvement in transitional care.

1.3 Post-Discharge Outcomes as a Measure of Quality

Acute care utilization after discharge (that is, return to the ED, observation stay, and readmission), for any reason, is disruptive to patients and caregivers, costly to the healthcare system, and puts patients at additional risk of hospital-acquired infections and complications. Although some hospital returns are unavoidable, others may result from poor quality of care, overutilization of care or inadequate transitional care. Transitional care includes effective discharge planning, transfer of information at the time of discharge, patient assessment and education, and coordination of care and monitoring in the post-discharge period. When appropriate care transition processes are in place (for example, patient is discharged to a suitable location, communication occurs between clinicians, medications are correctly reconciled, timely follow-up is arranged), fewer patients return to an acute care setting, either for an ED visit, observation stay, or hospital readmission during the 30 days post-discharge. Numerous studies have found an association between quality of inpatient or transitional care and early (typically 30-day) readmission rates,[13-20] and ED visits[21-25] for a wide range of conditions including AMI.

All acute care utilization is not, however, equal in its disruption, cost, or risk to patients. Prolonged acute care is worse from a patient perspective than a brief ED visit. That is why we elected to report the EDAC measure as a count of days: events lasting longer with more cost and disruption (such as readmissions) therefore naturally weigh more than brief events (such as ED visits) in the overall day count, and multiple events weigh more than a single event. Similarly, that is why we do not separately report rates of each type of event. A hospital with a high number of ED visits may still be able to achieve a low number of total days in acute care by actively coordinating care from the ED and avoiding rehospitalizations. That is, we assume that the rate of each type of event is not as relevant to patients as the total days that they spend in acute care settings.

1.4 Approach to Measure Development

CMS has contracted with Yale New Haven Health Services Corporation – Center for Outcomes Research & Evaluation (CORE) to develop a patient-centered measure of post-discharge outcomes for AMI. We developed this measure in consultation with national guidelines for publicly reported outcomes measures, following the technical approach to outcomes measurement set forth in the National Quality Forum (NQF) guidance for outcomes measures,[26,27] CMS Measure Management System guidance,[28] and the guidance articulated in the American Heart Association scientific statement, "Standards for Statistical Models Used for Public Reporting of Health Outcomes."[27] These standards include adequate risk adjustment and transparency. We sought and obtained expert input during measure development, both through CMS and through consultation with clinical and statistical experts.

1.5 Aims of the Measure

The primary objective of this work was to develop a 30-day post-discharge outcome measure that:

- Captures differences in days of acute care provided by hospitals to patients discharged alive after an AMI admission in the 30 days post-discharge;
- Adjusts for hospital case-mix;
- Assesses relative performance of hospitals; and
- Aligns with existing CMS AMI quality measures.

Using administrative claims data, we measure excess days in acute care (EDAC) for Medicare patients during the 30 days after hospitalization for AMI. The AMI EDAC measure captures acute care utilization in the inpatient and outpatient settings. Key decisions made in the

development of the AMI EDAC measure are aligned with key decisions made for the CMS 30-day AMI readmission measure.

2. Methods

2.1 Overview

We developed a hospital-level measure of post-discharge outcomes for patients aged 65 years and over admitted for AMI to a non-Federal acute care hospital in the U.S. (including U.S. Virgin Islands, Puerto Rico, Guam, Northern Mariana Islands, and American Samoa). This measure reports the full spectrum of acute care after discharge from an acute care setting for AMI. This measure reports a collective set of adverse outcomes that can occur post-discharge: ED visits, observation stays, and unplanned readmissions at any time during the 30 days post-discharge. The measure does not count planned readmissions in the measure outcome since they are generally not a signal of quality of care.

We developed the measure in the Medicare Fee-for-Service (FFS) population and aligned the cohort definition and risk-adjustment strategy with those of the existing CMS 30-day AMI readmission measure. The outcome is defined as days spent in acute care (that is, ED visits, observation stays, and readmissions). Use of a day-count outcome generates a clinically reasonable and natural weighting scheme such that events that take more days (that is, days rehospitalized) naturally carry more weight than events taking fewer days (that is, ED visits). That is, the weight of each component of the composite is determined by its actual impact and burden on patients, not by an arbitrary weighting scheme. We risk adjust the day count to account for age, gender, and comorbidities. We use a model appropriate for count data, and we incorporate exposure time to account for survival times shorter than 30 days. The final reported outcome of EDAC is risk-standardized by subtracting the average expected number of days in acute care from the average predicted number. These EDAC are multiplied by 100 to represent EDAC per 100 discharges for reporting purposes.

2.2 Data Sources

We used Medicare administrative claims data for measure development. To develop and test the measure, we used Medicare inpatient, outpatient, and physician Carrier claims data, enrollment data, and the Chronic Conditions Data Warehouse (CCW) data files.

We used two data sources to define the cohort, comorbidities, and other factors for risk adjustment, and to capture the outcome of hospitalization days within 30 days after the index hospitalization for AMI:

- Medicare Enrollment Database (EDB) (to determine eligibility). This dataset contains Medicare beneficiary demographic, benefit/coverage, enrollment status, and vital status information.

- Medicare hospital inpatient and outpatient claims, and physician Carrier claims.

We used a third data source to capture the outcome of days in acute care of ED visits and observation stays.

- CCW 100% condition-specific datasets. Specifically, we used the outpatient hospital institutional claims file and physician Carrier file (also known as the Physician/Supplier Part B claims file).

For measure development and testing, we constructed a full three-year dataset of AMI hospitalizations (July 1, 2010 to June 30, 2013) and then randomly split the dataset into two equal samples, stratified on hospital (so that each sample contained one half of each hospital's discharges). These samples served as a development sample and a validation sample. We used the development sample for statistical model selection and measure testing (including reliability testing), and we used the validation sample for model performance examination, model variable reliability and validity testing, and measure reliability testing.

2.3 Cohort Definition

We defined the eligible cohort for the measure as those hospitalizations eligible for the current, NQF-endorsed, CMS 30-day AMI readmission measure, except for patients admitted to Veterans Administration hospitals. That is, the cohort includes patients aged 65 years and older who were hospitalized with a principal discharge diagnosis of AMI at a non-Federal acute care facility and who were alive at discharge. Patients are eligible for inclusion if they had a qualifying diagnosis and continuous enrollment in Part A and Part B Medicare 12 months prior to the first day of the index hospitalization. Hospitalizations in which the patient was transferred to another acute care facility are not included, but hospitalizations at the facility receiving the transfer are included. We defined the cohorts using the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) diagnosis codes identified in inpatient claims data, as shown in Table C1.

2.3.1 Index Cohort Exclusions

Consistent with CMS's 30-day AMI readmission measure, we applied the following exclusion criteria to the cohort of index admissions (Figure 1):

- Hospitalizations without at least 30 days of post-discharge enrollment in Part A and Part B FFS Medicare
  Rationale: The 30-day outcome cannot be assessed in this group since claims data are used to determine whether a patient visited the ED, was placed under observation, or was readmitted.

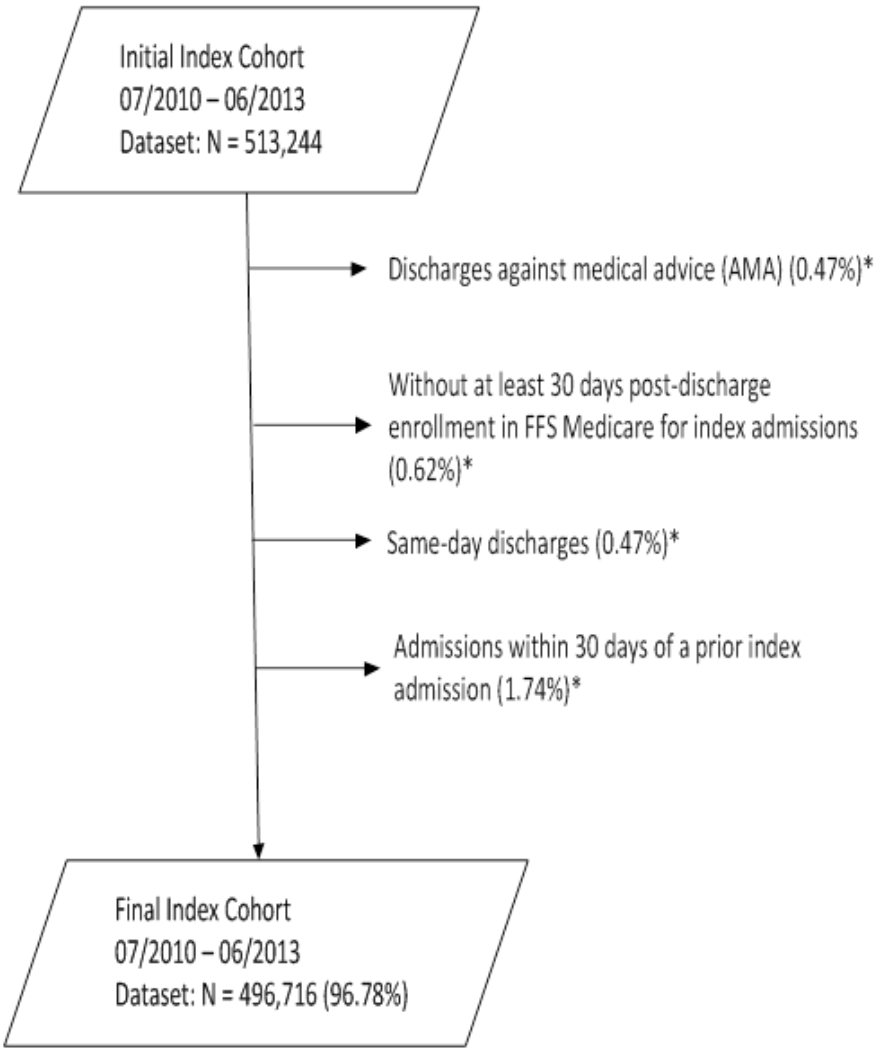
- Discharged against medical advice (AMA)
  Rationale: Providers did not have the opportunity to deliver full care and prepare the patient for discharge.

- Hospitalizations for patients admitted and discharged on the same day (and not transferred or deceased)
  Rationale: These patients likely did not suffer clinically significant AMIs.

- Hospitalizations for patients with an index admission within 30 days of a previous index admission
  Rationale: Additional AMI admissions within 30 days are excluded as index admissions because they are part of the outcome, and we choose not to count a single admission both as an index admission and a readmission for another index admission.

Admissions may have been counted in more than one exclusion category because they are not mutually exclusive.

Figure 1. Index acute myocardial infarction (AMI) cohort for the 2010 to 2013 dataset



2.4 Outcome Definition

The outcome is the number of days the patient spends in acute care (ED treat-and-release visits, observation stays, and readmissions) during the first 30 days after discharge from the hospital.

2.4.1 Definition of the Outcome

We define days in acute care as days spent in an ED, admitted to observation status, or admitted as an unplanned readmission for any cause within 30 days from the date of discharge from the index AMI hospitalization.

- We define an ED visit as a visit with revenue center codes '0450', '0451', '0452', '0459', or '0981'. See Table A1 in Appendix A for the code definitions. Each ED visit is counted as one half-day (0.5 days).

- We define an observation stay as a visit with revenue center code '0762' or Healthcare Common Procedure Coding System (HCPCS) code 'G0378' (in the outpatient data files) or Current Procedural Terminology (CPT) codes '99217' to '99220' or '99234' to '99236' (in the physician Carrier data files). This broad definition captures all post-discharge observation stays in the facility and physician Carrier files. See Table A1 in Appendix A for the code definitions. Observation stays are recorded in terms of hours and converted for the measure into half-days (rounded up).

- We define a readmission as any unplanned acute care hospital inpatient hospitalization within 30 days of the discharge date for the index hospitalization. "Planned" readmissions are those planned by providers for anticipated medical treatment or procedures that must be provided in the inpatient setting. To exclude planned readmissions, we use the planned readmission algorithm previously developed for the publicly reported CMS 30-day AMI readmission measure (see Appendix B).[29] Each rehospitalization is counted according to the length of stay, which is calculated as the discharge date minus the admission date. Admissions that extend beyond the 30-day follow-up period are truncated on day 30.

- When an ED visit, observation stay, or readmission overlaps with another event on the same day, we count only the most severe of the overlapping events. For example, we count only a readmission day if the readmission and either an observation stay or ED visit happens on the same day; we count only an observation day if an observation stay and an ED visit happen on the same day.

2.4.2 Multiple Events

We count all eligible outcomes occurring in the 30-day period, even if they are repeat occurrences. For example, if a patient returns to the ED three times on three different days, we count each ED visit as a half-day. Similarly, if a patient has two hospitalizations within 30 days, the days spent in each are counted. We take this approach in order to capture the full patient experience in the post-discharge period.

2.4.3 30-Day Timeframe

The measure assesses eligible outcomes within a 30-day period from the date of discharge from an index hospitalization. We considered 30 days as a clinically reasonable timeframe for two reasons:

1. Within a 30-day timeframe, ED visits, observation stays, and readmissions are more likely attributable to the care received during the index admission and during the transition to the outpatient setting than outcomes occurring later post-discharge. A number of studies have demonstrated that improvements in care at the time of patient discharge can reduce 30-day readmission rates.[25,30-40] Hospitals, in collaboration with their medical communities, can take a number of actions to reduce readmissions: ensure patients are clinically ready at discharge; reduce risk of infection; reconcile medications; improve communications among providers involved in transition of care; encourage strategies that promote disease management principles; and educate patients about symptoms to monitor, whom to contact with questions, and where and when to seek follow-up care.[25,30-40] Studies also show that it can take more than 14 days for the benefits of these interventions to appear.[41]

2. The 30-day timeframe is consistent with the existing CMS 30-day AMI readmission measure approved by NQF and publicly reported by CMS.

   Note that if a readmission or observation stay extends beyond 30 days, only that portion of the stay that occurs during the 30 days is included in the outcome. In addition, note that for patients who did not survive 30 days, we adjusted their total exposure period to reflect the number of days they survived (see Section 2.7.1).

2.4.4 All-Cause Days in Acute Care

We measure all-cause acute care utilization for several reasons. First, from the patient perspective, acute care utilization for any cause is undesirable. Second, limiting the measure to AMI acute care utilization may make it susceptible to gaming. Moreover, it is often hard to exclude quality concerns and accountability based on the documented cause of a hospital visit.

2.4.5 Transfers

The measure considers multiple contiguous hospitalizations to be a single acute episode-of-care. Admissions to a hospital within one day of discharge from another hospital are considered transfers whether or not the first institution indicates intent to transfer the patient in the discharge disposition code. Days in acute care for transferred patients are attributed to the hospital that ultimately discharges the patient to a non-acute care setting (for example, to

home or to a skilled nursing facility). Thus, if a patient is admitted to Hospital A, transferred to Hospital B, and ultimately discharged from Hospital B to a non-acute care setting, all ED visits, observation stays, and readmissions within 30 days of discharge are attributed to Hospital B. If a patient is readmitted to the same hospital on the same day of discharge for the same diagnosis as the index admission, the measure considers the patient to have had one single continuous admission. However, if the diagnosis of the readmission is different from the index admission, this is considered a readmission in the measure.

2.4.6 Exposure Time

Because some patients do not survive 30 days, not all patients are at risk for an acute event for the same amount of time. We calculated 'exposure time' as the number of days each patient survived after discharge, up to 30. This exposure time was incorporated as part of the outcome to reflect differential risk for EDAC after discharge. This differs from the existing CMS AMI 30-day readmission measure, which considers all patients to be equally at risk for a hospital event regardless of survival time.

2.5 Final Risk-Adjustment Variables

We used the final risk-adjustment variables in the current CMS 30-day AMI readmission measure in order to harmonize with the existing measure. We verified the adequacy of this risk-adjustment strategy with our new outcome by comparing the discrimination of the models with a full set of all comorbidities to the more parsimonious existing risk models. We found no meaningful improvement in model discrimination with the full set.

The measure adjusts for variables (that is, age, gender, comorbid diseases, and indicators of patient frailty) that are clinically relevant and have strong relationships with the outcome. For each patient, risk-adjustment variables are obtained from inpatient, outpatient, and physician Medicare administrative claims data extending 12 months prior to, and including, the index admission.

The measure seeks 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 that time or in the 12 months prior, and not complications that arise during the course of the index hospitalization, are included in the risk adjustment.

The measure does not adjust for patients' admission source or their discharge disposition (for example, skilled nursing facility) because these factors are associated with the structure of the healthcare system, not solely patients' clinical comorbidities. Regional differences in the availability of post-acute care providers and practice patterns might exert undue influence on

model results. In addition, these data fields are not audited and are not as reliable as diagnosis codes.

The measure also does not adjust for socioeconomic status (SES) because the association between SES and health outcomes can be due, in part, to differences in the quality of healthcare that patients with varying SES receive.

The Office of the Assistant Secretary for Planning and Evaluation (ASPE) is conducting research to examine the impact of SES on quality measures, resource use, and other measures under the Medicare program as directed by the Improving Medicare Post-Acute Care Transformation Act of 2014 (IMPACT Act), and will issue an initial report to Congress by October 2016 and a final report to Congress by October 2019. We will closely examine the findings of these reports and related Secretarial recommendations and consider how they apply to the measure at such time as they are available.

Refer to Table C2 for the list of risk-adjustment variables and Table C3 in Appendix C for the list of complications that are excluded from risk adjustment if occurring during the index admission for AMI.

2.6 Statistical Approach to Measure Calculation

We performed a number of analyses to determine the best model specification for the number of days in acute care. This is a pseudo-count variable (similar to a count variable, but taking half-integer values for half days of acute care), and we therefore considered models that were generalized count models. All model development was performed using the development sample.

2.6.1 Modeling Alternatives

Inspection of the distribution of the outcome determined that the number of event days was highly skewed, with a large number of zeroes. Thus, we considered models appropriate for skewed data, including approaches that modeled the zero-day outcomes and non-zero day outcomes separately. We only considered approaches that allowed us to incorporate exposure time to account for differential risk.

First, using only patients with non-zero days, we estimated a generalized linear model (GLM) using a Poisson specification, and applied a Park test;[42] the Park test indicated that Poisson was the best fit for our outcome. The Poisson model is commonly used for modeling count data and can be generalized to dependent variables that take non-integer values, such as ours.

We then considered three different model specifications for the full set of outcomes (zero and non-zero days):

1. Poisson: this is the conventional GLM model.

2. Zero-inflated Poisson: this is a generalization of the Poisson model, which includes separate parameters for zero and non-zero outcomes.

3. Two-part logit/Poisson: this two-part model (often called a "hurdle" model) assumes that the outcome results from two related processes: an initial dichotomous event – that a patient has at least one day of acute care – which is modeled as the logit of the probability of the event, and for patients with an event (those which clear the "hurdle"), the number of days, which is modeled as a Poisson process.

Importantly, for all three models we included the exposure time (see Section 2.4.6) as an offset. For the hurdle model, we included exposure time as an offset for each part.

For each of the three specifications listed above, we estimated (non-hierarchical) generalized linear models with days in acute care as the outcome. We compared the three different model specifications for the outcome using the following criteria:

1. Akaike information criterion (AIC);

2. Bayesian information criterion (BIC); and

3. Log likelihood.

We also graphed the distribution of each observed outcome with the predicted values from the model specifications.

The best performing model was the two-part logit/Poisson model.

2.7 Hospital Performance Reporting

2.7.1 Excess Days in Acute Care

For the final risk-adjustment model, we used a hierarchical generalized linear model (HGLM). This consists of the two-part logit/truncated Poisson model specifications for days in acute care and includes two random effects for hospitals – one for the logit part and one for the truncated Poisson part – with a non-zero covariance between the two random effects. This allowed us to account 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.

Explicitly, let Y_{ij} denote the number of days in acute care experienced by the *i*-th patient discharged from the *j*-th hospital, and ω_{ij} is the patient's exposure time (that is, the number of days alive up to 30). At the first stage, whether a patient has non-zero days in acute care is modeled via a logistic regression model. At the second stage, we assume that conditional on $Y_{ij} > 0$; Y_{ij} follows a zero-truncated Poisson distribution. Thus, we have the following "hurdle" model:

$$\begin{cases} \text{logit}(\pi_{ij}) = \log(\omega_{ij}) + X_{ij}C + v_j \text{ where } \pi_{ij} = \Pr\{Y_{ij} > 0\} \\ \log(\mu_{ij}) = \log(\omega_{ij}) + X_{ij}B + u_j \text{ where } Y_{ij} \mid Y_{ij} > 0 \sim \text{Truncated Poisson}(\mu_{ij}) \end{cases} \quad (1)$$

Note that $E(Y_{ij} \mid Y_{ij} > 0) = \mu_{ij}/(1 - \exp(-\mu_{ij}))$ and $E(Y_{ij}) = \pi_{ij}\mu_{ij}/(1 - \exp(-\mu_{ij}))$. $(v_j, u_j) \sim MVN(M, \Sigma)$, where v_j and u_j are random effects across hospitals with means $M = [C_0, B_0]$ and variance-covariance matrix Σ. The X_{ij} is a vector of patient risk factors, and B and C are vectors of coefficients.

We estimated the model and used the coefficient vectors B and C and the random effects v_j and $u_j$to calculate the predicted (P_{ij}) and expected (E_{ij}) days in acute care for each index admission, respectively. The predicted number of days is calculated as:

$$P_{ij} = \text{logit}^{-1}(X_{ij}C + v_j) * \frac{\exp(X_{ij}B + u_j)}{1 - \exp(-\exp(X_{ij}B + u_j))} \quad (2)$$

And, the expected number of days is calculated as:

$$E_{ij} = logit^{-1}(X_{ij}C + C_0) * \frac{\exp(X_{ij}B + B_0)}{1 - \exp(-\exp(X_{ij}B + B_0))} \quad (3)$$

where C_0 and B_0 are means of the random effects v_j and u_j.

We then calculated the EDAC for the hospital *j* as:

$$EDAC_j = 100 * \sum(P_{ij} - E_{ij})/m_j \quad (4)$$

where the sum is over all patients at hospital *j*, and m_j is the number of index admissions at hospital *j*. To be consistent with the reporting of the CMS 30-day heart failure readmission measure, we have multiplied the final measure by 100 so that EDAC represents EDAC per 100 discharges.

2.7.2 Estimation and Interval Estimates

The model (1) was first estimated using maximum likelihood, which indicated that Σ had non-zero off diagonal values (v_j and u_j have non-trivial covariance). Because the EDAC defined in (4) is a complex function of model estimates, and in particular because Σ is not diagonal, it is problematic to construct standard errors for P_{ij} from the maximum likelihood estimates, while the computational intensity of estimating model (1) made non-parametric bootstrapping impractical.

For these reasons, and to make fewer assumptions about the parameter distributions, we chose to estimate our final version of model (1) using fully Bayesian Markov Chain Monte Carlo (MCMC) estimation.[43] MCMC estimation allowed us to generate a large number of simulated values of P_{ij}, E_{ij}, v_j and u_j, from which to make inferences; using these simulated values, we calculated a similar number of values of $EDAC_j$ for each hospital. The median value was taken as the hospital estimate, with the 2.5th and 97.5th percentile order statistics taken as the endpoints of a 95% credible interval (CI).

2.7.3 Categorizing Hospital Performance

To categorize hospital performance, we estimated each hospital's EDAC and the corresponding 95% CI. We assigned hospitals to a performance category by comparing each hospital's EDAC interval estimate to zero. Comparative performance for hospitals with 25 or more eligible cases was classified as follows:

- "No different than expected" if the 95% CI surrounding the hospital's days includes zero.
- "Higher than expected" if the entire 95% CI surrounding the hospital's days is above zero.
- "Lower than expected" if the entire 95% CI surrounding the hospital's days is below zero.

If a hospital has fewer than 25 eligible cases for a measure, we assigned the hospital to a separate category: "The number of cases is too small (fewer than 25) to reliably tell how well the hospital is performing."

2.8 Measure Testing

To assess the reliability and validity of the measure, we used data from July 2010 to June 2013, divided as described above (Section 2.2) into development and validation samples.

2.8.1 Model Estimation

We used methods appropriate for MCMC estimation to assess convergence and the assumptions of the model. To estimate each MCMC model and to assess the convergence of the model, we generated three separate chains (series of iterations), each starting with different initial values of the between-hospital variances (Σ in model 1) – the estimates from an initial maximum likelihood (ML) model, one half those estimates, and twice those estimates. Retaining 4,000 simulations from each chain, we calculated the Gelman-Rubin diagnostic for each parameter using the first 3,000 from each chain.[44] Convergence was assumed if the Gelman-Rubin ratio was between 0.9 and 1.1. If convergence was achieved for all parameters, the last 1,000 iterations from each chain were combined, and the resulting 3,000 iterations used for all future inferences (that is, for all results). Unless otherwise specified, median values from this pooled set are reported.

2.8.2 Model Performance

We then used posterior predictive checking (PPC) to evaluate the overall fit of the model in the development sample.[45] PPC compares hypothetical data generated by our model to observed data. If the model is well-specified, then the distribution of the hypothetical data it generates should include the observed data. Because our primary unit of interest is the hospital, we applied PPC to observable hospital summary statistics. Using the results of model (1), and the underlying sampling distributions (logit, Poisson) we generated 3,000 datasets of simulated "observed" data; for each, we calculated the mean days in acute care per hospital and then the median, variance, interquartile range (IQR), and coefficient of variation (CV) across hospitals. The same statistics calculated from the observed data were compared to the distribution of simulated data, and the corresponding P-value calculated.

To assess model discrimination, we computed two different statistics -- one for the logit part of the model and one for the truncated Poisson part – using the development sample. For the logit model of zero versus non-zero days, which includes all patients in the cohort, we calculated the C-statistic. For the truncated Poisson model of non-zero days, which includes only patients with some acute care, we calculated the deviance R^2. The deviance R^2 is computed from the difference in the log-likelihoods between the final model and an empty model (no covariates) attributed to each observation, averaged over all observations.[46]

In a generalization of the calibration statistics for logistic models, we calculated the linear prediction Z = XB and W = XC using the coefficients B and C from the development sample and data X from the validation sample. We then estimated a model using the same functional form but only two independent variables, Z for the truncated Poisson part and W for the logit part. The intercepts and coefficients of Z and W in these second models are reported as (γ_0, γ_1), the

calibration statistics for each part of the model. The closer they are to (0, 1), the better the model calibration.[47]

We also created a calibration plot, with mean predicted and mean observed days in acute care plotted against decile of predicted utilization rate (predicted days/exposure days).

Finally, we summarized the EDACs, overall and according to hospital performance category or outlier status. In addition, to provide some insight into the relative contribution of each type of event to the overall outcome, and to provide some insight into patterns of performance by high-scoring and low-scoring hospitals, we examined the ED visit, observation stay, readmission rates, and average days for a random sample of ten hospitals each in the top and bottom quintile of performance on the EDAC measure.

2.8.2 Reliability of Data Elements

The data elements used in the measure are taken from claims data, and all, with the exception of age, are elements used for reimbursement. Prior efforts have established that the publicly reported CMS 30-day AMI readmission measure risk model variables derived from claims data are consistent with those based on medical chart review. We are using the same risk variables as are used in that measure.

We assessed the reliability of the data elements by comparing variable frequencies between our development sample and validation sample.

2.8.3 Measure Score Reliability

For test-retest reliability, we calculated the EDAC for each hospital using first the development sample, then again using the validation sample. Thus, we measured each hospital twice, but made each measurement using an entirely distinct set of patients. We then compared these using intraclass correlation coefficient (ICC) [2, 1].[48] Using two independent samples provides a stringent estimate of the measure's reliability as compared to using two random, but potentially overlapping samples, which would exaggerate the agreement.

We restricted this calculation to hospitals with at least 12 discharges in both samples in one and a half years to approximate the set of hospitals that would have more than 24 discharges over three years and are thus likely to be included in public reporting. We applied the Spearman-Brown prophecy formula to adjust the ICC [2,1] of the split samples to represent three years of data.[49]

2.8.4 Validity Testing

We demonstrated measure validity through relevant prior validity testing that we conducted for other claims-based measures, through use of established measure development guidelines, through assessment by external groups, and through systematic assessment of measure face validity by a technical expert panel (TEP) of national experts and stakeholder organizations.

This measure is closely related in design to the publicly reported, NQF-endorsed CMS 30-day AMI readmission measure. While this measure includes additional endpoints, and measures them in a different metric (that is, days rather than rates), we would expect that hospitals would have similar – though not identical – performance rankings on the two measures. Thus, as one assessment of validity, we compared the rankings of all hospitals using the two measures to assess the consistency of hospital performance on closely related outcomes. We calculated the Pearson correlation, and graphed the readmission measure against the EDAC measure to determine if there were outliers.

Additionally, we systematically assessed the face validity of the measure score as an indicator of quality by soliciting the TEP members' agreement with the following statement: "The EDAC obtained from the measure as specified can be used to distinguish between better and worse quality hospitals." We measured agreement using a six-point scale: 1=Strongly disagree, 2=Moderately disagree, 3=Somewhat disagree, 4=Somewhat agree, 5=Moderately agree, 6=Strongly agree.

3. Results

3.1 Model Results

In this section, we show results for the AMI measure.

3.1.1 Development and Validation Samples

After applying all inclusion and exclusion criteria, the full three-year dataset included 496,716 discharges. The development sample consisted of 248,358 discharges from 4,163 hospitals. Patients hospitalized for AMI were mostly male (50.6%) and had an average age of 78.9 years. The validation sample consisted of 248,358 discharges from 4,176 hospitals. Patients in the validation sample were mostly male (50.4%) and had an average age of 78.9 years.

3.1.2 Final Risk-Adjustment Variables

Consistent with the current CMS 30-day AMI readmission measure, the final risk-adjustment model included 31 variables. Table 1 shows the frequency of each risk variable in the final AMI days in acute care model in the development and validation samples. Compared to the development sample, the mean age of patients and the frequencies of risk-adjustment variables in the validation sample were similar.

Table 1. Frequency of risk model variables in the development and validation samples

Risk variable	Development sample (N=248,358)		Validation sample (N=248,358)	
	n	%	n	%
Age, continuous (mean [SD])	78.9 (8.3)		78.9 (8.3)	
Male	125,742	50.6	125,274	50.4
History of Coronary Artery Bypass Graft (CABG) surgery (ICD-9 codes V45.81, 36.10-36.16)	27,375	11.0	27,420	11.0
History of Percutaneous Transluminal Coronary Angioplasty (PTCA) (ICD-9 codes V45.82, 00.66, 36.06, 36.07)	40,889	16.5	40,461	16.3
Angina pectoris/old myocardial infarction (CC 83)	68,310	27.5	68,521	27.6
Congestive heart failure (CC 80)	81,338	32.8	81,389	32.8
Coronary atherosclerosis (CC 84)	212,635	85.6	212,363	85.6
Acute coronary syndrome (CC 81-82)	56,101	22.6	56,191	22.6
Specified arrhythmias and other heart rhythm disorders (CC 92- 93)	88,925	35.8	88,574	35.7
Valvular or rheumatic heart disease (CC 86)	78,943	31.8	78,402	31.6
Cerebrovascular disease (CC 97-99, 103)	52,767	21.3	52,904	21.3

Risk variable	Development sample (N=248,358)		Validation sample (N=248,358)	
	n	%	n	%
Stroke (CC 95-96)	18,727	7.5	18,521	7.5
Vascular or Circulatory Disease (CC 104, 105, 106)	90,995	36.6	90,988	36.6
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177-178)	15,976	6.4	15,977	6.4
Diabetes mellitus (DM) or DM complications (CC 15-20, 119-120)	116,027	46.7	116,364	46.9
Renal failure (CC 131)	66,781	26.9	67,028	27.0
End-stage renal disease or dialysis (CC 129-130)	8,021	3.2	7,920	3.2
Other urinary tract disorders (CC 136)	54,899	22.1	54,905	22.1
Chronic obstructive pulmonary disease (COPD) (CC 108)	76,222	30.7	76,037	30.6
Pneumonia (CC 111-113)	57,962	23.3	58,263	23.5
Asthma (CC 110)	16,797	6.8	16,894	6.8
Disorders of fluid/electrolyte/acid-base (CC 22-23)	70,748	28.5	70,975	28.6
History of infection (CC 1, 3-6)	67,351	27.1	67,463	27.2
Metastatic cancer or acute leukemia (CC 7)	5,135	2.1	5,034	2.0
Cancer (CC 8-12)	47,525	19.1	46,948	18.9
Iron deficiency or other unspecified anemias and blood disease (CC 47)	117,321	47.2	117,241	47.2
Decubitus ulcer or chronic skin ulcer (CC 148-149)	19,811	8.0	19,738	8.0
Dementia or other specified brain disorders (CC 49-50)	48,891	19.7	49,244	19.8
Protein-calorie malnutrition (CC 21)	15,435	6.2	15,301	6.2
Anterior Myocardial Infarction (ICD-9 410.00-410.19)	18,146	7.3	18,288	7.4
Other location of Myocardial Infarction (ICD-9 410.20-410.69)	27,825	11.2	27,646	11.1

3.1.3 Model Performance

All parameters had Gelman-Rubin ratios between 0.9 and 1.1, with the variance components having ratios very close to 1. The median parameter estimates for each of the two parts of the model are shown in Table 2 along with the credible interval (2.5th percentile and 97.5th percentile values).

Table 2. Median parameter estimates and credible interval (CI) of risk variables from the logit and Poisson models for the development sample

Risk variable	Part 1: Logit model		Part 2: Poisson model	
	Median	CI	Median	CI
Age minus 65 (years above 65, continuous)	0.009	(0.008, 0.010)	0.004	(0.004, 0.005)
Male	-0.088	(-0.105, -0.071)	-0.003	(-0.012, 0.004)
History of Coronary Artery Bypass Graft (CABG) surgery (ICD-9 codes V45.81, 36.10-36.16)	-0.014	(-0.042, 0.016)	-0.039	(-0.051, -0.026)
History of Percutaneous Transluminal Coronary Angioplasty (PTCA) (ICD-9 codes V45.82, 00.66, 36.06, 36.07)	-0.107	(-0.131, -0.082)	-0.041	(-0.053, -0.030)
Angina pectoris/old myocardial infarction (CC 83)	0.038	(0.014, 0.058)	-0.040	(-0.051, -0.031)
Congestive heart failure (CC 80)	0.140	(0.116, 0.162)	0.095	(0.086, 0.104)
Coronary atherosclerosis (CC 84)	0.010	(-0.016, 0.033)	-0.046	(-0.058, -0.032)
Acute coronary syndrome (CC 81-82)	0.024	(0.005, 0.047)	-0.035	(-0.045, -0.026)
Specified arrhythmias and other heart rhythm disorders (CC 92- 93)	0.099	(0.079, 0.125)	-0.014	(-0.023, -0.004)
Valvular or rheumatic heart disease (CC 86)	0.083	(0.066, 0.105)	0.064	(0.055, 0.073)
Cerebrovascular disease (CC 97-99, 103)	0.030	(0.007, 0.053)	-0.008	(-0.017, 0.002)
Stroke (CC 95-96)	0.045	(0.010, 0.080)	0.021	(0.006, 0.034)
Vascular or Circulatory Disease (CC 104, 105, 106)	0.069	(0.048, 0.089)	0.033	(0.022, 0.042)
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177-178)	0.079	(0.041, 0.121)	0.043	(0.028, 0.058)
Diabetes mellitus (DM) or DM complications (CC 15-20, 119-120)	0.111	(0.095, 0.129)	0.083	(0.075, 0.092)
Renal failure (CC 131)	0.107	(0.086, 0.132)	0.102	(0.092, 0.113)
End-stage renal disease or dialysis (CC 129-130)	0.344	(0.294, 0.398)	-0.036	(-0.053, -0.017)
Other urinary tract disorders (CC 136)	0.084	(0.062, 0.104)	0.019	(0.010, 0.028)
Chronic obstructive pulmonary disease (COPD) (CC 108)	0.203	(0.184, 0.223)	0.112	(0.104, 0.121)
Pneumonia (CC 111-113)	0.147	(0.124, 0.170)	0.114	(0.105, 0.123)
Asthma (CC 110)	0.047	(0.011, 0.084)	-0.049	(-0.064, -0.035)
Disorders of fluid/electrolyte/acid-base (CC 22-23)	0.135	(0.109, 0.157)	0.018	(0.009, 0.028)
History of infection (CC 1, 3-6)	0.033	(0.015, 0.055)	0.010	(0.000, 0.020)
Metastatic cancer or acute leukemia (CC 7)	0.204	(0.130, 0.272)	0.097	(0.069, 0.122)

Risk variable	Part 1: Logit model		Part 2: Poisson model	
	Median	CI	Median	CI
Cancer (CC 8-12)	0.016	(-0.009, 0.040)	-0.023	(-0.034, -0.013)
Iron deficiency or other unspecified anemias and blood disease (CC 47)	0.163	(0.143, 0.181)	0.172	(0.162, 0.182)
Decubitus ulcer or chronic skin ulcer (CC 148-149)	0.128	(0.097, 0.155)	0.059	(0.047, 0.071)
Dementia or other specified brain disorders (CC 49-50)	0.076	(0.054, 0.099)	-0.013	(-0.024, -0.003)
Protein-calorie malnutrition (CC 21)	0.139	(0.100, 0.179)	0.144	(0.130, 0.157)
Anterior Myocardial Infarction (ICD-9 410.00-410.19)	0.181	(0.148, 0.214)	0.103	(0.089, 0.120)
Other location of Myocardial Infarction (ICD-9 410.20-410.69)	-0.032	(-0.064, 0.000)	-0.051	(-0.065, -0.035)

The results of the PPC are shown in Table 3.

Table 3. Posterior predictive checking (PPC) results for development sample

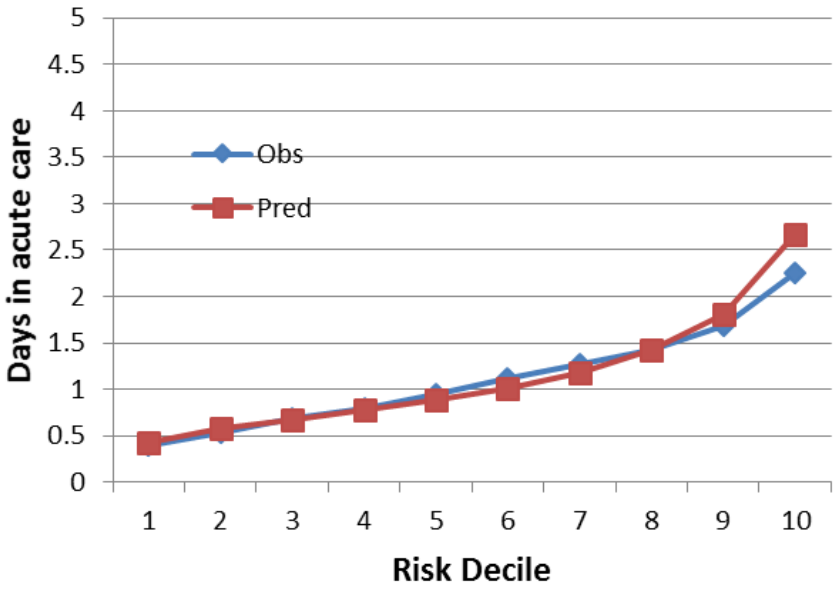
Statistic	Observed days in acute care	MCMC 95% credible interval (CI) for predicted days in acute care	P-value
Variance	1.27	(1.1200, 1.4815)	0.8400
Median	0.97	(1.0000, 1.0093)	0.0003
Interquartile range (IQR)	0.90	(0.8913, 0.9545)	0.1560
Coefficient of variation*	1.03	(0.9120, 1.0192)	0.0117

*Note: Coefficient of variation is defined as the ratio of the standard deviation to the mean.

As can be seen in Table 3, the variance and IQR of the hospital median days in acute care fell within the MCMC CIs; the median and coefficient of variation did not.

The C-statistic for the logit part of the model was 0.60; the deviance R^2 for the Poisson part was 0.040 or 4%. We applied the models in the development sample and the validation sample. The calibration statistics were (-0.10, 0.98) and (-0.04, 0.97) for the logit and truncated Poisson parts of the model, respectively. If the γ_0 in the validation samples are substantially far from zero, and the γ_1 is substantially far from one, there is potential evidence of over-fitting. The calibration value of close to zero at one end and close to one at the other end indicates very good calibration of the model. As shown in Figure 2, the model underestimates risk for the lowest risk decile patients and slightly overestimates risk for the highest risk decile patients.

Figure 2. Plot of observed versus predicted days in acute care in the development sample



3.1.4 Unadjusted and Adjusted Outcomes

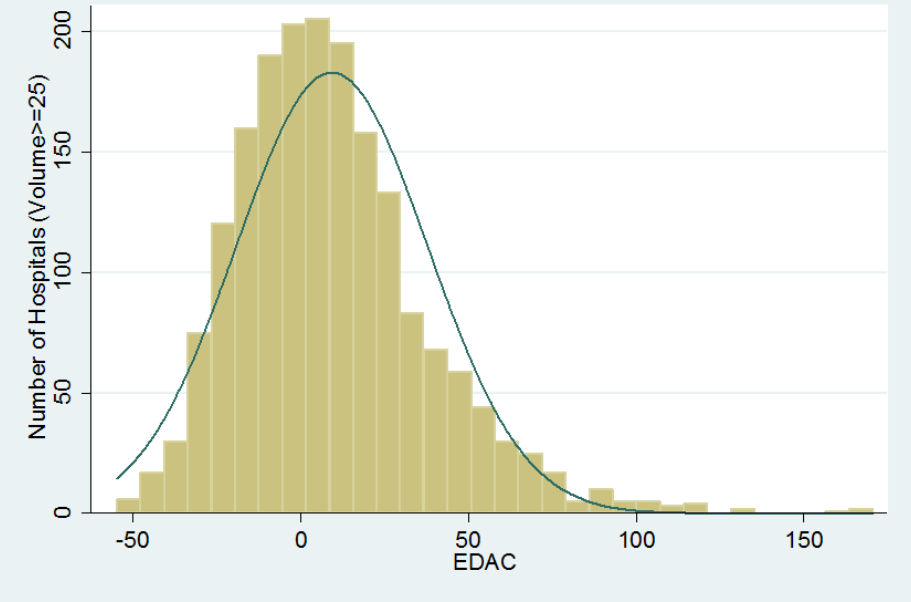
In Table 4 below, we show both unadjusted (observed) days of post-discharge events per 100 discharges and EDAC per 100 discharges for AMI in the development sample. Figure 3 illustrates the distribution of EDAC across hospitals for AMI. All results are shown at the hospital-level, and EDAC results are restricted to hospitals with at least 25 discharges in the measurement period.

Table 4. Hospital-level unadjusted distribution of overall acute care, emergency department (ED) visits, observation stays, and readmissions per 100 acute myocardial infarction (AMI) discharges, and distribution of excess days in acute care (EDAC)

Description	Mean ± SD	Median (Q1, Q3)	Range
Observed days in acute care	113.02 ± 43.44	106.25 (83.12, 134.94)	369.30
Days of ED visits	7.20 ± 3.17	6.82 (5.11, 8.92)	24.00
Days of observation stays	8.48 ± 6.39	7.35 (4.24, 11.49)	57.14
Days of readmissions	99.60 ± 43.80	92.73 (68.78, 121.64)	348.48
EDAC	9.27 ± 28.49	5.46 (-10.50, 24.48)	225.26
Days of predicted	115.22±35.55	109.13(89.88, 135.30)	276.68
Days of expected	105.95 ± 15.25	103.77(95.21, 113.78)	157.90

Note: Data from 2010-2013 FFS claims development sample for hospitals with ≥ 25 discharges; N=1,855; ED visit=0.5 day; observation stay hours are rounded up to the nearest 0.5 day.

Figure 3. Hospital-level, excess days in acute care (EDAC) per 100 discharges for hospitals with at least 25 discharges in the development sample



The mean EDAC per 100 discharges for hospitals in the top decile of performance is -23.3 compared to 170.4 for hospitals in the bottom decile. The variation in days in acute care suggests there are meaningful differences in the quality of care received across hospitals for the AMI EDAC measure.

To visualize the relative contributions of ED visits, observation stays, and readmissions, we sorted hospitals with at least 100 discharges according to their EDAC and randomly selected ten in the top quintile of performance and ten in the bottom quintile of performance. For purposes of illustration only, we include the unadjusted event rates and the mean days of events among patients with an event (Table 5). Only risk-adjusted days in acute care are considered in the calculation of the measure.

Distribution of Hospitals by Performance Category in the Three-Year Dataset

Of 4,286 hospitals in the study cohort, 254 had EDACs "lower than expected," 1,440 performed "no different than expected," and 579 had EDACs "higher than expected." 2,013 were classified as "number of cases too small" (fewer than 25) to reliably tell how well the hospital is performing.

Table 5. Random sample of hospitals in top and bottom quintiles of performance

Quintile	Excess days in acute care/100 discharges	Number of qualifying discharges	Unadjusted results					
			Readmission rate	Observation stay rate	Emergency department (ED) visit Rate	Mean readmission days*	Mean observation stay days*	Mean ED visit days*
Top	-29.43	175	8.0%	2.9%	13.7%	4.14	1.8	0.6
Top	-22.39	149	14.1%	4.7%	19.5%	3.71	1.64	0.67
Top	-21.57	103	15.5%	3.9%	13.6%	4.38	1.75	0.68
Top	-21.36	228	13.6%	5.3%	14.5%	4.81	1.54	0.58
Top	-20.97	121	12.4%	5.0%	19.0%	4.27	1.42	0.63
Top	-20.94	235	14.0%	3.8%	18.7%	3.97	1.61	0.65
Top	-20.94	194	15.5%	4.1%	17.5%	3.8	1.31	0.66
Top	-20.53	122	7.4%	1.6%	6.6%	3.78	1.75	0.56
Top	-19.37	170	13.5%	4.7%	13.5%	3.7	1.19	0.7
Top	-17.27	574	13.4%	5.9%	15.7%	4.21	1.51	0.66
Bottom	31.21	112	16.1%	3.6%	13.4%	7.5	2	0.5
Bottom	38.11	143	23.1%	4.9%	10.5%	6.73	1.5	0.57
Bottom	41.61	272	18.0%	0.4%	8.8%	7.33	2	0.52
Bottom	49.29	140	20.7%	4.3%	9.3%	6.86	2.08	0.62
Bottom	50.89	272	21.7%	4.8%	12.1%	6.41	1.69	0.58
Bottom	52.86	127	20.5%	2.4%	9.4%	7.42	2	0.5
Bottom	52.94	156	23.1%	1.9%	3.8%	6.44	1.33	0.67
Bottom	55.67	187	23.0%	3.2%	8.0%	7.26	1.25	0.5
Bottom	59.06	144	18.8%	3.5%	7.6%	7.48	2.1	0.68
Bottom	70.75	117	24.8%	2.6%	6.8%	7.38	3.5	0.5

Performance color key: =Better, =Worse

*Among patients with specified event

3.2 Measure Testing

3.2.1 Reliability Testing

The results of reliability testing are consistent with existing hospital-level measures of patient outcomes. Compared to the development sample, the mean age of patients and the frequency of the risk-adjustment variables were similar in the validation sample (Table 1).

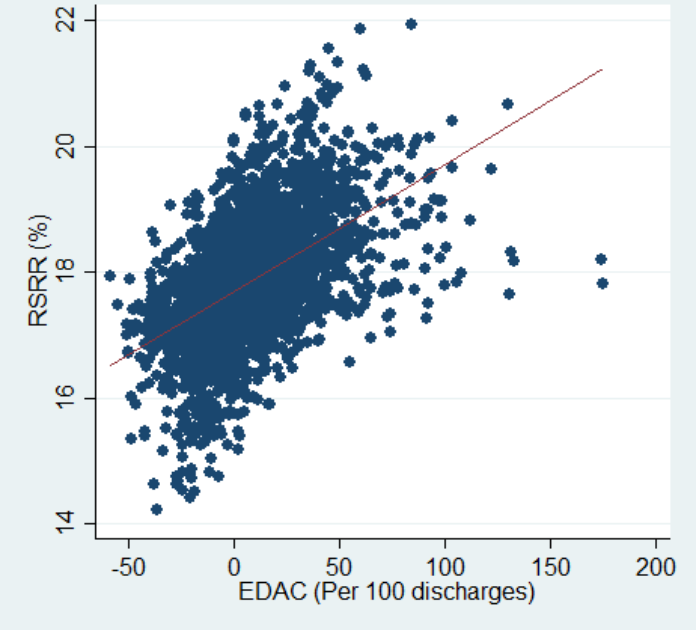
The agreement between the two EDAC values for each hospital was estimated for three years to be ICC [2,1] = 0.54, which according to the conventional interpretation is "moderate."[50] The ICC [2,1] score, estimated for three years of data, indicates fair agreement between samples across the full range of measure values. We interpret this to mean that when used with a full three years of data, the measure will be reliable by the standards of hospital measurement.

3.2.2 Validity Testing

Validity of Claims-Based Measures

Comparison of the new measure with the existing CMS 30-day AMI readmission measure found a Pearson's correlation of 0.610 (P < 0.0001). As shown in Figure 4, there was substantial correlation between the RSRRs and EDAC, indicating that the existing CMS 30-day AMI readmission measure and newly developed EDAC measure share underlying properties.

Figure 4. Comparison of excess days in acute care (EDAC) and risk-standardized readmission rates (RSRRs)



Face Validity

A total of 12 of the 16 TEP members responded to the survey of face validity, which was conducted in the initial, early phase of development at which time the outcomes of ED and observation use, and readmission and the day count approach had been established. Ten respondents indicated that they moderately or strongly agreed with the following statement: "The EDAC obtained from the measures as specified can be used to distinguish between better and worse quality hospitals" (Table 6). These validity testing results demonstrate TEP agreement with the overall face validity of the measure.

Table 6. Summary of measure rating by Technical Expert Panel (TEP)

Rating	Number of responses	Percent (%)	Cumulative percent (%)
6 (Strongly agree)	4	33.3%	33.3%
5 (Moderately agree)	6	50.0%	83.3%
4 (Somewhat agree)	1	8.3%	91.7%
3 (Somewhat disagree)	0	0.0%	91.7%
2 (Moderately disagree)	1	8.3%	100.0%
1 (Strongly disagree)	0	0.0	100.0%

4. Summary

This outcome measure of EDAC following hospitalization for AMI will inform healthcare providers and can help to facilitate their engagement in efforts to improve care. Reducing ED visits, observation stays, and unplanned readmissions for this common and costly condition are likely to improve outcomes for patients and impact Medicare spending. The final cohort and risk-adjustment model are consistent with the publicly reported CMS 30-day AMI readmission measure, and can be implemented using available data. Consistent with measure development guidelines, this measure was developed with input from clinical and methodological experts and multiple stakeholders.

5. References

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6. Appendices

Appendix A. Definition of Emergency Department Visits and Observation Stays

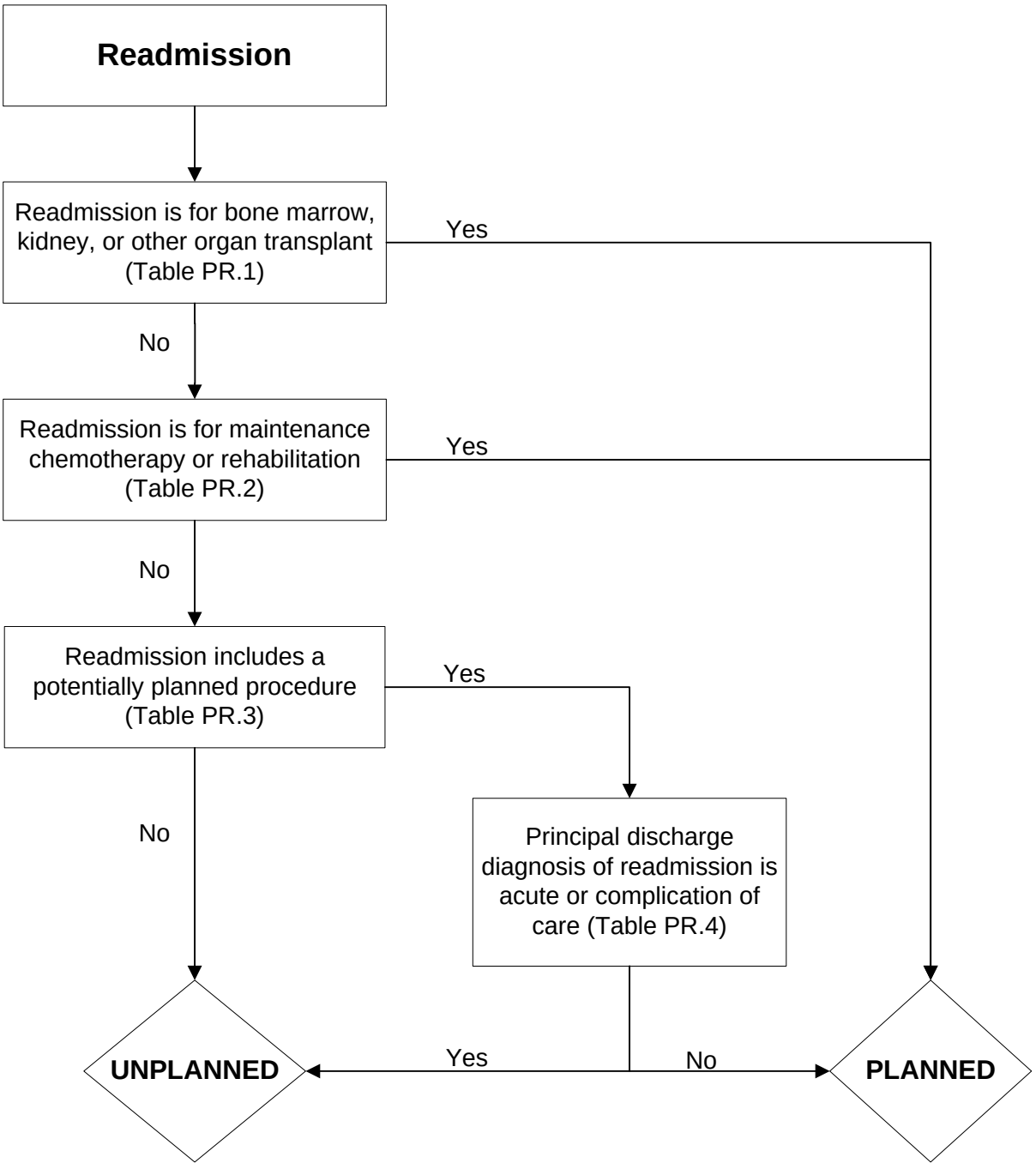
Table A1. Codes used to define emergency department (ED) visits and observation stays

Code (Code Type)	Description
Emergency Department (ED) Definition	
0450 (Revenue Center Code)	Emergency Room
0451 (Revenue Center Code)	Emergency Room: EM/EMTALA
0452 (Revenue Center Code)	Emergency Room: ER/Beyond EMTALA
0459 (Revenue Center Code)	Emergency Room: Other emergency room
0981 (Revenue Center Code)	Professional fees (096x) Emergency room
Observation Stay Definition	
0762 (Revenue Center Code)	Observation room
or	
G0378 (Healthcare Common Procedure Coding System [HCPCS] Code)	Hospital observation service, per hour
or	
99217 (Current Procedural Terminology [CPT] Code)	Hospital observation service, per hour
99218 (CPT Code)	Initial observation care, per day, for the evaluation and management of a patient which requires these three key components: a detailed or comprehensive history; a detailed or comprehensive examination; and medical decision making that is straightforward or of low complexity. Counseling and/or coordination of care with other providers or agencies are provided consistent with the nature of the problem(s) and the patient's and/or family's needs. Usually, the problem(s) requiring admission to observation status are of low severity
99219 (CPT Code)	Initial observation care, per day, for the evaluation and management of a patient, which requires these three key components: a comprehensive history; a comprehensive examination; and medical decision making of moderate complexity. Counseling and/or coordination of care with other providers or agencies are provided consistent with the nature of the problem(s) and the patient's and/or family's needs. Usually, the problem(s) requiring admission to observation status are of moderate severity.
99220 (CPT Code)	Initial observation care, per day, for the evaluation and management of a patient, which requires these three key components: a comprehensive history; a comprehensive examination; and medical decision making of high complexity. Counseling and/or coordination of care with other providers or agencies are provided consistent with the nature of the problem(s) and the patient's and/or family's needs. Usually, the problem(s) requiring admission to observation status are of high severity.

99234 (CPT Code)	Observation or inpatient hospital care, for the evaluation and management of a patient including admission and discharge on the same date which requires these three key components: a detailed or comprehensive history; a detailed or comprehensive examination; and medical decision making that is straightforward or of low complexity. Counseling and/or coordination of care with other providers or agencies are provided consistent with the nature of the problem(s) and the patient's and/or family's needs. Usually the presenting problem(s) requiring admission are of low severity.
99235 (CPT Code)	Observation or inpatient hospital care, for the evaluation and management of a patient including admission and discharge on the same date which requires these three key components: a comprehensive history; a comprehensive examination; and medical decision making of moderate complexity. Counseling and/or coordination of care with other providers or agencies are provided consistent with the nature of the problem(s) and the patient's and/or family's needs. Usually the presenting problem(s) requiring admission are of moderate severity.
99236 (CPT Code)	Observation or inpatient hospital care, for the evaluation and management of a patient including admission and discharge on the same date which requires these three key components: a comprehensive history; a comprehensive examination; and medical decision making of high complexity. Counseling and/or coordination of care with other providers or agencies are provided consistent with the nature of the problem(s) and the patient's and/or family's needs. Usually the presenting problem(s) requiring admission are of high severity.

Appendix B. Planned Readmission Algorithm

Figure PR.1. Planned readmission algorithm version 3.0 flowchart



Planned Readmission Algorithm Version 3.0 Tables – Acute Myocardial Infarction (AMI)

Table PR.1. Procedure categories that are always planned (version 3.0)

Procedure CCS	Description
64	Bone marrow transplant
105	Kidney transplant
134	Cesarean section (Included only in all-payer population, not Medicare)
135	Forceps; vacuum; and breech delivery (Included only in all-payer population, not Medicare)
176	Other organ transplantation

Table PR.2. Diagnosis categories that are always planned (version 3.0)

Diagnosis CCS	Description
45	Maintenance chemotherapy
194	Forceps delivery (Included only in all-payer population, not Medicare)
196	Normal pregnancy and/or delivery(Included only in all-payer population, not Medicare)
254	Rehabilitation (Includes only V52.0, V52.1, V52.4, V52.8, V52.9, V53.8, and V58.82 - Refer to Appendix C – Annual Updates in the 2015 Measure Updates and Specifications Report Hospital-Level 30-Day Risk-Standardized Readmission Measures: Acute Myocardial Infarction, Heart Failure, Pneumonia, Chronic Obstructive Pulmonary Disease, and Stroke on *QualityNet* for more detail)

Table PR.3. Potentially planned procedure categories (version 3.0)

Procedure CCS	Description
3	Laminectomy; excision intervertebral disc
5	Insertion of catheter or spinal stimulator and injection into spinal
9	Other OR therapeutic nervous system procedures
10	Thyroidectomy; partial or complete
12	Other therapeutic endocrine procedures
33	Other OR therapeutic procedures on nose; mouth and pharynx
36	Lobectomy or pneumonectomy
38	Other diagnostic procedures on lung and bronchus
40	Other diagnostic procedures of respiratory tract and mediastinum
43	Heart valve procedures
44	Coronary artery bypass graft (CABG)
45	Percutaneous transluminal coronary angioplasty (PTCA)
47	Diagnostic cardiac catheterization; coronary arteriography
48	Insertion; revision; replacement; removal of cardiac pacemaker or cardioverter/defibrillator
49	Other OR heart procedures
51	Endarterectomy; vessel of head and neck
52	Aortic resection; replacement or anastomosis
53	Varicose vein stripping; lower limb
55	Peripheral vascular bypass
56	Other vascular bypass and shunt; not heart
59	Other OR procedures on vessels of head and neck
62	Other diagnostic cardiovascular procedures
66	Procedures on spleen
67	Other therapeutic procedures; hemic and lymphatic system
74	Gastrectomy; partial and total
78	Colorectal resection
79	Local excision of large intestine lesion (not endoscopic)
84	Cholecystectomy and common duct exploration
85	Inguinal and femoral hernia repair
86	Other hernia repair
99	Other OR gastrointestinal therapeutic procedures
104	Nephrectomy; partial or complete
106	Genitourinary incontinence procedures
107	Extracorporeal lithotripsy; urinary
109	Procedures on the urethra
112	Other OR therapeutic procedures of urinary tract
113	Transurethral resection of prostate (TURP)
114	Open prostatectomy
119	Oophorectomy; unilateral and bilateral

Procedure CCS	Description
120	Other operations on ovary
124	Hysterectomy; abdominal and vaginal
129	Repair of cystocele and rectocele; obliteration of vaginal vault
132	Other OR therapeutic procedures; female organs
142	Partial excision bone
152	Arthroplasty knee
153	Hip replacement; total and partial
154	Arthroplasty other than hip or knee
157	Amputation of lower extremity
158	Spinal fusion
159	Other diagnostic procedures on musculoskeletal system
166	Lumpectomy; quadrantectomy of breast
167	Mastectomy
169	Debridement of wound; infection or burn (This procedure category is always considered unplanned in the stroke readmission measure)
170	Excision of skin lesion
172	Skin graft
ICD-9 Codes	**Description**
30.1, 30.29, 30.3, 30.4, 31.74, 34.6	Laryngectomy, revision of tracheostomy, scarification of pleura (from Procedure CCS 42- Other OR Rx procedures on respiratory system and mediastinum)
38.18	Endarterectomy leg vessel (from Procedure CCS 60- Embolectomy and endarterectomy of lower limbs)
55.03, 55.04	Percutaneous nephrostomy with and without fragmentation (from Procedure CCS 103- Nephrotomy and nephrostomy)
94.26, 94.27	Electroshock therapy (from Procedure CCS 218- Psychological and psychiatric evaluation and therapy)

Table PR.4. Acute diagnosis categories (version 3.0)

Diagnosis CCS	Description
1	Tuberculosis
2	Septicemia (except in labor)
3	Bacterial infection; unspecified site
4	Mycoses
5	HIV infection
7	Viral infection
8	Other infections; including parasitic
9	Sexually transmitted infections (not HIV or hepatitis)
54	Gout and other crystal arthropathies
55	Fluid and electrolyte disorders
60	Acute posthemorrhagic anemia
61	Sickle cell anemia
63	Diseases of white blood cells
76	Meningitis (except that caused by tuberculosis or sexually transmitted disease)
77	Encephalitis (except that caused by tuberculosis or sexually transmitted disease)
78	Other CNS infection and poliomyelitis
82	Paralysis
83	Epilepsy; convulsions
84	Headache; including migraine
85	Coma; stupor; and brain damage
87	Retinal detachments; defects; vascular occlusion; and retinopathy
89	Blindness and vision defects
90	Inflammation; infection of eye (except that caused by tuberculosis or sexually transmitted disease)
91	Other eye disorders
92	Otitis media and related conditions
93	Conditions associated with dizziness or vertigo
99	Hypertension with complications
100	Acute myocardial infarction (with the exception of ICD-9 codes 410.x2)
102	Nonspecific chest pain
104	Other and ill-defined heart disease
107	Cardiac arrest and ventricular fibrillation
109	Acute cerebrovascular disease
112	Transient cerebral ischemia
116	Aortic and peripheral arterial embolism or thrombosis
118	Phlebitis; thrombophlebitis and thromboembolism
120	Hemorrhoids
122	Pneumonia (except that caused by TB or sexually transmitted disease)
123	Influenza
124	Acute and chronic tonsillitis

Diagnosis CCS	Description
125	Acute bronchitis
126	Other upper respiratory infections
127	Chronic obstructive pulmonary disease and bronchiectasis
128	Asthma
129	Aspiration pneumonitis; food/vomitus
130	Pleurisy; pneumothorax; pulmonary collapse
131	Respiratory failure; insufficiency; arrest (adult)
135	Intestinal infection
137	Diseases of mouth; excluding dental
139	Gastroduodenal ulcer (except hemorrhage)
140	Gastritis and duodenitis
142	Appendicitis and other appendiceal conditions
145	Intestinal obstruction without hernia
146	Diverticulosis and diverticulitis
148	Peritonitis and intestinal abscess
153	Gastrointestinal hemorrhage
154	Noninfectious gastroenteritis
157	Acute and unspecified renal failure
159	Urinary tract infections
165	Inflammatory conditions of male genital organs
168	Inflammatory diseases of female pelvic organs
172	Ovarian cyst
197	Skin and subcutaneous tissue infections
198	Other inflammatory condition of skin
225	Joint disorders and dislocations; trauma-related
226	Fracture of neck of femur (hip)
227	Spinal cord injury
228	Skull and face fractures
229	Fracture of upper limb
230	Fracture of lower limb
232	Sprains and strains
233	Intracranial injury
234	Crushing injury or internal injury
235	Open wounds of head; neck; and trunk
237	Complication of device; implant or graft
238	Complications of surgical procedures or medical care
239	Superficial injury; contusion
240	Burns
241	Poisoning by psychotropic agents
242	Poisoning by other medications and drugs

Diagnosis CCS	Description
243	Poisoning by nonmedicinal substances
244	Other injuries and conditions due to external causes
245	Syncope
246	Fever of unknown origin
247	Lymphadenitis
249	Shock
250	Nausea and vomiting
251	Abdominal pain
252	Malaise and fatigue
253	Allergic reactions
259	Residual codes; unclassified
650	Adjustment disorders
651	Anxiety disorders
652	Attention-deficit, conduct, and disruptive behavior disorders
653	Delirium, dementia, and amnestic and other cognitive disorders
656	Impulse control disorders, NEC
658	Personality disorders
660	Alcohol-related disorders
661	Substance-related disorders
662	Suicide and intentional self-inflicted injury
663	Screening and history of mental health and substance abuse codes
670	Miscellaneous disorders
ICD-9 codes	**Description**
Acute ICD-9 codes within Diagnosis CCS 97: Peri-; endo-; and myocarditis; cardiomyopathy	
032.82	Diphtheritic myocarditis
036.40	Meningococcal carditis, unspecified
036.41	Meningococcal pericarditis
036.42	Meningococcal endocarditis
036.43	Meningococcal myocarditis
074.20	Coxsackie carditis, unspecified
074.21	Coxsackie pericarditis
074.22	Coxsackie endocarditis
074.23	Coxsackie myocarditis
112.81	Candidal endocarditis
115.03	Infection by Histoplasma capsulatum, pericarditis
115.04	Infection by Histoplasma capsulatum, endocarditis
115.13	Infection by Histoplasma duboisii pericarditis
115.14	Histoplasma duboisii, endocarditis
115.93	Histoplasmosis, unspecified, pericarditis
115.94	Histoplasmosis, unspecified, endocarditis
130.3	Myocarditis due to toxoplasmosis

Diagnosis CCS	Description
391.0	Acute rheumatic pericarditis
391.1	Acute rheumatic endocarditis
391.2	Acute rheumatic myocarditis
391.8	Other acute rheumatic heart disease, unspecified
391.9	Acute rheumatic heart disease, unspecified
392.0	Rheumatic chorea with heart involvement
398.0	Rheumatic myocarditis
398.90	Rheumatic heart disease, unspecified
398.99	Other Rheumatic heart diseases
420.0	Acute pericarditis in diseases classified elsewhere
420.90	Acute pericarditis, unspecified
420.91	Acute idiopathic pericarditis
420.99	Other acute pericarditis
421.0	Acute and subacute bacterial endocarditis
421.1	Acute and subacute infective endocarditis in diseases classified elsewhere
421.9	Acute endocarditis, unspecified
422.0	Acute myocarditis in diseases classified elsewhere
422.90	Acute myocarditis, unspecified
422.91	Idiopathic myocarditis
422.92	Septic myocarditis
422.93	Toxic myocarditis
422.99	Other acute myocarditis
423.0	Hemopericardium
423.1	Adhesive pericarditis
423.2	Constrictive pericarditis
423.3	Cardiac tamponade
429.0	Myocarditis, unspecified
Acute ICD-9 codes within Diagnosis CCS 105: Conduction disorders	
426.0	Atrioventricular block, complete
426.10	Atrioventricular block, unspecified
426.11	First degree atrioventricular block
426.12	Mobitz (type) II atrioventricular block
426.13	Other second degree atrioventricular block
426.2	Left bundle branch hemiblock
426.3	Other left bundle branch block
426.4	Right bundle branch block
426.50	Bundle branch block, unspecified
426.51	Right bundle branch block and left posterior fascicular block
426.52	Right bundle branch block and left anterior fascicular block
426.53	Other bilateral bundle branch block
426.54	Trifascicular block
426.6	Other heart block

Diagnosis CCS	Description
426.7	Anomalous atrioventricular excitation
426.81	Lown-Ganong-Levine syndrome
426.82	Long QT syndrome
426.9	Conduction disorder, unspecified
Acute ICD-9 codes within Diagnosis CCS 106: Dysrhythmia	
427.2	Paroxysmal tachycardia, unspecified
427.69	Other premature beats
427.89	Other specified cardiac dysrhythmias
427.9	Cardiac dysrhythmia, unspecified
785.0	Tachycardia, unspecified
Acute ICD-9 codes within Diagnosis CCS 108: Congestive heart failure; nonhypertensive	
398.91	Rheumatic heart failure (congestive)
428.0	Congestive heart failure, unspecified
428.1	Left heart failure
428.20	Systolic heart failure, unspecified
428.21	Acute systolic heart failure
428.23	Acute on chronic systolic heart failure
428.30	Diastolic heart failure, unspecified
428.31	Acute diastolic heart failure
428.33	Acute on chronic diastolic heart failure
428.40	Combined systolic and diastolic heart failure, unspecified
428.41	Acute combined systolic and diastolic heart failure
428.43	Acute on chronic combined systolic and diastolic heart failure
428.9	Heart failure, unspecified
Acute ICD-9 codes within Diagnosis CCS 149: Biliary tract disease	
574.00	Calculus of gallbladder with acute cholecystitis, without mention of obstruction
574.01	Calculus of gallbladder with acute cholecystitis, with obstruction
574.30	Calculus of bile duct with acute cholecystitis, without mention of obstruction
574.31	Calculus of bile duct with acute cholecystitis, with obstruction
574.60	Calculus of gallbladder and bile duct with acute cholecystitis, without mention of obstruction
574.61	Calculus of gallbladder and bile duct with acute cholecystitis, with obstruction
574.80	Calculus of gallbladder and bile duct with acute and chronic cholecystitis, without mention of obstruction
574.81	Calculus of gallbladder and bile duct with acute and chronic cholecystitis, with obstruction
575.0	Acute cholecystitis
575.12	Acute and chronic cholecystitis
576.1	Cholangitis
Acute ICD-9 codes with Diagnosis CCS 152: Pancreatic disorders	
577.0	Acute pancreatitis

Appendix C. Final Measure Specifications

Cohort

Inclusion Criteria

1. Principal discharge diagnosis of acute myocardial infarction (AMI) (Table C1)

   Rationale: AMI is the condition targeted for measurement.

2. Enrolled in Medicare FFS

   Rationale: Claims data are consistently available only for Medicare FFS.

3. Aged 65 or over

   Rationale: Medicare patients younger than 65 usually qualify for the program due to severe disability. They are not included in the measure because they are considered to be too clinically distinct from Medicare patients 65 and over.

4. Discharged alive from a non-Federal acute care hospital

   Rationale: Patients who are alive are eligible for an emergency department (ED) visit, observation stay, or readmission.

5. Not transferred to another acute care facility

   Rationale: Transferred patients are still included in the measure cohort.

6. 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 were Medicare FFS beneficiaries and that their comorbidities are captured from claims for risk adjustment. Medicare Part A is required at the time of admission to ensure no Medicare Advantage patients are included in the measure.

Exclusion Criteria

1. Without at least 30 days of post-discharge enrollment in FFS Medicare

   Rationale: The 30-day outcome cannot be assessed in this group since claims data are used to determine whether a patient visited the ED, was placed under observation, or was readmitted.

2. Discharged against medical advice (AMA)

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

3. Hospitalizations for patients admitted and discharged on the same day (and not transferred or deceased)

   Rationale: These patients likely did not suffer clinically significant AMIs.

4. Hospitalizations for patients with an index admission within 30 days of a previous index admission

   Rationale: Additional AMI admissions within 30 days are excluded as index admissions because they are part of the outcome, and we choose not to count a single admission both as an index admission and a readmission for another index admission.

Table C1. International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes for the AMI cohort

ICD-9-CM code	Description
410.00	Acute myocardial infarction of anterolateral wall, episode of care unspecified
410.01	Acute myocardial infarction of anterolateral wall, initial episode of care
410.10	Acute myocardial infarction of other anterior wall, episode of care unspecified
410.11	Acute myocardial infarction of other anterior wall, initial episode of care
410.20	Acute myocardial infarction of inferolateral wall, episode of care unspecified
410.21	Acute myocardial infarction of inferolateral wall, initial episode of care
410.30	Acute myocardial infarction of inferoposterior wall, episode of care unspecified
410.31	Acute myocardial infarction of inferoposterior wall, initial episode of care
410.40	Acute myocardial infarction of other inferior wall, episode of care unspecified
410.41	Acute myocardial infarction of other inferior wall, initial episode of care
410.50	Acute myocardial infarction of other lateral wall, episode of care unspecified
410.51	Acute myocardial infarction of other lateral wall, initial episode of care
410.60	True posterior wall infarction, episode of care unspecified
410.61	True posterior wall infarction, initial episode of care
410.70	Subendocardial infarction, episode of care unspecified
410.71	Subendocardial infarction, initial episode of care
410.80	Acute myocardial infarction of other specified sites, episode of care unspecified
410.81	Acute myocardial infarction of other specified sites, initial episode of care
410.90	Acute myocardial infarction of unspecified site, episode of care unspecified
410.91	Acute myocardial infarction of unspecified site, initial episode of care

Risk Adjustment

Table C2. Risk variables for the AMI measure

Variable	Description
n/a	Age minus 65 (years above 65, continuous)
n/a	Male
ICD-9 codes V45.82, 00.66, 36.06, 36.07	History of Percutaneous Transluminal Coronary Angioplasty (PTCA)
ICD-9 codes V45.81, 36.10–36.16	History of Coronary Artery Bypass Graft (CABG)
ICD-9 codes 410.00-410.12	Anterior myocardial infarction
ICD-9 codes 410.20-410.62	Other location of myocardial infarction
CC 1, 3-6	History of infection
CC 7	Metastatic cancer or acute leukemia
CC 8-12	Cancer
CC 15-20, 119-120	Diabetes mellitus (DM) or DM complications
CC 21	Protein-calorie malnutrition
CC 22-23	Disorders of fluid/electrolyte/acid-base
CC 47	Iron deficiency or other specified anemias and blood disease
CC 49-50	Dementia and other specified brain disorders
CC 67-69, 100-102, 177-178	Hemiplegia, paraplegia, paralysis, functional disability
CC 80	Congestive heart failure
CC 81-82	Acute coronary syndrome
CC 83	Angina pectoris/old myocardial infarction
CC 84	Coronary atherosclerosis
CC 86	Valvular or rheumatic heart disease
CC 92-93	Specified arrhythmias and other heart rhythm disorders
CC 95-96	Stroke
CC 97-99, 103	Cerebrovascular disease
CC 104-106	Vascular or circulatory disease
CC 108	Chronic obstructive pulmonary disease (COPD)
CC 110	Asthma
CC 111-113	Pneumonia
CC 129-130	End-stage renal disease or dialysis
CC 131	Renal failure
CC 136	Other urinary tract disorders
CC 148-149	Decubitus ulcer or chronic skin ulcer

Table C3. Complications of care variables not used in risk adjustment if occurring only during the index admission of AMI measure

(Includes the subset of risk variables from Table C2 that are not used in risk adjustment if occurring only during the index admission)

Variable	Description
CC 6	Other infectious diseases
CC 17	Diabetes with acute complications
CC 23	Disorders of fluid/electrolyte/acid-Base
CC 80	Congestive heart failure
CC 81	Acute myocardial infarction
CC 82	Other acute/subacute forms of ischemic heart disease
CC 92	Specified arrhythmias
CC 93	Other heart rhythm and conduction disorders
CC 95	Cerebral hemorrhage
CC 96	Ischemic or unspecified stroke
CC 97	Precerebral arterial occlusion and transient cerebral ischemia
CC 100	Hemiplegia/hemiparesis
CC 101	Diplegia (upper), monoplegia, and other paralytic syndromes
CC 102	Speech, language, cognitive, perceptual
CC 104	Vascular disease with complications
CC 105	Vascular disease
CC 106	Other circulatory disease
CC 111	Aspiration and specified bacterial pneumonias
CC 112	Pneumococcal pneumonia, emphysema, lung abscess
CC 129	End-stage renal disease
CC 130	Dialysis status
CC 131	Renal failure
CC 148	Decubitus ulcer of skin
CC 177	Amputation status, lower limb/amputation
CC 178	Amputation status, upper limb

Outcome

Outcome Criteria

1. All-cause days in acute care

   Rationale: We define days in acute care as days spent in an ED, admitted to observation status, or admitted as an unplanned readmission for any cause within 30 days from the date of discharge from the index AMI hospitalization. From a patient perspective, days in acute care from any cause is an adverse event.

2. Count multiple events

   Rationale: We take this approach in order to capture the full patient experience in the post-discharge period.

3. 30-day time frame

   Rationale: Outcomes occurring within 30 days of discharge can be influenced by hospital care. 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 days in acute care.