Hybrid Hospital-Wide Readmission Measure with Electronic Health Record Extracted Risk Factors
(Version 1.2)

Submitted By

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1. INTRODUCTION

NOTE: This report has been updated to reflect recent testing on expansion of the measure cohort to include Medicare Advantage beneficiaries. All other measure specifications remain the same. Information on the methodology and results of testing are presented in <u>Appendix D</u>.

1.1 OVERVIEW

In 2013, the Centers for Medicare & Medicaid Services (CMS) contracted with Yale New Haven Services Corporation, Center for Outcomes Research and Evaluation (CORE) to demonstrate whether clinical data derived from <u>electronic health records (EHRs)</u> could be used to reengineer and enhance the Hospital-Wide All-Cause Unplanned Readmission (HWR) measure.[1] Under contract with CMS, CORE had previously identified a set of <u>core clinical data elements</u> (CCDE) that are feasibly extracted from hospital EHRs and are related to patients' clinical status at the start of an inpatient encounter. This report builds on this prior work by using the CCDE to reengineer the HWR measure.

The CCDE specific to the risk adjustment for the HWR measure consists of patients' gender, age, weight, the first set of vital signs captured within 2 hours of the start of the episode of care, and the results of the first complete blood count and basic chemistry panel drawn within 24 hours of the start of the episode of care.[2] Preliminary work had established that the CCDE could be used to risk adjust measures of 30-day mortality across a variety of common and costly medical conditions. Application of these same data elements to the original HWR measure allows us to examine the use of the CCDE in a broader cohort of hospitalized medical and surgical patients as well as to examine its utility in predicting hospital readmission. Therefore, CORE specifically sought to determine whether the use of clinical data for risk adjustment in place of, or in combination with, comorbidity data from Medicare claims would improve the discrimination of the HWR models or the reliability of the measure.

Because the CCDE does not include follow-up data for capturing outcomes, it's not practical to reengineer the measure without some use of Medicare claims data. Thus, we considered a hybrid approach that links the patient-level electronically specified, or <u>eSpecified</u>, EHR data to CMS claims data for risk adjustment and utilizes the original HWR measure methodology for cohort and outcome determination. We compared four risk-adjustment strategies: the original HWR approach that used claims-only data; and three new approaches that used the CCDE in various combinations with claims data. One model applied the CCDE to the full HWR risk-adjustment model. We assumed that this model would out-perform models that used only clinical or only claims data because it is the most comprehensive model. A second model used only the CCDE for risk adjustment. A third model used the CCDE in addition to the principal discharge diagnoses from the original HWR risk-adjustment model.

We compared these models with the understanding that the simpler and more parsimonious models might be advantageous if they performed as well or better than the original HWR measure. We compared the statistical models for all three approaches to the original HWR measure using claims and EHR datasets provided by a large hospital system in California. We then selected and tested the best-performing model to create the Hybrid Hospital-Wide Readmission Measure with Claims and EHR Data (Hybrid eHWR). Note that this new measure is not an electronic specification of the original HWR measure, but a separate hybrid measure that utilizes both clinical data from the EHR and claims data.

1.2 RATIONALE FOR REENGINEERING

The increased use of EHRs by hospitals creates an opportunity to incorporate clinical data into outcome

measures without the laborious process of abstracting them from paper medical records. Although claims-based risk adjustment has been shown to be comparable to risk adjustment using clinical data when observing hospital-level performance, clinical providers continue to express preference for using patient-level clinical data.[3,4] Use of the CCDE for risk adjustment of outcome measures would be responsive to these stakeholder concerns about a claims-only approach.

There are several other potential benefits to incorporating clinical data from EHRs into hospital outcome measures. For example, it could provide an opportunity to align the measure with clinical decision support systems that many providers utilize to alert care teams about patients at increased risk of poor outcomes, such as readmission, in real time during the inpatient stay.[5] Utilizing the same variables to calculate hospital performance that are used to support clinical decision- would be clinically sensible and cost effective, as it reduces the burden of EHR data mapping and extraction required for quality reporting.

In addition, clinical data captured in electronic health records are recorded by clinicians who are interacting with the patient and who value the accuracy of the data to guide the care they provide. Therefore, many clinical data elements that are captured in real-time to support patient care are less susceptible to gaming, coding drift, and variations in billing practices compared with administrative data used for billing purposes. This allows for more stable measurements over time.

Finally, a hospital-wide cohort includes a broad set of inpatient admissions for a variety of medical conditions and surgical procedures. If the CCDE can be shown to enhance prediction models across many conditions, it can potentially be adopted as the foundation of risk adjustment for many condition- or procedure-specific outcome measures. This would greatly reduce the cost and effort required for measure development and would improve harmonization in risk-adjustment across measures.

1.3 REPORT UPDATE

Please note that this report has been modified from its original version for posting with the Hospital Inpatient Prospective Payment Systems 2016 Proposed Rule.

We identified a standard set of core clinical data elements that are captured during routine clinical practice on most adult hospitalized patients and can be readily extracted from most currently operating EHRs. We established that this list of 21 core clinical data elements can be used to risk adjust measures of 30-day mortality across a variety of common and costly medical conditions. For further details, please see the "2013 Core Clinical Data Elements Technical Report (Version 1.1)" posted along with this report.

The hospital 30-day risk-standardized acute myocardial infarction (AMI) mortality eMeasure (NQF #2473) (now referred to as a hybrid measure) originally identified several of the core clinical data elements for inclusion in the risk-adjustment model. The final model includes age, heart rate, systolic blood pressure, and creatinine. It also includes one AMI-specific data element, the laboratory value for troponin ratio (initial troponin value / troponin upper range limit for hospital). For further details, please see the "Hybrid 30-day Risk-standardized Acute Myocardial Infarction Mortality Measure with Electronic Health Record Extracted Risk Factors (Version 1.1)" posted along with this report.

The hybrid hospital-wide 30-day readmission measure was developed to examine the use of the core clinical data elements in a broader cohort of hospitalized medical and surgical patients as well as to

examine its utility in predicting hospital readmission. The measure is a composite of five models that group similar conditions and procedures. The following core clinical data elements are predictive in at least one of those models: age, heart rate, respiratory rate, temperature, systolic blood pressure, oxygen saturation, weight, hematocrit, white blood cell count, sodium, potassium, bicarbonate, creatinine and glucose. For further details, please see the "Hybrid Hospital-Wide Readmission Measure with Electronic Health Record Extracted Risk Factors (Version 1.1)" posted along with this report.

2. METHODOLOGY

2.1 DATA SOURCE

All data used to develop the Hybrid eHWR were provided by Kaiser Permanente of Northern California (KPNC) from their administrative and EHR data warehouses. KPNC is an integrated health care delivery system that serves over 3.3 million members at its 21 acute-care hospitals. All KPNC hospitals use an integrated EHR system that runs Epic software to capture and store patient management, administrative, and clinical data in their outpatient and inpatient healthcare settings. The Systems Research Initiative within the Kaiser Permanente Division of Research has worked to develop an extensive clinical risk-adjustment methodology for internal benchmarking and quality assurance and is in the process of developing the capability to use these clinical data in real time for clinical decision support and quality measurement. Their work has required mapping specific clinical data elements within their databases, extracting data, and validating their source and accuracy.

Additionally, members enrolled in the KPNC health system receive nearly all of their care from the KPNC network of outpatient and inpatient providers. In the rare instance that a member is admitted to an acute-care facility outside of the network, KPNC will receive a claim for those services unless the patient decides to pay out-of-pocket. Thus, almost all hospital admissions in this patient population are captured in the KPNC administrative database, which facilitates observation of readmission outcomes.

We partnered with KPNC to provide datasets that include all admissions for adult patients to any of their member hospitals between January 1, 2009 and January 31, 2013. These datasets contained both the claims data as well as the clinical data that were used to derive the cohort, outcome, comorbidities, and CCDE. The clinical data included values for the 21 data elements in the CCDE from which we derived first-captured vital signs and laboratory test results from all hospital entry locations including the Emergency Department, operating rooms, inpatient floors, and units. Specifically they provided:
- Hospital identifier and hospital entry location;
- Time and date stamps for patients' arrival at the hospital for care;
- Principal discharge diagnosis (ICD-9 codes);
- Secondary diagnoses (ICD-9 codes);
- The patients' vital signs and laboratory test results from each admission (including data values, time and date stamps) from which we can derive the CCDE; and,
- Variables related to cohort exclusion criteria (discharged against medical advice, transferred to another acute care facility, and in-hospital death).

In addition, they provided the following information from claims submitted by their members for admissions to out-of-network hospitals: admission dates, discharge dates, and principal discharge diagnoses. In this dataset, all of these data elements were linked to a single hospital admission using a unique encounter identification number. Individual patients may have had one or more admissions in the database and were linked using unique patient identifiers assigned by KPNC.

2.2 COHORT

We adhered to the methodology of the original HWR measure to define the cohort. The inclusion and exclusion criteria applied are identical to the original HWR measure methodology except where the criteria did not apply to the Kaiser Healthcare system.

<u>Inclusion and Exclusion Criteria</u>

The inclusion and exclusion criteria for <u>index admissions</u>, the hospitalizations to which the readmission outcomes are attributed, were applied to this dataset for specification of the Hybrid eHWR. In the KPNC test data, we included admissions for patients:

- **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 Medicare patients younger than 65 are considered to be clinically distinct from Medicare patients 65 and over. For measure development and testing, we used patients' age to approximate a population of Medicare beneficiaries within the KPNC dataset.

- **Without an in-hospital death**

Rationale: Patients who die during the index admission are not eligible for readmission.

- **Not transferred to another acute care facility**

Rationale: Readmission is attributed to the hospital that discharged the patient to the non- acute care setting. For measure development and testing, there were no transfers out of the KPNC network. Within network transfers were considered a single contiguous admission.

In the KPNC test data, the following measure exclusions were applied:

- **Discharged against medical advice (AMA)**

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

- **Admitted for primary psychiatric diagnoses**

Rationale: Patients admitted for psychiatric treatment are typically cared for in separate psychiatric or rehabilitation centers that are not comparable to acute care hospitals (<u>Table A.1</u>).

- **Admitted for rehabilitation**

Rationale: These admissions are not typically to an acute care hospital and are not for acute care.

- **Admitted for medical treatment of cancer**

Rationale: These admissions have a different mortality and readmission profile than the rest of the Medicare population, and outcomes for these admissions do not correlate well with outcomes for other admissions (<u>Table A.3</u>). Patients with cancer admitted for other diagnoses or for surgical treatment of their cancer remain in the measure.

For a full list of inclusion and exclusion criteria that would be applied to a <u>Medicare fee-for-service (FFS)</u> population, refer to <u>Appendix A</u>.

<u>Transfers between Hospitals</u>

The Hybrid eHWR uses the original HWR measure methodology to define transfers and attribute readmission outcomes. The measure considers multiple contiguous admissions to two different hospitals as 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.

Readmissions for transferred patients are attributed to the hospital that ultimately discharges the patient to a non-acute care setting (e.g., to home or 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, a readmission within 30 days of discharge to any acute care hospital is 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 second admission has a diagnosis that differs from the index admission it is considered a readmission.

<u>Development and Testing Samples</u>

Once the inclusion and exclusion criteria were applied, we defined three separate samples of index admissions to the 21 KPNC hospitals between January 1, 2010 and December 31, 2012. These samples were used for measure development and testing. The index admissions occurring between January 1, 2010 and December 31 2011 were randomly split into a *development sample* which we used to develop a risk-adjusted model and a *validation sample* which we used to re-test the model; the random split was stratified by hospital and specialty cohort. The third sample included index admissions between January 1, 2012 and December 31, 2012 and was used to assess the stability of risk-adjustment variables across calendar years.

<u>Specialty Cohort Assignment</u>

In each of these three samples, we replicated the methodology used in the original HWR measure to define cohorts of index admissions by specialty. Admissions were grouped into specialty cohorts based on the overlap in clinical presentations, treatment strategies, and in the teams of clinicians that typically provide care for patients in each condition category. For example, in large hospitals, patients admitted for treatment of neurological conditions such as stroke or epilepsy are commonly cared for by teams of neurology specialists. Patients admitted for acute myocardial infarction or cardiac arrhythmia are commonly cared for by a separate team of cardiologists. These patients might also be located in separate units of the hospital.

To group patients into these cohorts, the principal discharge diagnosis codes associated with each admission were aggregated into the 285 mutually exclusive diagnosis categories using the Agency for Healthcare Research & Quality (AHRQ) diagnosis Clinical Classification Software (CCS). In addition, procedure codes associated with each admission were aggregated into 231 mutually exclusive procedure categories through AHRQ procedure CCS. The AHRQ diagnosis and procedure categories were further aggregated into 5 mutually exclusive specialty cohorts. The original HWR measure development team created a list of AHRQ procedure categories which could typically result in surgical or gynecological teams caring for the patient. Any admission during which a procedure was performed with a CCS category code from this list (Table A.2 in Appendix A) was assigned to the **Surgery/Gynecology** cohort regardless of the principal discharge diagnosis. After all surgical and gynecological admissions were aggregated, the remaining admissions were sorted based on the principal discharge diagnosis into the following four non-surgical groups:

- **The cardiorespiratory cohort,** which includes admissions for heart failure as well as admissions for various chronic and acute respiratory diseases such as pneumonia, bronchitis, chronic obstructive pulmonary disease, asthma, and others (Table A.4);
- **The cardiovascular cohort,** which includes cardiovascular condition categories such as acute myocardial infarction, cardiac arrhythmias, and others (Table A.5);
- **The neurology cohort,** which includes admissions for neurologic diseases such as stroke and

epilepsy ([Table A.6](#)); or,

- **The medicine cohort,** which includes all remaining CCS categories with the exception of excluded categories (e.g., admissions for primary psychiatric diagnoses, rehabilitation, and treatment of cancer) ([Table A.7](#)).

The updated 2013 AHRQ CCS categories were reviewed to ensure that no revisions to the specialty group assignment of CCS were required. For a diagram listing all of the inclusions, exclusions, and process for specialty cohort selection, refer to [Figure A.1](#).

According to the original HWR measure methodology, hospitals must have at least 25 qualifying index admissions within each of the 5 specialty cohorts in order to calculate a measure result for each specialty cohort. However, the composite measure combining results from each of the 5 specialty cohorts is calculated if some, but not all, cohorts meet the 25 case criterion. All 21 hospitals in the KPNC dataset used for measure development and testing had sufficient numbers of admissions for inclusion in measure testing.

2.3 OUTCOME ASSESSMENT

The Hybrid eHWR approach to assessment of the readmission outcome is identical to the original HWR measure methodology. The outcome is 30-day all-cause [unplanned readmissions](#). The measure counts any unplanned readmissions because it is designed to capture readmissions that arise from acute clinical events requiring urgent re-hospitalization within 30 days of discharge. To assess the readmission outcome for the last month of the 2012 cohort, admissions through January 31, 2013 were included in the dataset. [Planned readmissions](#), which are generally not a signal of quality of care, are not counted in the outcome of this or any other CMS readmission measure.

If the first readmission after discharge is planned, any subsequent unplanned readmission is not counted as an outcome for that index admission because the unplanned readmission could be related to care provided during the intervening planned readmission rather than during the index admission. In this measure, a readmission is also included as an index admission if it meets all other eligibility criteria. However, because the measure only counts the first readmission for any given index admission, readmissions are never attributed to two different index admissions.

Planned readmissions are identified using an algorithm that uses a set of criteria and Medicare [administrative claims data](#) to classify readmissions among the general Medicare population. The planned readmission algorithm identifies admissions that are typically planned and may occur within 30 days of discharge from the hospital.

The planned readmission algorithm has three fundamental principles:

1. A few specific, limited types of care are always considered planned (transplant surgery, maintenance chemotherapy/radiotherapy/ immunotherapy, rehabilitation);
2. Otherwise, a planned readmission is defined as a non-acute readmission for a scheduled procedure; and
3. Admissions for acute illness or for complications of care are never planned.

The algorithm was developed in 2011 as part of the original HWR measure, and in 2013, CMS applied the algorithm to its other readmission measures. The planned readmission algorithm uses a flowchart and four tables of specific procedure categories and discharge diagnosis categories to classify

readmissions as planned (Figure PR.1 in Appendix A). Readmissions are considered planned if any of the following occurs during the readmission:

1. A procedure is performed that is in one of the procedure categories that are always planned regardless of diagnosis (Table PR1);
2. The principal diagnosis is in one of the diagnosis categories that are always planned (Table PR2); or
3. A procedure is performed that is in one of the potentially planned procedure categories (Table PR3) and the principal diagnosis is not in the list of acute discharge diagnoses (Table PR4).

In the measure development and testing dataset, only index admissions to one of the 21 KPNC hospitals were eligible for inclusion as an index admission. Members who were admitted to and discharged from out-of-network hospitals were not included. However, readmissions to out-of-network hospitals were counted as readmissions if they met the definition for unplanned readmission. Data submitted to KPNC from out-of-network hospitals for purposes of payment included principal discharge diagnosis, procedures performed, admission dates, and discharge dates which were used to identify planned readmissions using the algorithm. In order to verify that qualified readmissions were captured in the KPNC administrative data, we merged this dataset with data from the California Office of Statewide Health Planning and Development (OSHPD) for the same set of KPNC hospitals over the same period and calculated the proportion of readmissions captured in both systems.

2.4 RISK FACTORS

The approach to risk adjustment is the only component of the Hybrid eHWR that differs from the original HWR measure methodology. The original HWR measure uses claims data to adjust for two aspects of risk: 1) case mix or how sick individual admitted patients are; and, 2) service mix or the proportion of admitted patients with various different principal discharge diagnoses. Different claims data are used to assess each of these.

- For case mix, patients' age and secondary conditions (or comorbidities) documented in inpatient claims from 12 months prior to, and including, the index admission are used. Refer to Table A.8 for the list of case mix risk-adjustment variables, which are common to each specialty cohort for simplicity and ease of data collection and analysis. All of these fixed risk-adjustment variables are included in each specialty cohort model regardless of whether they were significant predictors of readmission for the specialty cohort. Thus, several variables that are not significant predictors or only weak predictors of readmission are included in the models and measure specifications. Comorbid conditions that could be a result of complications of care and that are present only during the index admission are not included (Table A.10).
- For service mix, the principal discharge diagnoses documented in the inpatient claims during the index admissions are used. The principal discharge diagnoses used for risk-adjustment are the same as those used to group admissions into each specialty cohort (Table A.4, Table A.5, Table A.6, Table A.7), with the exception of the surgical cohort (Table A.9), which is based on procedure categories.

To align with the original HWR measure, the Hybrid eHWR measure also does not adjust for the patients' admission source, their discharge disposition (e.g., skilled nursing facility), or for socioeconomic status (SES).

<u>Risk-Adjustment Variables Tested in the Hybrid eHWR Measure</u>

The risk-adjustment variables included in the development and testing of the Hybrid eHWR are derived from both claims and clinical (EHR) data. The variables were:

1. The core clinical data elements (CCDE) derived from EHR data
2. The AHRQ CCS categories for the principal discharge diagnosis associated with each index admission derived from ICD-9 codes in administrative claims data from the index admission
3. Comorbid conditions of each patient identified from inpatient claims in the 12 months prior to and including the index admission derived from ICD-9 codes and grouped into the CMS condition categories (CC).

We sought to determine whether we could improve the discrimination of the original HWR measure by including the CCDE for risk adjustment. When captured at the start of an index admission, the CCDE, like secondary diagnoses or comorbidities, can be used to adjust for case mix because the CCDE also provide information about how sick hospitalized patients are. In addition, the CCDE and comorbidities might convey slightly overlapping and complementary types of information. For example, a patient's claims data might tell us that they carry a diagnosis of hypertension. Their CCDE will tell us if they had an elevated blood pressure at the time they presented to the hospital. Both types of data might confer important information about the patient's risk of readmission. Therefore, we developed a model with the CCDE and comorbidities to adjust for case mix and claims data to adjust for service mix. We also developed a model with only CCDE for case mix and claims data to adjust for service mix.

We also developed a parsimonious model which included only the CCDE with no service mix adjustment. Such a model would be most closely aligned with EHR-based clinical decision support tools designed to predict patients' risk of readmission in real time. We realized, however, that the exclusion of service mix from the risk-adjustment approach might yield a less discriminating model of unplanned readmission. To determine the best approach for the Hybrid eHWR, we compared each of these models in terms of discrimination (c-statistic).

1. *Original HWR:*
    - <u>Service mix</u>: Agency for Healthcare Research and Quality (AHRQ) <u>Clinical Classification Software</u> (CCS) categories for patients' principal discharge diagnoses (<u>Appendix A</u>)
    - <u>Case mix</u>: CMS <u>Condition Categories (CCs)</u> for patients' <u>comorbidities</u> captured during hospitalizations in the 12 months prior to and including the index admission (<u>Table A.8</u>)
2. *CCDE with Original HWR (Hybrid eHWR):*
    - <u>Service mix</u>*:* Agency for Healthcare Research and Quality (AHRQ) Clinical Classification Software (CCS) categories for patients' principal discharge diagnoses
    - <u>Case mix</u>*:* Both the CCDE and CMS Condition Categories (CCs) for patients' comorbidities captured during hospitalizations in the 12 months prior to and including the index admission
3. *CCDE with Principal Discharge Diagnosis CCS category:*
    - <u>Service mix</u>*:* Agency for Healthcare Research and Quality (AHRQ) Clinical Classification Software (CCS) categories for patients' principal discharge diagnoses
    - <u>Case mix</u>*:* CCDE only
4. *CCDE Alone:*
    - <u>Service mix</u>: None
    - <u>Case mix</u>: CCDE only

We included claims data in the KPNC dataset from January 2009 through December 2010 for development of our risk-adjusted models when historical information about patient comorbidities was required for the 2010-2011 split development and validation samples.

Core Clinical Data Elements

Unlike claims data, which is submitted for reimbursement of medical services, the CCDE is obtained from the clinical data in the EHR systems and is not currently collected through any national reporting program. These data elements would be the only data to be electronically specified in the new Hybrid eHWR measure. The data elements in the CCDE were selected because they meet the following feasibility criteria: (1) obtained consistently under current clinical practice; (2) captured with a standard definition across providers and care settings; and (3) entered in a structured field to reduce the burden of extraction and ensure consistent reporting[2].

The CCDE included in the HWR risk adjustment models is a set of 21 data elements that consists of patients' age, gender and weight as well as the first-captured value for basic vital signs recorded in the EHR within 2 hours of arrival at the hospital, and the first captured value for laboratory test results recorded within 24 hours of arrival at the hospital (Table 2.1). The first captured value is the one recorded in the EHR closest to the time of arrival. These values for each vital sign and laboratory test result were selected for the CCDE in order to ensure that the data reflect the patients' clinical status at the start of the hospital encounter and do not reflect response to treatment, which could be a signal of quality.

In practice, identifying the first captured value requires two separate pieces of information: the location where patients first appear (e.g., the emergency department, pre-operative area, inpatient floor or unit), and the time stamp associated with the first recorded contact patients have with hospital staff at the start of the hospital encounter. Arrival location and time of arrival data will often be collected from the patient management system and correspond with the time a patient is registered as "arrived" at the hospital. This is when a patient's insurance and contact information are first collected by the hospital administrative staff. This time of arrival should consistently precede the capture of any vital signs and laboratory tests.

The feasibility and stability of the CCDE were assessed in the HWR cohort by calculating the rate of capture and distribution of data values of each of the 21 data elements for all adult admissions occurring in each specialty cohort in the development, validation, and testing (2012) samples.

Table 2.1: Candidate Core Clinical Data Elements (CCDE)

Clinical Data Elements	Units of Measurement	Window for First Captured Values
Patient Characteristics		
Age	Years	---
Gender	Male or female	---
First-Captured Vital Signs		
Heart Rate	Beats per minute	0-2 hours
Systolic Blood Pressure	mmHg	0-2 hours
Diastolic Blood Pressure	mmHg	0-2 hours
Respiratory Rate	Breath per minute	0-2 hours
Temperature	Degrees Fahrenheit	0-2 hours
Oxygen Saturation	Percent	0-2 hours

Clinical Data Elements	Units of Measurement	Window for First Captured Values
Weight	Pounds	0-24 hours
First-Captured Laboratory Results		
Hemoglobin	g/dL	0-24 hours
Hematocrit	% red blood cells	0-24 hours
Platelet	Count	0-24 hours
WBC Count	Cells/mL	0-24 hours
Potassium	mEq/L	0-24 hours
Sodium	mEq/L	0-24 hours
Chloride	mEq/L	0-24 hours
Bicarbonate	mmol/L	0-24 hours
Anion Gap	mEq/L	0-24 hours
BUN	mg/dL	0-24 hours
Creatinine	mg/dL	0-24 hours
Glucose	mg/dL	0-24 hours

CCDE Data Element Specification and Reduction

The values of several variables from the CCDE are highly correlated because they measure the same or very similar physiological processes. For example, hemoglobin measures the concentration of the iron-binding protein carried by red blood cells and hematocrit measures the percentage of blood made up of red blood cells respectively. Only one variable in a pair or set of highly correlated variables was included for testing in the risk-adjusted models. For consistency across models, we made the determination to use creatinine over BUN, sodium over chloride, bicarbonate over anion gap, hematocrit over hemoglobin, and systolic blood pressure over diastolic blood pressure. Patients' gender was not included for consideration in the models because we could not identify a physiological reason that would put patients of a certain gender at higher risk of readmission in a hospital-wide cohort; this was the same reasoning used to omit gender from the original HWR model. This left 15 candidate variables from the CCDE for inclusion in the risk-adjusted models.

We also examined the distribution of the CCDE data values to determine what proportion were out of physiological range and might represent data errors. We found that most values fell within physiological range and that there were few apparent errors in the data entry. To reduce the effect of the spurious outliers, we transformed extreme values by replacing them with a value at the outer limit of a designated range by a process called Winsorization.[6, 7] All continuous variables with values less than 1st percentile or higher than the 99th percentile were Winsorized, percentiles (i.e., values less than the 1st percentile were assigned to the value of the 1st percentile, and values greater than the 99th percentile were assigned to the value of the 99th percentile). Missing data values were set to the median value for the cohort. In addition, dummy variables for missing data were included in the statistical models. Refer to the CCDE development report for additional information and results of this analysis[2].

Because each of the CCDE is a set of continuous variables with the exception of gender, we examined the plots for each of the remaining 15 Winsorized data elements against the logit of the unplanned readmission outcome within each specialty cohort to ensure that the relationships conformed to clinical expectations. For example, we anticipated that, within the adult population, increasing age in years would have a linear relationship with greater risk of unplanned readmission. However, some data

elements, such as temperature, were expected to predict greater risk of readmission at very low and very high values and to have little predictive value within the physiologically normal range. Data elements that, upon visual inspection, appeared to have a linear relationship with the outcome were included in risk adjusted regression models without transformation. For data elements with more complex relationships with the outcome, such as temperature we tested two approaches to data transformation, quadratic functions and spline terms.

We sought to identify the approach that improved predictive ability of readmission models without adding unnecessary complexity to measure calculation. We determined that the use of splines might necessitate the need to recalculate new nodes or data values to properly split the data distribution, for each specialty cohort and potentially for each new data year. Because quadratic functions and spline transformations produced similar results in our models, we selected the simpler quadratic functions to adjust for non-linear relationship with the outcome. The variables that required this transformation were heart rate, systolic blood pressure, temperature, white blood cell count, potassium, and bicarbonate.

Unlike the claims comorbidity indicators, we did not use a fixed list of CCDE variables for each of the 5 specialty cohorts. Only variables that were significant predictors of readmission in each specialty cohort were included in the separate regression models. However, some terms were forced into the models regardless of their predictive value. For example, both the linear and quadratic terms for several CCDE variables, as well as terms for missing CCDE data values, were forced into the models. Inclusion of these terms had no impact on model performance. Many of these variables are important for face validity in that even if they are not predictive, omitting them might raise concerns about the model. This approach does not bias the measure results or the hospital performance scores.

2.5 MODEL SPECIFICATION AND VALIDATION

To develop the Hybrid eHWR, we tested and compared three different risk-adjustment approaches using the CCDE and the original HWR measure. All strategies were variations on the basic HWR structure which models the outcome for each of 5 specialty cohorts. For each strategy we made analogous modifications to each of the 5 models.

For model development we used logistic regression models, with outcome Y_i for the ith patient equal to 1 if the patient was readmitted within 30 days of discharge and 0 otherwise. In contrast with the final models described below for calculating the measure, logistic regression models are substantially less computationally intensive, and development using models with fully specified error structures would have taken prohibitively long. Also, by using logistic regression models that did not account for hospital effects, we were able to assess risk factors and model performance without reference to the variation in performance across hospitals. We developed separate logistic regression models of unplanned readmission using the three separate risk-adjustment strategies and the original HWR measure approach listed in Section 2.4. We compared the discrimination for each specialty cohort across the four different models. We selected the best-performing alternative model based on discrimination in terms of the C-statistic. The two alternative models with lower discrimination were discarded. We then continued measure development and testing only for the best-performing model containing the CCDE.

After identifying the best alternative approach using the ordinary logistic regression patient-level model, we used hierarchical logistic regression to model the log-odds of readmission for each of the

five cohorts to account for patient clustering within hospitals.[8] This is also consistent with the original fully specified HWR models. We then compared the results of this best approach with the results from original HWR measure approach. Readmission within 30 days was modeled as a function of patient-level demographics, clinical characteristics, comorbidities, and a random hospital-level intercept. This model specification accounts for within-hospital correlation of the observed outcomes and models the assumption that underlying differences in quality among the health care facilities being evaluated lead to systematic differences in outcomes. We estimated a separate hierarchical logistic regression model for each specialty cohort.

Specifically, for a given specialty cohort, we estimated a hierarchical logistic regression model as follows. Let Y_{ij} denote the outcome (equal to 1 if patient i is readmitted 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:

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

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

where $\mathbf{Z_{ij}} = (Z_1, Z_2, ... Z_k)$ is a set of k patient-level covariates. α_j represents the hospital specific intercept; μ is the adjusted average outcome over all hospitals; and τ^2 is the between hospital variance component and $\varepsilon \sim N(0,\sigma^2)$ captures any over- or under-dispersion. The hierarchical logistic regression model for each cohort was estimated using the SAS software system (GLIMMIX procedure).

Hospital performance assessment

The previous section describes how the models for each specialty cohort are specified and estimated, using a separate hierarchical logistic regression model for that cohort. Each model is then used to calculate a standardized risk ratio (SRR) for each hospital which contributes index admissions to that model. These SRRs, weighted by volume, are then pooled for each hospital to create a composite hospital-wide SRR.

We used the results of each hierarchical logistic regression model to calculate the predicted number of readmissions and the expected number of readmissions at each hospital. The predicted number of readmissions in each cohort was calculated, using the corresponding hierarchical logistic regression model, as the sum of the predicted probability of readmission for each patient, including the hospital-specific (random) effect. The expected number of readmissions in each cohort for each hospital was similarly calculated as the sum of the predicted probability of readmission for each patient, ignoring the hospital specific (random) effect. Using the notation of the previous section, the model specific risk standardized readmission ratio is calculated as follows. To calculate the predicted number of admissions pred_{Cj} for index admissions in cohort C=1,...,5 at hospital j, we used

$$\text{pred}_{Cj} = \Sigma \text{logit}^{-1}(\alpha_j + \boldsymbol{\beta}*\mathbf{Z_{ij}}) \tag{2}$$

where the sum is over all m_{Cj} index admissions in cohort C with index admissions at hospital j. To calculate the expected number exp_{Cj} we used

$$\text{exp}_{Cj} = \Sigma \text{logit}^{-1}(\mu + \boldsymbol{\beta}*\mathbf{Z_{ij}}) \tag{3}$$

Then, as a measure of excess or reduced readmissions among index admissions in cohort C at hospital j, we calculated the standardized risk ratio SRR_{Cj} as

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$$SRR_{Cj} = pred_{Cj}/exp_{Cj} \qquad (4)$$

Risk-standardized hospital-wide 30-day readmission rate

To report a single readmission score, the separate specialty cohort SRRs were combined into a single value. We created a single score as follows.

For a given hospital, j, which has patients in some subset of cohorts $C \subseteq {}^1$, calculate the SRR as described above for each specialty cohort for which the hospital discharged patients. If the hospital does not have index admissions in a given cohort c, then $m_{cj} = 0$ and we take $SRR_{cj} = 1$. Then, calculate the volume-weighted logarithmic mean:

$$SRR_j = exp((\Sigma\, m_{cj} \log(SRR_{cj})) / \Sigma m_{cj}) \qquad (5)$$

where the sums are over all specialty cohorts; note that if a hospital does not have index admissions in a given cohort ($m_{cj} = 0$) then that cohort contributes nothing to the overall score SRR_j. **This value, SRR_j, is the hospital-wide standardized risk ratio** for hospital *j*. To aid interpretation, this ratio is then multiplied by the overall raw readmission rate for all index admissions in all cohorts for the 21 KPNC hospitals, to produce **the risk-standardized hospital-wide readmission rate (RSRR_j)**.

$$RSRR_j = SRR_j * \bar{Y} \qquad (6)$$

Model Performance Assessment

We completed hierarchical modeling and calculated measure results for the original HWR model and for the best-performing model containing the CCDE, which we have referred to as the Hybrid eHWR. Assessment of the Hybrid eHWR performance included model calibration (to assess over-fitting), discrimination in terms of predictive ability (the range of observed readmission rates across deciles of predicted rates), and distribution of model residuals. These analyses were done in the development, validation, and testing (2012) samples. We also calculated the model estimates as well as the coefficients and 95% confidence intervals for risk-adjustment variables for the best-performing model in the development and validation samples.

2.6 MEASURE TESTING

To assess the overall internal consistency of the specialty cohort SRRs and appropriateness of combining the SRRs into a composite score, we calculated Cronbach's coefficient α. This coefficient reflects the proportion of total variance in the summated scale composite score that is accounted for by a common source among the condition measures. Theoretically, α varies from 0 to 1 and higher values of α are more desirable.

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 RSRR from the Hybrid eHWR using each half of the split-sample 2010-2011 data (the development and validation samples). Thus, we obtain two RSRRs for each 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).[9, 10] For the hospital event rate based on the patient binomial outcomes like readmission (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.[10]

We considered all measure testing as preliminary due to the small sample of hospitals in the KPNC database, and the lack of patient sociodemographic diversity within the integrated network of KPNC hospitals. Confirming the validity and reliability of the measure requires data from a larger, more diverse set of hospitals and more than one EHR system. Currently there is no large national dataset that includes patient-level EHR data and captures admissions and readmissions to all hospitals from Medicare or non-Medicare claims data.

2.7 COMPARISON OF HYBRID eHWR AND ORIGINAL HWR MEASURE RESULTS

We compared the results of the original HWR measure with the results of the reengineered Hybrid eHWR to describe differences in hospital performance assessed by the two measures. We calculated the correlations between the specialty cohort specific standardized risk ratios (SRRs) and the composite risk standardized readmission rates (RSRRs) from the two models. We also compared hospitals' ranking based on the composite RSRRs calculated using the two measures. These results should also be considered preliminary given the small number of hospitals used in these analyses.

3. RESULTS

3.1 COHORT

The exclusion criteria for the measure that were applied to the KPNC dataset are presented in Section 2.2. The percentage of patients meeting each exclusion criterion in the 2010-2012 dataset is presented in Figure 3.1. The number of index admissions for each specialty cohort in the KPNC dataset is listed in Table 3.1.

Figure 3.1: Index eHWR Cohort in 2010-2012 KPNC Dataset
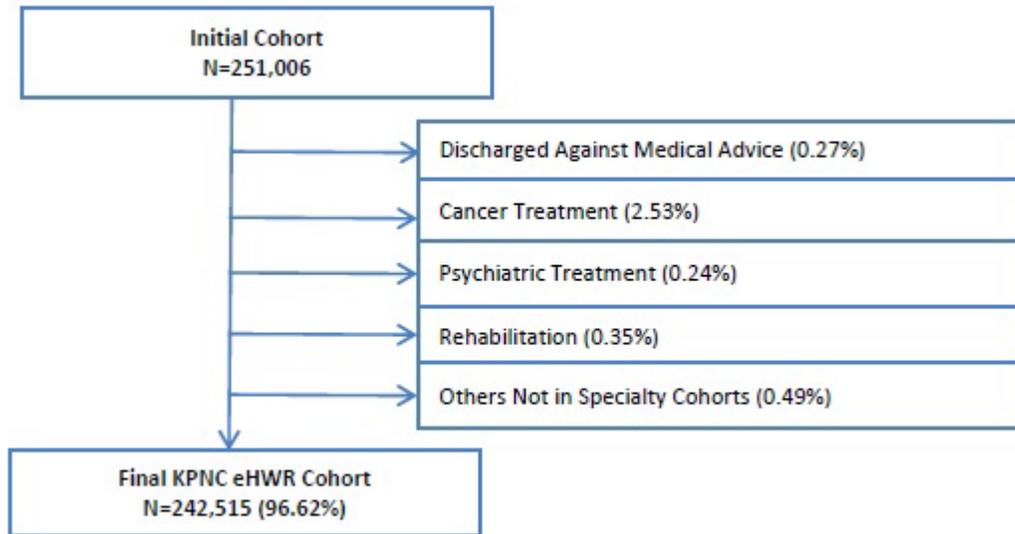
Table 3.1: Index Admissions by Specialty Cohort

Specialty Cohort	Number of Admissions
Surgery/gynecology	72,162
Cardiorespiratory	27,695
Cardiovascular	24,483
Neurology	13,235
Medicine	104,940

3.2 OUTCOME

Assessment of the 30-Day Unplanned Readmission Outcome

The matching analysis performed to verify that KPNC captured all or nearly all readmissions to hospitals within and outside of their network showed that 98% of readmissions captured within the hospital inpatient claims database maintained by the California Office of Statewide Health Planning and Development were also captured in the KPNC database. This confirmed that the KPNC claims dataset is an accurate source of information to assess the readmission outcome.

The unplanned readmission rate for the patients in the development sample was 14.8%. Rates of unplanned readmission in the development sample varied across the five specialty cohorts from the lowest rate of 9.5% in the surgical cohort to 19.9% in the cardiorespiratory cohort. The rates were

similar across the 3 samples with a slightly lower rate in the 2012 sample ([Table 3.2](#)).

Table 3.2: Unplanned Readmission Rates by Specialty Cohort and Data Sample

Specialty Cohort	Development Sample		Validation Sample		2012 Sample	
	Index Admissions	Readmission Rate	Index Admissions	Readmission Rate	Index Admissions	Readmission Rate
Surgery/ Gynecology	23,201	9.5%	23,490	10.1%	25,471	8.5%
Cardiorespiratory	9,261	19.9%	9,364	20.0%	9,070	19.1%
Cardiovascular	8,108	10.2%	8,037	10.6%	8,338	9.3%
Neurology	4,400	12.8%	4,348	13.2%	4,487	11.9%
Medicine	34,619	18.4%	34,574	18.2%	35,747	16.7%
Overall eHWR	79,589	14.8	79,813	15.0	83,113	13.4

3.3 RISK-ADJUSTMENT VARIABLES

Feasibility and Reliability of CCDE Risk Variables

Vital signs including blood pressure, heart rate, respiratory rate, temperature, and oxygen saturation (by pulse oximetry) were captured within 2 hours of arrival to the hospital in at least 90% of the hospital admissions in each specialty cohort. Weight was captured within the first 24 hours of admission because it is not likely to change substantially during that timeframe. Laboratory test results (complete blood count and basic chemistry panel) were captured within 24 hours in more than 90% of admissions in each of the non-surgical specialty cohorts. Surgical patients typically have laboratory tests drawn in the days leading up to their surgery and may not be entered into the hospital's EHR system. Therefore, within this cohort the rate of capture for these data elements within 24 hours was 70.6% to 83.3% in the development sample. Rates of capture were consistent across the three samples ([Table 3.3](#)).

The median data values, 1st, and 99th percentile values for each of the retained CCDE variables (excluding age) were consistent across the development and validation samples ([Table 3.4](#)).

Table 3.3: Percent of Index Admission in Which the CCDE Values Were Captured Within Specified Timeframes by Specialty Cohort and Data Sample

Specialty Cohort	Development Sample	Validation Sample	2012 Sample
Heart rate (% captured)			
Surgery/Gynecology	95.0	95.2	96.6
Cardiorespiratory	98.7	98.4	99.1
Cardiovascular	97.7	97.9	98.5
Neurology	97.7	98.1	98.6
Medicine	98.1	98.1	98.7
Systolic BP (% captured)			
Surgery/Gynecology	94.5	94.6	96.0
Cardiorespiratory	98.5	98.1	98.8
Cardiovascular	97.6	97.8	97.9
Neurology	97.7	98.1	98.5
Medicine	97.9	97.9	98.5
Respiratory Rate (% captured)			
Surgery/Gynecology	94.4	94.4	96.1
Cardiorespiratory	97.8	97.7	98.1
Cardiovascular	96.8	97.3	97.3
Neurology	97.0	97.3	97.6
Medicine	97.1	97.2	97.6
Temperature (% captured)			
Surgery/Gynecology	93.7	94.0	95.7
Cardiorespiratory	95.0	94.5	95.2
Cardiovascular	93.6	93.8	94.3
Neurology	93.1	94.0	94.5
Medicine	95.1	95.0	96.0
Weight (% captured)			
Surgery/Gynecology	94.1	94.1	95.7
Cardiorespiratory	93.7	93.6	94.9
Cardiovascular	94.3	94.7	95.2
Neurology	91.0	91.6	92.4
Medicine	91.1	91.2	92.3
Oxygen Saturation (% captured)			
Surgery/Gynecology	93.3	93.5	95.8
Cardiorespiratory	97.6	97.3	98.4
Cardiovascular	96.1	96.3	97.4
Neurology	96.2	96.6	97.4
Medicine	96.0	95.9	97.3
Hematocrit (% captured)			
Surgery/Gynecology	83.3	83.8	82.0
Cardiorespiratory	98.5	98.5	99.0
Cardiovascular	95.4	95.5	94.9
Neurology	97.8	97.9	98.0
Medicine	97.6	97.6	98.0
Platelets (% captured)			
Surgery/Gynecology	79.3	80.0	78.5
Cardiorespiratory	98.4	98.2	98.8

Specialty Cohort	Development Sample	Validation Sample	2012 Sample
Cardiovascular	95.2	95.2	94.7
Neurology	97.6	97.7	97.7
Medicine	97.2	97.3	97.6
WBC Count (% captured)			
Surgery/Gynecology	79.4	80.1	78.6
Cardiorespiratory	98.5	98.4	98.9
Cardiovascular	95.3	95.3	94.9
Neurology	97.8	97.8	97.9
Medicine	97.4	97.4	97.8
Potassium (% captured)			
Surgery/Gynecology	70.6	71.1	70.0
Cardiorespiratory	96.8	96.5	97.1
Cardiovascular	93.6	93.6	93.5
Neurology	96.1	95.9	95.8
Medicine	95.6	95.6	95.8
Sodium (% captured)			
Surgery/Gynecology	71.8	72.3	71.1
Cardiorespiratory	98.7	98.5	99.1
Cardiovascular	95.0	95.2	94.8
Neurology	98.0	98.0	98.3
Medicine	97.4	97.4	97.9
Bicarbonate (% captured)			
Surgery/Gynecology	71.3	71.7	70.8
Cardiorespiratory	98.8	98.5	99.1
Cardiovascular	95.0	95.3	94.8
Neurology	98.0	97.9	98.2
Medicine	97.4	97.4	97.8
Creatinine (% captured)			
Surgery/Gynecology	72.0	72.2	71.5
Cardiorespiratory	98.7	98.5	99.1
Cardiovascular	95.2	95.3	94.8
Neurology	98.1	98.0	98.3
Medicine	97.4	97.4	97.9
Glucose (% captured)			
Surgery/Gynecology	71.1	71.4	70.5
Cardiorespiratory	98.6	98.4	99.0
Cardiovascular	94.9	95.1	94.6
Neurology	98.0	97.9	98.2
Medicine	97.3	97.3	97.8

Table 3.4: CCDE Data Values by Specialty Cohort and Data Sample – Median (1st-99th percentiles)

Specialty Cohort	Development Sample	Validation Sample	2012 Sample
Heart rate (bpm)			
Surgery/Gynecology	72 (47-122)	72 (47-122)	72 (47-123)
Cardiorespiratory	87 (48-150)	87 (46-150)	87 (47-150)
Cardiovascular	75 (36-167)	76 (35-166)	76 (35-162)
Neurology	78 (47-138)	78 (47-141)	78 (48-137)

Specialty Cohort	Development Sample	Validation Sample	2012 Sample
Medicine	84 (47-146)	84 (47-145)	85 (48-147)
Systolic BP (mmHg)			
Surgery/Gynecology	139 (92-199)	138 (92-198)	139 (91-199)
Cardiorespiratory	138 (83-215)	138 (83-215)	138 (83-211)
Cardiovascular	141 (81-215)	140 (81-212)	140 (81-213)
Neurology	148 (88-223)	148 (87-224)	149 (87-224)
Medicine	136 (78-213)	136 (78-213)	135 (77-210)
Respiratory Rate (breath per minute)			
Surgery/Gynecology	18 (12-26)	18 (12-25)	18 (12-26)
Cardiorespiratory	20 (14-40)	20 (13-40)	20 (13-40)
Cardiovascular	18 (12-32)	18 (12-33)	18 (12-33)
Neurology	18 (12-31)	18 (12-32)	18 (12-31)
Medicine	18 (12-36)	18 (12-36)	18 (12-36)
Temperature (⁰F)			
Surgery/Gynecology	98.0 (96.3-100.5)	98.0 (96.3-100.6)	98.0 (96.4-100.6)
Cardiorespiratory	98.1 (95.9-102.8)	98.1 (95.6-102.7)	98.1 (95.8-102.2)
Cardiovascular	98.0 (95.9-101.3)	98.0 (96.0-101.6)	98.0 (96.0-100.7)
Neurology	98.0 (95.8-101.7)	98.1 (95.6-102.2)	98.0 (95.8-101.3)
Medicine	98.2 (95.5-103.1)	98.2 (95.4-103.1)	98.2 (95.6-103.2)
Weight (pounds*)			
Surgery/Gynecology	170 (94-293)	169 (94-294)	169 (94-293)
Cardiorespiratory	162 (87-325)	160 (85-316)	164 (85-327)
Cardiovascular	166 (92-295)	166 (93-299)	168 (95-302)
Neurology	156 (87-275)	158 (88-270)	157 (86-286)
Medicine	159 (85-304)	159 (86-307)	159 (86-307)
Oxygen Saturation (%)			
Surgery/Gynecology	98 (90-100)	98 (90-100)	98 (90-100)
Cardiorespiratory	96 (73-100)	96 (71-100)	96 (70-100)
Cardiovascular	98 (85-100)	98 (85-100)	98 (85-100)
Neurology	98 (85-100)	98 (85-100)	98 (86-100)
Medicine	97 (80-100)	97 (81-100)	97 (81-100)
Hematocrit (% red blood cells)			
Surgery/Gynecology	34.4 (22.0-47.8)	34.4 (22.0-47.3)	34.7 (22.0-47.6)
Cardiorespiratory	36.4 (22.3-49.4)	36.6 (22.5-49.7)	36.3 (22.0-50.2)
Cardiovascular	37.7 (23.0-49.0)	37.8 (22.8-49.1)	38.0 (23.5-49.1)
Neurology	38.0 (22.6-49.6)	37.9 (23.6-48.8)	38.2 (24.2-49.8)
Medicine	36.0 (18.7-49.2)	36.1 (18.8-49.1)	35.9 (18.3-49.1)
Platelets (count)			
Surgery/Gynecology	196 (75-493)	197 (74-479)	197 (75-501)
Cardiorespiratory	210 (64-550)	210 (64-531)	207 (67-525)
Cardiovascular	202 (71-469)	204 (78-477)	203 (68-474)
Neurology	210 (69-506)	209 (51-520)	210 (60-505)
Medicine	215 (47-564)	214 (48-576)	215 (43-578)
WBC Count (cells/mL)			
Surgery/Gynecology	9.4 (3.7-24.1)	9.3 (3.7-24.4)	9.4 (3.7-24.8)
Cardiorespiratory	9.0 (3.2-27.1)	9.1 (3.2-29.0)	8.8 (3.1-26.4)
Cardiovascular	7.8 (3.4-22.5)	7.9 (3.4-22.0)	7.9 (3.4-20.7)
Neurology	8.1 (3.4-23.3)	8.1 (3.1-22.8)	8.0 (3.2-22.5)

Specialty Cohort	Development Sample	Validation Sample	2012 Sample
Medicine	9.4 (2.0-30.2)	9.3 (2.1-30.4)	9.4 (1.8-31.2)
Potassium (mEq/L)			
Surgery/Gynecology	4.2 (3.0-5.8)	4.2 (3.0-5.8)	4.2 (3.0-5.8)
Cardiorespiratory	4.4 (3.0-6.3)	4.4 (3.1-6.4)	4.3 (3.1-6.3)
Cardiovascular	4.3 (3.1-6.0)	4.3 (3.1-6.1)	4.3 (3.0-6.1)
Neurology	4.3 (3.0-6.0)	4.2 (3.1-5.9)	4.2 (2.9-5.8)
Medicine	4.3 (2.9-6.6)	4.3 (2.9-6.5)	4.3 (2.8-6.4)
Sodium (mEq/L)			
Surgery/Gynecology	137 (126-145)	137 (126-145)	138 (126-146)
Cardiorespiratory	139 (121-147)	138 (121-148)	139 (122-148)
Cardiovascular	139 (124-146)	139 (124-146)	139 (126-147)
Neurology	139 (125-147)	139 (124-148)	140 (125-148)
Medicine	138 (119-152)	138 (119-151)	138 (119-152)
Bicarbonate (mmol)			
Surgery/Gynecology	27 (18-35)	27 (18-35)	26 (16-34)
Cardiorespiratory	27 (17-44)	27 (17-42)	26 (16-40)
Cardiovascular	27 (17-36)	27 (17-36)	25 (16-34)
Neurology	27 (16-36)	27 (17-36)	26 (16-34)
Medicine	27 (14-38)	26 (14-38)	25 (13-36)
Creatinine (mg/dL)			
Surgery/Gynecology	0.88 (0.47-5.80)	0.88 (0.47-6.23)	0.86 (0.44-6.00)
Cardiorespiratory	1.06 (0.46-6.31)	1.06 (0.45-6.84)	1.06 (0.45-6.10)
Cardiovascular	1.02 (0.52-6.91)	1.02 (0.52-6.70)	1.00 (0.51-7.41)
Neurology	0.96 (0.49-6.06)	0.95 (0.50-6.45)	0.93 (0.44-6.64)
Medicine	1.05 (0.46-8.21)	1.06 (0.47-8.39)	1.04 (0.44-8.24)
Glucose (mg/dL)			
Surgery/Gynecology	122 (71-328)	121 (71-319)	120 (72-327)
Cardiorespiratory	118 (63-382)	118 (60-383)	119 (62-379)
Cardiovascular	114 (64-372)	114 (66-376)	114 (67-377)
Neurology	112 (64-433)	112 (65-407)	112 (69-370)
Medicine	118 (59-450)	117 (57-458)	118 (60-451)

3.4 MODEL DEVELOPMENT AND VALIDATION

Selection of Best-Performing Model

To select the best-performing model containing the CCDE, we compared the results of logistic regression models calculated using the four risk-adjustment approaches within each specialty cohort. In the interest of reducing the amount of data included in this report, we omitted the full measure specifications for the models that were not selected as the best performer according to model discrimination in terms of the C-statistic. The full specifications for the best-performing model are provided in Appendix B. The C-statistics for each risk-adjustment approach by specialty cohort are shown in Table 3.5. The *CCDE with Original HWR* approach produced the model with the highest c-statistic for each of the 5 specialty cohorts, although the incremental gain in c-statistic over the *Original HWR* approach was modest.

Table 3.5: Logistic Regression C-Statistics for Four Risk Model Approaches (Development Sample)

Specialty Cohort	HWR	HWR + CCDE	CCDE+Principal Diagnosis	CCDE Only
Surgery/Gynecology	0.800	0.802	0.770	0.617
Cardiorespiratory	0.653	0.668	0.645	0.611
Cardiovascular	0.713	0.731	0.692	0.686
Neurology	0.670	0.708	0.674	0.672
Medicine	0.646	0.651	0.611	0.585

Based on superior model discrimination, the *CCDE with Original HWR* model was identified as the best-performing model of those evaluated and will be referred to as the Hybrid eHWR. This model was carried forward for measure development and testing using hierarchical logistic regression. The other two approaches that included the CCDE were discarded.

Model Results

The final Hybrid eHWR model variables for each specialty cohort can be found in Appendix B in Table B.1, Table B.2, Table B.3, Table B.4, and Table B.5. Those tables also list the parameter estimates, standard errors, odds ratios and 95% confidence intervals for the model risk factors for each specialty cohort in the development sample. The standardized risk ratios (SRRs) for each specialty cohort and the risk-standardized readmission rate (RSRRs) or full composite measure results for the Hybrid eHWR are shown in Table 3.6.

Table 3.6: SRR & RSRR Distribution by Specialty Cohort for the Hybrid eHWR (Development Sample)

Value	Surgery/ Gynecology	Cardio- respiratory	Cardio- vascular	Neurology	Medicine	Overall
Mean SRR	0.997	1.004	1.000	0.998	1.007	1.002
Min SRR	0.830	0.950	0.997	0.768	0.906	0.887
Median SRR	0.994	1.006	0.999	0.999	0.995	1.015
Max SRR	1.199	1.046	1.004	1.162	1.155	1.091
Mean RSRR (%)	9.48	20.02	10.20	12.77	18.49	14.84
Min RSRR (%)	7.88	18.94	10.17	9.83	16.63	13.15
Median RSRR (%)	9.44	20.06	10.19	12.79	18.27	15.04
Max RSRR (%)	11.39	20.87	10.24	14.87	21.21	16.16

Model Performance of the Hybrid eHWR

Examination of the performance of the Hybrid eHWR across the development, validation, and 2012 samples showed stable model characteristics in terms of model calibration (to assess over-fitting) and distribution of model residuals (to assess predictive ability) (Table 3.7 and Table 3.8). The calibration values of close to 0 at the lower end and close to one at the upper end in each model in the validation sample indicates good calibration and an absence of over-fitting across samples. Discrimination measures the ability to distinguish high-risk subjects from low-risk subjects. The wide range in observed rates between the lowest decile and highest decile of predicted rates shows excellent discrimination of the model and good predictive ability across samples. We also found stability of model estimates and stability in the odds ratios and coefficients in the development and validation samples (Appendix B).

Table 3.7: Logistic Regression Model Statistics by Specialty Cohort and Data Sample

Specialty Cohort	Hybrid eHWR Development Sample	Hybrid eHWR Validation Sample	Hybrid eHWR 2012 Sample
Calibration (γ0, γ1)			
Surgery/Gynecology	(0.000, 1.000)	(-0.049,0.948)	(-0.192,0.971)
Cardiorespiratory	(0.000, 1.000)	(-0.004,0.995)	(-0.111,0.931)
Cardiovascular	(0.000, 1.000)	(0.067,1.007)	(-0.333,0.854)
Neurology	(0.000, 1.000)	(-0.129,0.920)	(-0.464,0.781)
Medicine	(0.000, 1.000)	(-0.047,0.977)	(0.077,1.108)
c-statistics			
Surgery/Gynecology	0.802	0.799	0.800
Cardiorespiratory	0.668	0.673	0.666
Cardiovascular	0.731	0.717	0.726
Neurology	0.708	0.697	0.693
Medicine	0.651	0.656	0.665
Discrimination-Predictive Ability (lowest decile %, highest decile%)			
Surgery/Gynecology	0-35	0-36	0-31
Cardiorespiratory	9-39	7-41	6-36
Cardiovascular	2-29	2-32	2-24
Neurology	4-33	5-37	5-34
Medicine	8-35	7-35	6-34

Table 3.8: Distribution of Model Residuals by Specialty Cohort and Data Sample

Distribution of Model Residuals (%)	Hybrid eHWR Development Sample	Hybrid eHWR Validation Sample	Hybrid eHWR 2012 Sample
Surgery/Gynecology			
<-2	0.0%	0.0%	0.0%
[-2,0	90.5%	89.9%	91.5%
[0,2]	3.7%	4.0%	2.9%
[2+	5.8%	6.1%	5.6%
Cardiorespiratory			
<-2	0.0%	0.0%	0.0%
[-2,0	80.1%	80.0%	80.9%
[0,2]	12.2%	12.3%	11.2%
[2+	7.8%	7.7%	7.9%
Cardiovascular			
<-2	0.0%	0.0%	0.0%
[-2,0	89.8%	89.4%	90.7%
[0,2]	3.1%	3.3%	2.1%
[2+	7.1%	7.3%	7.2%
Neurology			
<-2	0.0%	0.0%	0.0%
[-2,0	87.2%	86.8%	88.1%
[0,2]	4.4%	4.9%	4.0%
[2+	8.4 %	8.3%	7.9%
Medicine			
<-2	0.0%	0.0%	0.0%
[-2,0	81.6%	81.8%	83.3%

Distribution of Model Residuals (%)	Hybrid eHWR Development Sample	Hybrid eHWR Validation Sample	Hybrid eHWR 2012 Sample
[0,2]	9.2%	9.1%	7.7%
[2+	9.2%	9.1%	9.0%

3.5 MEASURE TESTING

<u>Reliability of Measure Components and Results</u>

The internal consistency among SRRs for the specialty cohorts was high as indicated by the Cronbach's α of 0.83 for both the Hybrid eHWR measure as well as the Original HWR measure (Table 3.9) indicating an excellent internal consistency among the SRRs for the five specialty cohorts.

Table 3.9: Cronbach's Alpha

Cronbach's Alpha	Original HWR	Hybrid eHWR
Standardized SRR	0.8370	0.8334

When comparing the hospitals' RSRRs in the development and validation samples for the Hybrid eHWR, hospital-level risk-standardized readmission rates were highly correlated (ICC=0.688), as shown in Figure 3.2.

Figure 3.2: Correlation of RSRRs in Development and Validation Samples
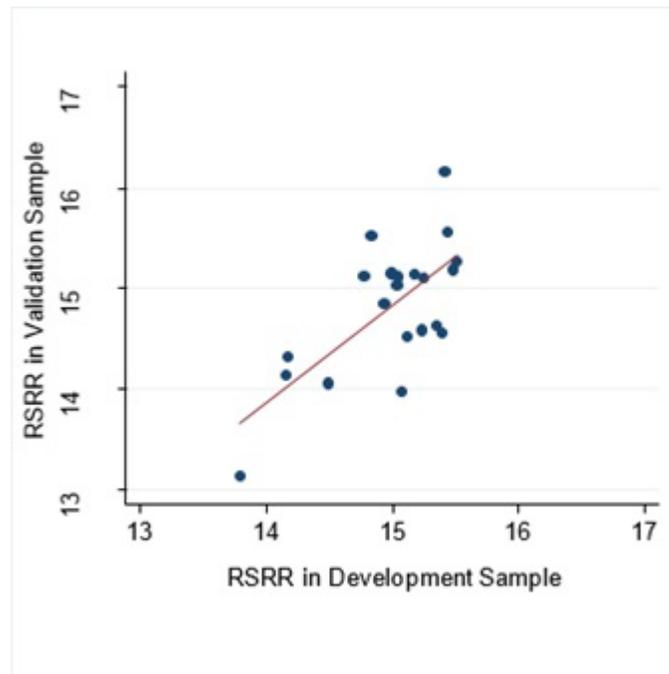
3.6 COMPARISON OF HWR AND HYBRID eHWR RESULTS

The original HWR measure was also calculated to compare with the Hybrid eHWR results.

The standardized risk ratios and risk standardized readmission rates were highly correlated between the two models (Table 3.10). Ranking of hospitals based on the composite RSRRs differed only slightly by measure. Ranking for most hospitals (11 of 21) were unchanged, and shifted up or down by at most two positions on the list (Table 3.11).

Table 3.10: Correlation of Original HWR and Hybrid eHWR RSRRs (Development Sample)

Value	Surgery/ Gynecology	Cardio-respiratory	Cardiovascular	Neurology	Medicine	Overall
Correlation of RSRRS	0.9888	0.9829	0.9818	0.9707	0.9953	0.9902

Table 3.11: Hospital Rankings by Risk Model Approach (Development Sample)

Hospital ID	Original HWR		Hybrid eHWR	
-	Rank	RSRR	Rank	RSRR
A	1	13.26	1	13.15
B	2	13.91	2	13.99
C	3	13.98	3	14.06
D	4	14.10	4	14.14
E	5	14.29	5	14.33
F	6	14.46	6	14.52
G	7	14.60	9	14.64
H	8	14.62	7	14.56
I	9	14.74	8	14.59
J	10	14.83	11	15.04
K	11	14.89	10	14.86
L	12	15.04	14	15.12
M	13	15.05	13	15.12
N	14	15.14	12	15.10
O	15	15.16	16	15.16
P	16	15.19	17	15.19
Q	17	15.22	15	15.14
R	18	15.23	18	15.28
S	19	15.43	19	15.52
T	20	15.73	20	15.56
U	21	16.31	21	16.16

4. SUMMARY

This technical report describes the methodology used to reengineer the original HWR measure into a new hybrid readmission measure, which includes clinical data from patients' EHRs (CCDE) in the risk adjustment models as well as claims data. We used a 3-year dataset from the 21 hospitals in the KPNC network to develop and evaluate a statistical model of all-cause unplanned readmission. The dataset consisted of all acute-care hospital admissions for patients 65-years and older. The results indicate that the CCDE combined with the Original HWR approach to risk adjustment yielded the best predictive model of readmission. This approach uses a combination of claims data to capture patients' comorbidities and principal discharge diagnoses associated with each index admission, as well as clinical data from EHRs to capture patients' clinical status at the start of each encounter.

Measure specifications were adopted from the original HWR measure methodology including the cohort definition, assessment of patients' principal discharge diagnoses, comorbidities, and the unplanned readmission outcome. Each hospital's risk-standardized readmission rate (RSRR) is the volume weighted average of the standardized risk ratios calculated from five hierarchical logistic regression models, each for one of the five specialty cohorts. The new measure, which we term the Hybrid eHWR measure, represents an important innovation in hospital outcome measures in two respects:

1. The Hybrid eHWR responds to the preference of many providers and other stakeholders that physiological data that are captured by clinicians during hospitalizations be used to adjust for patient-level risk factors in hospital outcome measures. By including the CCDE into the risk adjustment methodology, we have taken a first step toward developing outcome measures that rely on physiological information captured at the beginning of the episode of care. This is the same data that clinicians use to assess how sick their patients are and to guide their treatment plans in real time. This alignment gives face validity to the outcome measure and might support the development of other types of measures that can be reported in real-time.
2. The Hybrid eHWR also provides new efficiencies in measure development and implementation. Once the CCDE is collected for this broad cohort of patients, they can be used in the development of risk-adjusted condition- and procedure-specific measures with no additional reporting burden for providers. This would greatly reduce the redundancies in data element feasibility testing during measure development and improve harmonization across measures.

When added to claims data, the CCDE enhanced the discriminative ability of the 30-day unplanned readmission model. Therefore, we selected the *CCDE with Original HWR* approach as the risk-adjustment model for the new Hybrid eHWR measure. Although our results indicate that the CCDE, by itself, is not as predictive of readmission as claims data, under some circumstances there might be advantages to a more parsimonious model that uses clinical data alone or clinical data with principal discharge diagnoses. More parsimonious models are simpler and better harmonized with tools that require physiological data captured in real time, such as clinical decision support. In the future, as the use and function of EHRs continues to evolve, it might be possible to add new feasible data elements to the CCDE that improve the performance of a more parsimonious risk-adjusted model. Future versions of the CCDE will ultimately have to improve discrimination, reliability, and validity over existing models.

As with CMS's claims-based outcome measures, Hybrid eHWR measure results used in public reporting must be calculated by CMS to determine hospitals' risk-adjusted rates relative to national rates. Also,

this Hybrid eHWR measure uses data from both administrative claims (cohort and outcome derivation) and EHR data sources (CCDE). For CMS to link the administrative claims to the CCDE for each episode of care, hospitals would submit administrative data elements such as admission and discharge dates, CMS certification number, and date of birth.

A public comment period on this report was held July 7, 2014 – August 8, 2014. For the public comment summary report, please see Appendix C.

5. GLOSSARY OF TERMS

- *Administrative claims data:* An electronic environment 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, name, 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

- *Clinical Classification Software (CCS) categories*: Groupings of related ICD-9 diagnosis and procedure codes in clinically relevant categories. These categories are defined by the Agency for Healthcare Research & Quality (AHRQ) and can be found at http://www.hcup-us.ahrq.gov/toolssoftware/ccs/ccs.jsp.

- *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

- *Condition Categories (CCs):* Groupings of ICD-9-CM diagnosis codes in clinically relevant categories, from the Hierarchical Condition Categories (HCCs) system. CMS uses the grouping but not the hierarchical logic of the system to create risk factor variables. Description of the CCs can be found at http://www.cms.hhs.gov/Reports/downloads/pope_2000_2.pdf

- *Core Clinical Data Elements (CCDE)*: A standardized set of clinical data that are consistently obtained on adult hospital inpatients that could be feasibly extracted from electronic health records, to be used in risk-adjustment for hospital quality outcome measures.

- *Data mapping*: Data mapping is the process by which two distinct data models are created and a link between these models is defined. It is most readily used in software engineering to describe the best way to access or represent some form of information. In this report, the two data models are the EHR's clinical interface where clinical, laboratory, and other staff capture relevant data and the thousands of linked data tables that make up the EHR's permanent data warehouse where those data are transmitted and stored.

- *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.

- *Electronic Specification/eSpecification*: Refers to measure specifications derived from EHRs and contain four main components: measure overview/description, measure logic, measure code lists, and quality data sets elements.

- *Expected readmissions:* The number of readmissions expected based on average hospital performance with a given hospital's case mix.

- *First captured values:* The first value for a data element recorded in the electronic health record after a patient arrives at the facility for care. Identification of the first value requires a time and date stamp for the first interaction a patient has with facility staff which results in a time or date stamp being entered in the Patient Management System. This is most often the time and date of registration when basic demographic and insurance information are provided and confirmed by

non-clinical staff. An arrival location is also required because patients can arrive in various locations including the Emergency Department, pre-operative area, or to an inpatient unit or floor. The time and date stamps associated with the specific data elements are then compared against the time of arrival to identify the first captured value.

- *Feasibility*: Data elements that are consistently captured in current clinical practice, captured with a standard definition, and entered in structured fields across individuals as well as EHR and hospital systems.
- *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 readmission 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 readmission risk.
- *Hospital entry location*: The department in which a patient first enters the hospital to receive care, such as the ED, the operating room, or the inpatient floor.
- *Hospital-specific intercept:* A measure of the hospital quality of care calculated based on the hospital's actual readmission rate relative to hospitals with similar patients, considering how many patients it served, its patients' risk factors, and how many died or were readmitted. 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" readmissions.
- *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.
- *Outcome:* The result of a broad set of healthcare activities that affect patients' well-being. For this readmission measure, the outcome is readmission within 30 days of discharge.
- *Patient management system*: Electronic system or software environment that manages certain administrative activities including allocating physicians, applying policies, and assigning beds. These systems also capture and store patient information, such as name, gender, date of birth, date of encounter visit, national ID or hospital identification number. These systems capture data about patient care workflow, including the registration of patient information, bed tracking, and discharge. The system might or might not be integrated with the clinical EHR.
- *Planned readmissions:* A readmission within 30 days of discharge from an acute care hospital that is a scheduled part of the patient's plan of care. Planned readmissions are not counted as outcomes in this measure.
- *Predicted readmissions:* The number of readmissions 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.
- *Service Mix:* The particular conditions and procedures of the patients with index admissions at a given hospital
- *Specialty cohorts*: A group of index admissions for patients with related conditions or procedures

categories that are likely to be cared for by specific teams of clinicians; there are five defined cohorts in this report (medicine, neurology, cardiorespiratory, cardiovascular, surgery/gynecology).

- *Structured data*: Data captured in a format that is numerical, such as integers or fractions; pseudo-numerical, such as dates; or list, such as "positive" or "negative."
- *Time of arrival*: The time stamp that is captured closest to the moment a patient first reaches the hospital for care.
- *Unplanned readmissions:* Acute clinical events a patient experiences that require urgent rehospitalization. Unplanned readmissions are counted as outcomes in the measure.

6. APPENDICES

APPENDIX A: HYBRID eHWR MEASURE SPECIFICATIONS FOR MEDICARE FFS POPULATION

<u>Cohort</u>

Inclusion Criteria for HWR Measure

1. **Enrolled in <u>Medicare FFS</u>**
   Rationale: Claims data are consistently available only for Medicare FFS.
2. **Aged 65 or older**
   Rationale: Medicare patients younger than 65 usually qualify for the program due to severe disability. They are not included in the measure because Medicare patients younger than 65 are considered to be too clinically distinct from Medicare patients 65 and over.
3. **Discharged from non-federal acute care hospitals**
   Rationale: Data from federal hospitals were not available during the development of this measure.
4. **Without an in-hospital death**
   Rationale: Patients who are discharged alive are eligible for readmission.
5. **Not transferred to another acute care facility**

   Rationale: Readmission is attributed to the hospital that discharged the patient to the non-acute care setting. Transferred patients are still included in the measure cohort, but the initial admitting hospital is not accountable for the outcome.
6. **Enrolled in Part A for the 12 months prior to and including the date of the index admission**
   Rationale: The 12-month prior enrollment ensures a full year of administrative data for risk adjustment.

Exclusion Criteria for HWR Measure

1. **Admissions to Prospective Payment System (PPS)-exempt cancer hospitals**
   Rationale: These hospitals care for a unique population of patients that cannot reasonably be compared to patients admitted to other hospitals.
2. **Without at least 30 days of post-discharge enrollment in FFS Medicare**
   Rationale: The 30-day readmission outcome cannot be assessed in this group since claims data are used to determine whether a patient was readmitted.
3. **Discharged against medical advice (AMA)**
   Rationale: Providers did not have the opportunity to deliver full care and prepare the patient for discharge.
4. **Admissions for primary psychiatric diagnoses**
   Rationale: Patients admitted for psychiatric treatment are typically cared for in separate psychiatric or rehabilitation centers that are not comparable to acute care hospitals.
5. **Admissions for rehabilitation**
   Rationale: These admissions are not typically to an acute care hospital and are not for acute care.
6. **Admissions for medical treatment of cancer**
   Rationale: These admissions have a different mortality and readmission profile than the rest of the Medicare population, and outcomes for these admissions do not correlate well with outcomes for other admissions. Patients with cancer admitted for other diagnoses or for surgical treatment of their cancer remain in the measure.

Figure A.1: HWR Flow Diagram of Inclusion and Exclusion Criteria and Specialty Cohort Assignment for the Index Admission
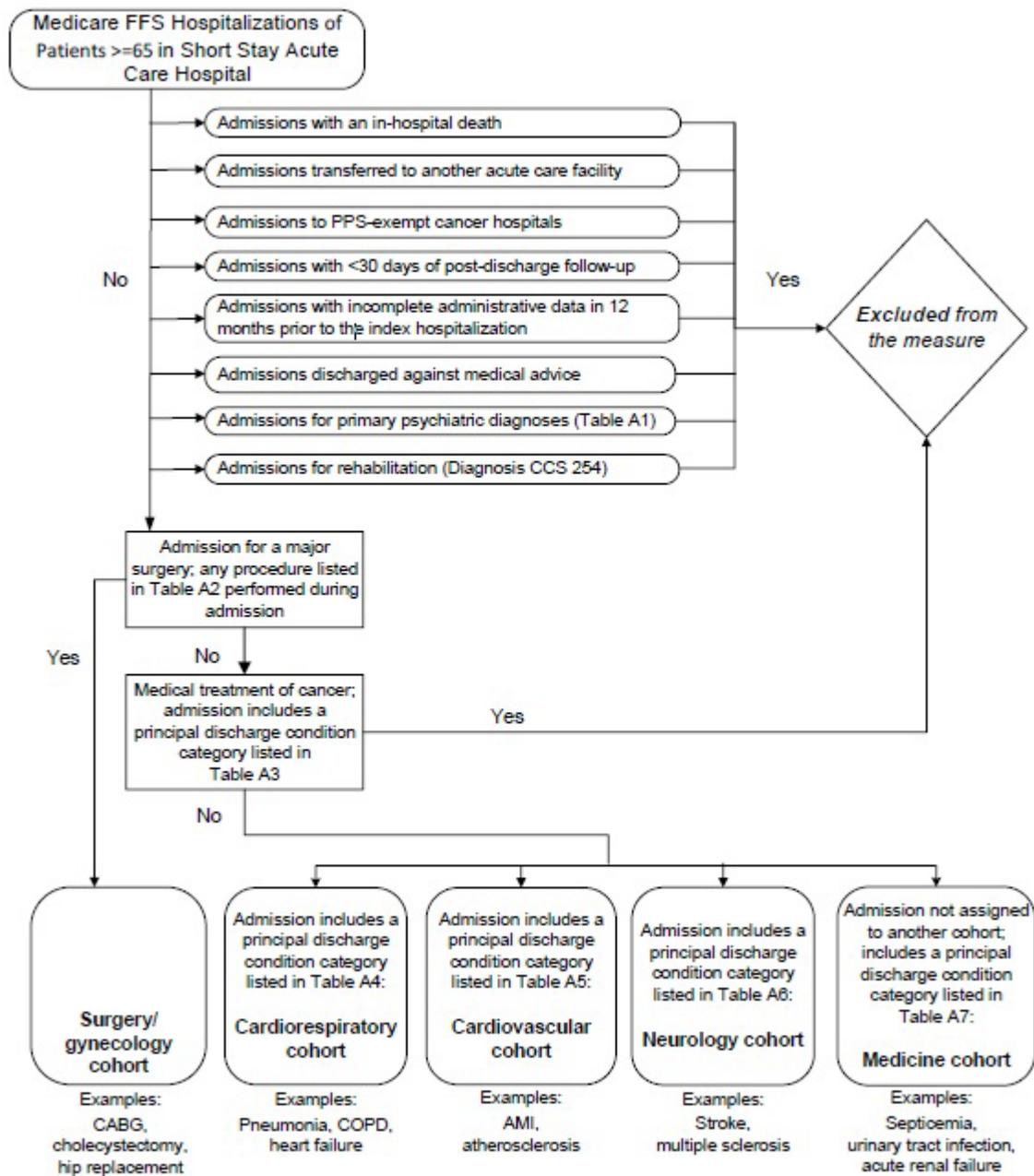
Table A.1: Psychiatric Discharge Diagnosis Categories Excluded from the Measure

AHRQ Procedure CCS	Description
657	Mood disorders
659	Schizophrenia and other psychotic disorders
651	Anxiety disorders
670	Miscellaneous disorders
654	Developmental disorders
650	Adjustment disorders
658	Personality disorders
652	Attention-deficit, conduct, and disruptive behavior disorders
656	Impulse control disorders, NEC
655	Disorders usually diagnosed in infancy, childhood, or adolescence
662	Suicide and intentional self-inflicted injury

Table A.2: Procedure Categories Defining the Surgery/Gynecology Cohort*

AHRQ Procedure CCS	Description
1	Incision and excision of CNS
2	Insertion; replacement; or removal of extracranial ventricular shunt
3	Laminectomy; excision intervertebral disc
9	Other OR therapeutic nervous system procedures
10	Thyroidectomy; partial or complete
12	Other therapeutic endocrine procedures
13	Corneal transplant
14	Glaucoma procedures
15	Lens and cataract procedures
16	Repair of retinal tear; detachment
17	Destruction of lesion of retina and choroid
20	Other intraocular therapeutic procedures
21	Other extraocular muscle and orbit therapeutic procedures
22	Tympanoplasty
23	Myringotomy
24	Mastoidectomy
26	Other therapeutic ear procedures
28	Plastic procedures on nose
30	Tonsillectomy and/or adenoidectomy
33	Other OR therapeutic procedures on nose; mouth and pharynx
36	Lobectomy or pneumonectomy
42	Other OR Rx procedures on respiratory system and mediastinum
43	Heart valve procedures
44	Coronary artery bypass graft (CABG)
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

AHRQ Procedure CCS	Description
59	Other OR procedures on vessels of head and neck
60	Embolectomy and endarterectomy of lower limbs
66	Procedures on spleen
67	Other therapeutic procedures; hemic and lymphatic system
72	Colostomy; temporary and permanent
73	Ileostomy and other enterostomy
74	Gastrectomy; partial and total
75	Small bowel resection
78	Colorectal resection
79	Local excision of large intestine lesion (not endoscopic)
80	Appendectomy
84	Cholecystectomy and common duct exploration
85	Inguinal and femoral hernia repair
86	Other hernia repair
89	Exploratory laparotomy
90	Excision; lysis peritoneal adhesions
94	Other OR upper GI therapeutic procedures
96	Other OR lower GI therapeutic procedures
99	Other OR gastrointestinal therapeutic procedures
101	Transurethral excision; drainage; or removal urinary obstruction
103	Nephrotomy and nephrostomy
104	Nephrectomy; partial or complete
105	Kidney transplant
106	Genitourinary incontinence procedures
112	Other OR therapeutic procedures of urinary tract
113	Transurethral resection of prostate (TURP)
114	Open prostatectomy
118	Other OR therapeutic procedures; male genital
119	Oophorectomy; unilateral and bilateral
120	Other operations on ovary
121	Ligation or occlusion of fallopian tubes
122	Removal of ectopic pregnancy
123	Other operations on fallopian tubes
124	Hysterectomy; abdominal and vaginal
125	Other excision of cervix and uterus
126	Abortion (termination of pregnancy)
127	Dilatation and curettage (D&C); aspiration after delivery or abortion
129	Repair of cystocele and rectocele; obliteration of vaginal vault
131	Other non-OR therapeutic procedures; female organs
132	Other OR therapeutic procedures; female organs
133	Episiotomy
134	Cesarean section
135	Forceps; vacuum; and breech delivery
136	Artificial rupture of membranes to assist delivery
137	Other procedures to assist delivery
139	Fetal monitoring
140	Repair of current obstetric laceration
141	Other therapeutic obstetrical procedures

AHRQ Procedure CCS	Description
142	Partial excision bone
143	Bunionectomy or repair of toe deformities
144	Treatment; facial fracture or dislocation
145	Treatment; fracture or dislocation of radius and ulna
146	Treatment; fracture or dislocation of hip and femur
147	Treatment; fracture or dislocation of lower extremity (other than hip or femur)
148	Other fracture and dislocation procedure
150	Division of joint capsule; ligament or cartilage
151	Excision of semilunar cartilage of knee
152	Arthroplasty knee
153	Hip replacement; total and partial
154	Arthroplasty other than hip or knee
157	Amputation of lower extremity
158	Spinal fusion
160	Other therapeutic procedures on muscles and tendons
161	Other OR therapeutic procedures on bone
162	Other OR therapeutic procedures on joints
164	Other OR therapeutic procedures on musculoskeletal system
166	Lumpectomy; quadrantectomy of breast
167	Mastectomy
172	Skin graft
175	Other OR therapeutic procedures on skin and breast
176	Other organ transplantation

* Not mutually exclusive; multiple procedures may be performed during a single admission.

Table A.3: Cancer Discharge Diagnosis Categories Excluded from the Measure

AHRQ Diagnosis CCS	Description
11	Cancer of head and neck
12	Cancer of esophagus
13	Cancer of stomach
14	Cancer of colon
15	Cancer of rectum and anus
16	Cancer of liver and intrahepatic bile duct
17	Cancer of pancreas
18	Cancer of other GI organs; peritoneum
19	Cancer of bronchus; lung
20	Cancer; other respiratory and intrathoracic
21	Cancer of bone and connective tissue
22	Melanomas of skin
23	Other non-epithelial cancer of skin
24	Cancer of breast
25	Cancer of uterus
26	Cancer of cervix
27	Cancer of ovary
28	Cancer of other female genital organs
29	Cancer of prostate

AHRQ Diagnosis CCS	Description
30	Cancer of testis
31	Cancer of other male genital organs
32	Cancer of bladder
33	Cancer of kidney and renal pelvis
34	Cancer of other urinary organs
35	Cancer of brain and nervous system
36	Cancer of thyroid
37	Hodgkin`s disease
38	Non-Hodgkin`s lymphoma
39	Leukemias
40	Multiple myeloma
41	Cancer; other and unspecified primary
42	Secondary malignancies
43	Malignant neoplasm without specification of site
44	Neoplasms of unspecified nature or uncertain behavior
45	Maintenance chemotherapy; radiotherapy

Table A.4: Diagnosis Categories Defining the Cardiorespiratory Cohort

AHRQ Diagnosis CCS	Description
56	Cystic Fibrosis
103	Pulmonary heart disease
108	Congestive heart failure; nonhypertensive
122	Pneumonia (except that caused by tuberculosis or sexually transmitted disease)
125	Acute bronchitis
127	Chronic obstructive pulmonary disease and bronchiectasis
128	Asthma
131	Respiratory failure; insufficiency; arrest (adult)

Table A.5: Diagnosis Categories Defining the Cardiovascular Cohort

AHRQ Diagnosis CCS	Description
96	Heart valve disorders
97	Peri-; endo-; and myocarditis; cardiomyopathy (except that caused by tuberculosis or sexually transmitted)
100	Acute myocardial infarction
101	Coronary atherosclerosis and other heart disease
102	Nonspecific chest pain
104	Other and ill-defined heart disease
105	Conduction disorders
106	Cardiac dysrhythmias
107	Cardiac arrest and ventricular fibrillation
114	Peripheral and visceral atherosclerosis
115	Aortic; peripheral; and visceral artery aneurysms
116	Aortic and peripheral arterial embolism or thrombosis
117	Other circulatory disease

AHRQ Diagnosis CCS	Description
213	Cardiac and circulatory congenital anomalies

Table A.6: Diagnosis Categories Defining the Neurology Cohort

AHRQ Diagnosis CCS	Description
78	Other CNS infection and poliomyelitis
79	Parkinson`s disease
80	Multiple sclerosis
81	Other hereditary and degenerative nervous system conditions
82	Paralysis
83	Epilepsy; convulsions
85	Coma; stupor; and brain damage
95	Other nervous system disorders
109	Acute cerebrovascular disease
110	Occlusion or stenosis of precerebral arteries
111	Other and ill-defined cerebrovascular disease
112	Transient cerebral ischemia
113	Late effects of cerebrovascular disease
216	Nervous system congenital anomalies
227	Spinal cord injury
233	Intracranial injury

Table A.7: Diagnosis Categories Defining the Medicine Cohort

AHRQ Diagnosis CCS	Description
1	Tuberculosis
2	Septicemia (except in labor)
3	Bacterial infection; unspecified site
4	Mycoses
5	HIV infection
6	Hepatitis
7	Viral infection
8	Other infections; including parasitic
9	Sexually transmitted infections (not HIV or hepatitis)
10	Immunizations and screening for infectious disease
46	Benign neoplasm of uterus
47	Other and unspecified benign neoplasm
48	Thyroid disorders
49	Diabetes mellitus without complication
50	Diabetes mellitus with complications
51	Other endocrine disorders
52	Nutritional deficiencies
53	Disorders of lipid metabolism
54	Gout and other crystal arthropathies
55	Fluid and electrolyte disorders
57	Immunity disorders
58	Other nutritional; endocrine; and metabolic disorders

AHRQ Diagnosis CCS	Description
59	Deficiency and other anemia
60	Acute posthemorrhagic anemia
61	Sickle cell anemia
62	Coagulation and hemorrhagic disorders
63	Diseases of white blood cells
64	Other hematologic conditions
76	Meningitis (except that caused by tuberculosis or sexually transmitted disease)
77	Encephalitis (except that caused by tuberculosis or sexually transmitted disease)
84	Headache; including migraine
86	Cataract
87	Retinal detachments; defects; vascular occlusion; and retinopathy
88	Glaucoma
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
94	Other ear and sense organ disorders
98	Essential hypertension
99	Hypertension with complications and secondary hypertension
118	Phlebitis; thrombophlebitis and thromboembolism
119	Varicose veins of lower extremity
120	Hemorrhoids
121	Other diseases of veins and lymphatics
123	Influenza
124	Acute and chronic tonsillitis
126	Other upper respiratory infections
129	Aspiration pneumonitis; food/vomitus
130	Pleurisy; pneumothorax; pulmonary collapse
132	Lung disease due to external agents
133	Other lower respiratory disease
134	Other upper respiratory disease
135	Intestinal infection
136	Disorders of teeth and jaw
137	Diseases of mouth; excluding dental
138	Esophageal disorders
139	Gastroduodenal ulcer (except hemorrhage)
140	Gastritis and duodenitis
141	Other disorders of stomach and duodenum
142	Appendicitis and other appendiceal conditions
143	Abdominal hernia
144	Regional enteritis and ulcerative colitis
145	Intestinal obstruction without hernia
146	Diverticulosis and diverticulitis
147	Anal and rectal conditions
148	Peritonitis and intestinal abscess

AHRQ Diagnosis CCS	Description
149	Biliary tract disease
151	Other liver diseases
152	Pancreatic disorders (not diabetes)
153	Gastrointestinal hemorrhage
154	Noninfectious gastroenteritis
155	Other gastrointestinal disorders
156	Nephritis; nephrosis; renal sclerosis
157	Acute and unspecified renal failure
158	Chronic renal failure
159	Urinary tract infections
160	Calculus of urinary tract
161	Other diseases of kidney and ureters
162	Other diseases of bladder and urethra
163	Genitourinary symptoms and ill-defined conditions
164	Hyperplasia of prostate
165	Inflammatory conditions of male genital organs
166	Other male genital disorders
167	Nonmalignant breast conditions
168	Inflammatory diseases of female pelvic organs
169	Endometriosis
170	Prolapse of female genital organs
171	Menstrual disorders
172	Ovarian cyst
173	Menopausal disorders
174	Female infertility
175	Other female genital disorders
197	Skin and subcutaneous tissue infections
198	Other inflammatory condition of skin
199	Chronic ulcer of skin
200	Other skin disorders
201	Infective arthritis and osteomyelitis (except that caused by tuberculosis or sexually transmitted disease)
202	Rheumatoid arthritis and related disease
203	Osteoarthritis
204	Other non-traumatic joint disorders
205	Spondylosis; intervertebral disc disorders; other back problems
206	Osteoporosis
207	Pathological fracture
208	Acquired foot deformities
209	Other acquired deformities
210	Systemic lupus erythematosus and connective tissue disorders
211	Other connective tissue disease
212	Other bone disease and musculoskeletal deformities
214	Digestive congenital anomalies
215	Genitourinary congenital anomalies
217	Other congenital anomalies
225	Joint disorders and dislocations; trauma-related

AHRQ Diagnosis CCS	Description
226	Fracture of neck of femur (hip)
228	Skull and face fractures
229	Fracture of upper limb
230	Fracture of lower limb
231	Other fractures
232	Sprains and strains
234	Crushing injury or internal injury
235	Open wounds of head; neck; and trunk
236	Open wounds of extremities
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
243	Poisoning by nonmedicinal substances
244	Other injuries and conditions due to external causes
245	Syncope
246	Fever of unknown origin
247	Lymphadenitis
248	Gangrene
249	Shock
250	Nausea and vomiting
251	Abdominal pain
252	Malaise and fatigue
253	Allergic reactions
255	Administrative/social admission
256	Medical examination/evaluation
257	Other aftercare
258	Other screening for suspected conditions (not mental disorders or infectious disease)
259	Residual codes; unclassified
653	Delirium, dementia, and amnestic and other cognitive disorders
660	Alcohol-related disorders
661	Substance-related disorders
663	Screening and history of mental health and substance abuse codes

Risk Adjustment

Table A.8: Comorbidity Indicators Common to All Specialty Cohorts

Variable	Description
n/a	Mean age, years
CC 7	Metastatic cancer/acute leukemia
CC 8, 9	Severe Cancer
CC 10-12	Other cancers
CC 44	Severe hematological disorders
CC 46	Coagulation defects and other specified hematological disorders
CC 47	Iron deficiency or other unspecified anemias and blood disease
CC 25, 26	End-stage liver disease
CC 32	Pancreatic disease
CC 130	Dialysis status
CC 131	Acute renal failure
CC 128, 174	Transplants
CC 1, 3-5	Severe Infection
CC 6, 111-113	Other infectious diseases and pneumonias
CC 2	Septicemia/Shock
CC 80	CHF
CC 81-84, 89, 98, 99, 103-106	Coronary atherosclerosis or angina, cerebrovascular disease
CC 92, 93	Specified arrhythmias
CC 79	Cardio-respiratory failure or cardio-respiratory shock
CC 108	COPD
CC 109	Fibrosis of lung or other chronic lung disorders
CC 21	Protein-calorie malnutrition
CC 22, 23	Disorders of fluid, electrolyte, acid-base
CC 38	Rheumatoid arthritis and inflammatory connective tissue disease
CC 15-20, 119, 120	Diabetes mellitus
CC 148, 149	Decubitus ulcer or chronic skin ulcer
CC 67-69, 100-102, 177, 178	Hemiplegia, paraplegia, paralysis, functional disability
CC 74	Seizure disorders and convulsions
CC 77	Respirator dependence/tracheostomy status
CC 51, 52	Drug and Alcohol disorders
CC 54-56, 58, 60	Psychiatric comorbidity
CC 158	Hip fracture/dislocation

Table A.9: Principal Discharge Diagnosis Indicators for Surgery/Gynecology Specialty Cohort

Variable	Description
CCS 1	Tuberculosis
CCS 2	Septicemia (except in labor)
CCS 3	Bacterial infection; unspecified site
CCS 4	Mycoses
CCS 5	HIV infection
CCS 6	Hepatitis
CCS 7	Viral infection
CCS 8	Other infections; including parasitic
CCS 9	Sexually transmitted infections (not HIV or hepatitis)
CCS 10	Immunizations and screening for infectious disease

Variable	Description
CCS 11	Cancer of head and neck
CCS 12	Cancer of esophagus
CCS 13	Cancer of stomach
CCS 14	Cancer of colon
CCS 15	Cancer of rectum and anus
CCS 16	Cancer of liver and intrahepatic bile duct
CCS 17	Cancer of pancreas
CCS 18	Cancer of other GI organs; peritoneum
CCS 19	Cancer of bronchus; lung
CCS 20	Cancer; other respiratory and intrathoracic
CCS 21	Cancer of bone and connective tissue
CCS 22	Melanomas of skin
CCS 23	Other non-epithelial cancer of skin
CCS 24	Cancer of breast
CCS 25	Cancer of uterus
CCS 26	Cancer of cervix
CCS 27	Cancer of ovary
CCS 28	Cancer of other female genital organs
CCS 29	Cancer of prostate
CCS 30	Cancer of testis
CCS 31	Cancer of other male genital organs
CCS 32	Cancer of bladder
CCS 33	Cancer of kidney and renal pelvis
CCS 34	Cancer of other urinary organs
CCS 35	Cancer of brain and nervous system
CCS 36	Cancer of thyroid
CCS 37	Hodgkin's disease
CCS 38	Non-Hodgkin's lymphoma
CCS 39	Leukemias
CCS 40	Multiple myeloma
CCS 41	Cancer; other and unspecified primary
CCS 42	Secondary malignancies
CCS 43	Malignant neoplasm without specification of site
CCS 44	Neoplasms of unspecified nature or uncertain behavior
CCS 45	Maintenance chemotherapy; radiotherapy
CCS 46	Benign neoplasm of uterus
CCS 47	Other and unspecified benign neoplasm
CCS 48	Thyroid disorders
CCS 49	Diabetes mellitus without complications
CCS 50	Diabetes mellitus with complications
CCS 51	Other endocrine disorders
CCS 52	Nutritional deficiencies
CCS 53	Disorders of lipid metabolism
CCS 54	Gout and other crystal arthropathies
CCS 55	Fluid and electrolyte disorders
CCS 57	Immunity disorders
CCS 58	Other nutritional; endocrine; and metabolic disorders
CCS 59	Deficiency and other anemia

Variable	Description
CCS 60	Acute posthemorrhagic anemia
CCS 61	Sickle cell anemia
CCS 62	Coagulation and hemorrhagic disorders
CCS 63	Diseases of white blood cells
CCS 64	Other hematologic conditions
CCS 76	Meningitis (except that caused by tuberculosis or sexually transmitted disease)
CCS 77	Encephalitis (except that caused by tuberculosis or sexually transmitted disease)
CCS 78	Other CNS infection and poliomyelitis
CCS 79	Parkinson's disease
CCS 80	Multiple sclerosis
CCS 81	Other hereditary and degenerative nervous system conditions
CCS 82	Paralysis
CCS 83	Epilepsy; convulsions
CCS 84	Headache; including migraine
CCS 85	Coma; stupor; and brain damage
CCS 86	Cataract
CCS 87	Retinal detachments; defects; vascular occlusion; and retinopathy
CCS 88	Glaucoma
CCS 89	Blindness and vision defects
CCS 90	Inflammation; infection of eye (except that caused by tuberculosis or sexually transmitted disease)
CCS 91	Other eye disorders
CCS 92	Otitis media and related conditions
CCS 93	Conditions associated with dizziness or vertigo
CCS 94	Other ear and sense organ disorders
CCS 95	Other nervous system disorders
CCS 96	Heart valve disorders
CCS 97	Peri-; endo-; and myocarditis; cardiomyopathy (except that caused by tuberculosis or sexually transmitted disease)
CCS 98	Essential hypertension
CCS 99	Hypertension with complications and secondary hypertension
CCS 100	Acute myocardial infarction
CCS 101	Coronary atherosclerosis and other heart disease
CCS 102	Nonspecific chest pain
CCS 103	Pulmonary heart disease
CCS 104	Other and ill-defined heart disease
CCS 105	Conduction disorders
CCS 106	Cardiac dysrhythmias
CCS 107	Cardiac arrest and ventricular fibrillation
CCS 108	Congestive heart failure; non-hypertensive
CCS 109	Acute cerebrovascular disease
CCS 110	Occlusion or stenosis of precerebral arteries
CCS 111	Other and ill-defined cerebrovascular disease
CCS 112	Transient cerebral ischemia
CCS 113	Late effects of cerebrovascular disease
CCS 114	Peripheral and visceral atherosclerosis
CCS 115	Aortic; peripheral; and visceral artery aneurysms
CCS 116	Aortic and peripheral arterial embolism or thrombosis

Variable	Description
CCS 117	Other circulatory disease
CCS 118	Phlebitis; thrombophlebitis and thromboembolism
CCS 119	Varicose veins of lower extremity
CCS 120	Hemorrhoids
CCS 121	Other diseases of veins and lymphatics
CCS 122	Pneumonia (except that caused by tuberculosis or sexually transmitted disease)
CCS 123	Influenza
CCS 124	Acute and chronic tonsillitis
CCS 125	Acute bronchitis
CCS 126	Other upper respiratory infections
CCS 127	Chronic obstructive pulmonary disease and bronchiectasis
CCS 128	Asthma
CCS 129	Aspiration pneumonitis; food/vomitus
CCS 130	Pleurisy; pneumothorax; pulmonary collapse
CCS 131	Respiratory failure; insufficiency; arrest (adult)
CCS 132	Lung disease due to external agents
CCS 133	Other lower respiratory disease
CCS 134	Other upper respiratory disease
CCS 135	Intestinal infection
CCS 136	Disorders of teeth and jaw
CCS 137	Diseases of mouth; excluding dental
CCS 138	Esophageal disorders
CCS 139	Gastroduodenal ulcer (except hemorrhage)
CCS 140	Gastritis and duodenitis
CCS 141	Other disorders of stomach and duodenum
CCS 142	Appendicitis and other appendiceal conditions
CCS 143	Abdominal hernia
CCS 144	Regional enteritis and ulcerative colitis
CCS 145	Intestinal obstruction without hernia
CCS 146	Diverticulosis and diverticulitis
CCS 147	Anal and rectal conditions
CCS 148	Peritonitis and intestinal abscess
CCS 149	Biliary tract disease
CCS 151	Other liver diseases
CCS 152	Pancreatic disorders (not diabetes)
CCS 153	Gastrointestinal hemorrhage
CCS 154	Noninfectious gastroenteritis
CCS 155	Other gastrointestinal disorders
CCS 156	Nephritis; nephrosis; renal sclerosis
CCS 157	Acute and unspecified renal failure
CCS 158	Chronis kidney disease
CCS 159	Urinary tract infections
CCS 160	Calculus of urinary tract
CCS 161	Other diseases of kidney and ureters
CCS 162	Other diseases or bladder and urethra
CCS 163	Genitourinary symptoms and ill-defined conditions
CCS 164	Hyperplasia of prostate
CCS 165	Inflammatory conditions of male genital organs

Variable	Description
CCS 166	Other male genital disorders
CCS 167	Nonmalignant breast conditions
CCS 168	Inflammatory diseases of female pelvic organs
CCS 169	Endometriosis
CCS 170	Prolapse of female genital organs
CCS 171	Menstrual disorders
CCS 172	Ovarian cyst
CCS 173	Menopausal disorders
CCS 175	Other female genital disorders
CCS 197	Skin and subcutaneous tissue infections
CCS 198	Other inflammatory condition of skin
CCS 199	Chronic ulcer of skin
CCS 200	Other skin disorders
CCS 201	Infective arthritis and osteomyelitis (except that caused by tuberculosis or sexually transmitted disease)
CCS 202	Rheumatoid arthritis and related disease
CCS 203	Osteoarthritis
CCS 204	Other non-traumatic joint disorders
CCS 205	Spondylosis; intervertebral disc disorders; other back problems
CCS 206	Osteoporosis
CCS 207	Pathological fracture
CCS 208	Acquired foot deformities
CCS 209	Other acquired deformities
CCS 210	Systemic lupus erythematosus and connective tissue disorders
CCS 211	Other connective tissue disease
CCS 212	Other bone disease and musculoskeletal deformities
CCS 213	Cardiac and circulatory congenital anomalies
CCS 214	Digestive congenital anomalies
CCS 215	Genitourinary congenital anomalies
CCS 216	Nervous system congenital anomalies
CCS 217	Other congenital anomalies
CCS 225	Joint disorders and dislocations; trauma-related
CCS 226	Fracture of neck or femur (hip)
CCS 227	Spinal cord injury
CCS 228	Skull and face fractures
CCS 229	Fracture of upper limb
CCS 231	Other fractures
CCS 234	Crushing injury or internal injury
CCS 236	Open wounds of extremities
CCS 237	Complication of device; implant or graft
CCS 230	Fracture of lower limb
CCS 232	Sprains and strains
CCS 233	Intracranial injury (CCS 233)
CCS 235	Open wounds of head; neck; and trunk
CCS 238	Complications of surgical procedures or medical care
CCS 239	Superficial injury; contusion
CCS 240	Burns
CCS 241	Poisoning by psychotropic agents

Variable	Description
CCS 242	Poisoning by other medications and drugs
CCS 243	Poisoning by nonmedical substances
CCS 244	Other injuries and conditions due to external causes
CCS 248	Gangrene
CCS 249	Shock
CCS 250	Nausea and vomiting
CCS 251	Abdominal pain
CCS 252	Malaise and fatigue
CCS 253	Allergic reactions
CCS 256	Medical examination/evaluation
CCS 257	Other aftercare
CCS 258	Other screening for suspected conditions (not mental disorders or infectious disease)
CCS 259	Residual codes; unclassified
CCS 653	Delirium, dementia, and amnestic and other cognitive disorders
CCS 660	Alcohol-related disorders
CCS 661	Substance-related disorders
CCS 663	Screening and history of mental health and substance abuse codes

Table A.10: Complications of Care Variables Not Used in Risk Adjustment If Occurring Only During the Index Admission

Variable	Description
CC 2	Septicemia/Shock
CC 6	Other Infectious Diseases
CC 17	Diabetes with Acute Complications
CC 23	Disorders of Fluid/Electrolyte/Acid-Base
CC 28	Acute Liver Failure/Disease
CC 31	Intestinal Obstruction/Perforation
CC 34	Peptic Ulcer, Hemorrhage, Other Specified Gastrointestinal Disorders
CC 46	Coagulation Defects and Other Specified Hematological Disorders
CC 48	Delirium and Encephalopathy
CC 75	Coma, Brain Compression/Anoxic Damage
CC 77	Respirator Dependence/Tracheostomy Status
CC 78	Respiratory Arrest
CC 79	Cardio-Respiratory Failure and Shock
CC 80	Congestive Heart Failure
CC 81	Acute Myocardial Infarction
CC 82	Unstable Angina and Other Acute Ischemic Heart Disease
CC 92	Specified Heart 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

Variable	Description
CC 111	Aspiration and Specified Bacterial Pneumonias
CC 112	Pneumococcal Pneumonia, Emphysema, Lung Abscess
CC 114	Pleural Effusion/Pneumothorax
CC 129	End Stage Renal Disease
CC 130	Dialysis Status
CC 131	Renal Failure
CC 132	Nephritis
CC 133	Urinary Obstruction and Retention
CC 135	Urinary Tract Infection
CC 148	Decubitus Ulcer of Skin
CC 152	Cellulitis, Local Skin Infection
CC 154	Severe Head Injury
CC 155	Major Head Injury
CC 156	Concussion or Unspecified Head Injury
CC 158	Hip Fracture/Dislocation
CC 159	Major Fracture, Except of Skull, Vertebrae, or Hip
CC 163	Poisonings and Allergic Reactions
CC 164	Major Complications of Medical Care and Trauma
CC 165	Other Complications of Medical Care
CC 174	Major Organ Transplant Status
CC 175	Other Organ Transplant/Replacement
CC 176	Artificial Openings for Feeding or Elimination
CC 177	Amputation Status, Lower Limb/Amputation
CC 178	Amputation Status, Upper Limb
CC 179	Post-Surgical States/Aftercare/Elective

Outcome

1. **30-day timeframe**

   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 readmissions.

2. **All-cause readmission**

   Rationale: From a patient perspective, an unplanned readmission from any cause is an adverse event.

3. **Unplanned readmission**

   Rationale: Planned readmissions are generally not a signal of quality of care. Including planned readmissions in a readmission measure could create a disincentive to provide appropriate care to patients who are scheduled for elective or necessary procedures within 30 days of discharge.

Figure PR.1: Planned Readmission Algorithm Version 3.0 Flowchart
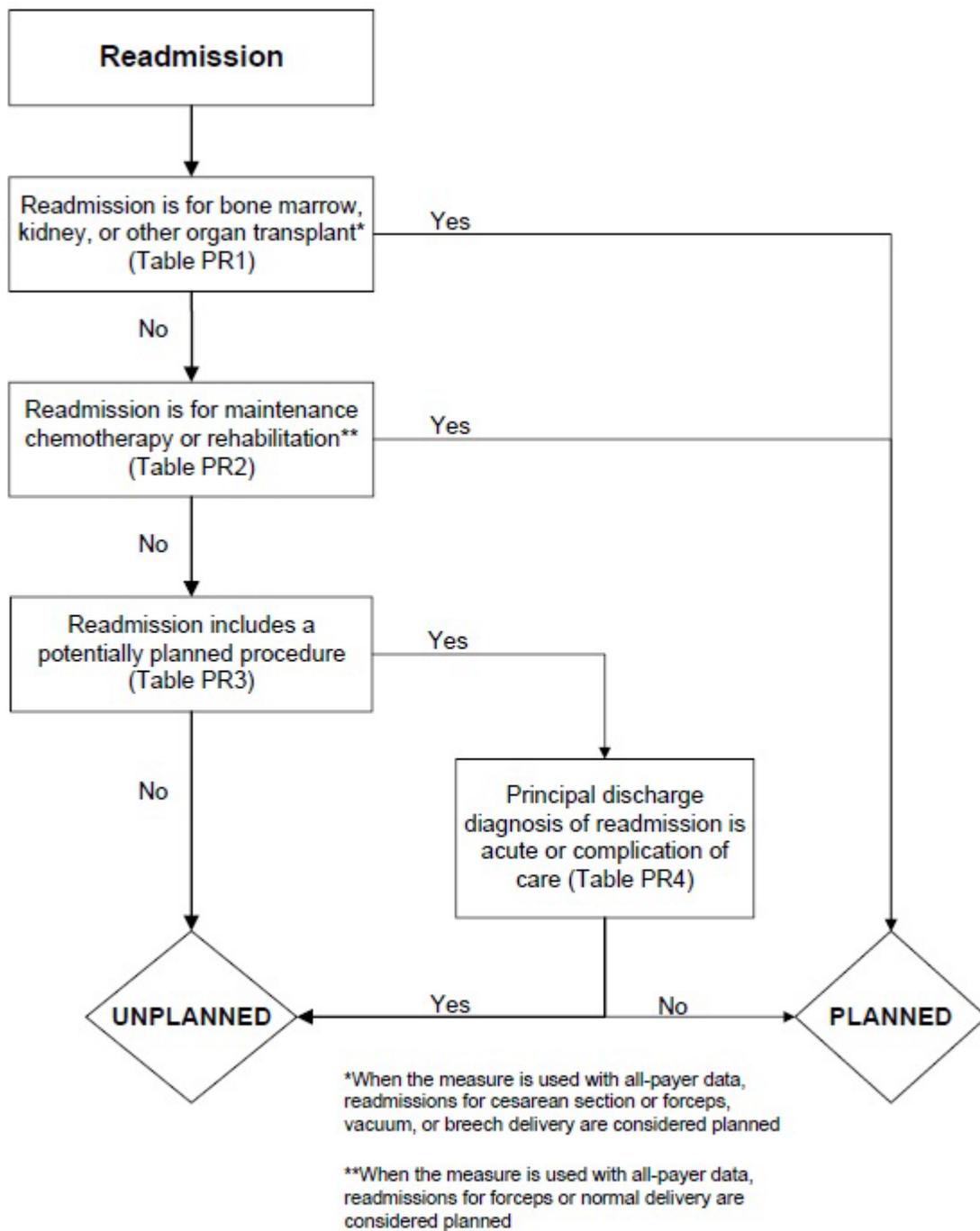
Planned Readmission Algorithm Version 3.0 Tables – Hybrid eHWR Measure

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*
135	Forceps; vacuum; and breech delivery*
176	Other organ transplantation

*CCS to be included only in all-payer settings, not intended for inclusion in CMS' claims-based readmission measures for Medicare fee-for-service beneficiaries aged 65+ years.

Table PR.2: Diagnosis Categories that are Always Planned (Version 3.0)

Diagnosis CCS	Description
45	Maintenance chemotherapy
194	Forceps delivery*
196	Normal pregnancy and/or delivery*
254	Rehabilitation

*CCS to be included only in all-payer settings, not intended for inclusion in CMS' claims-based readmission measures for Medicare fee-for-service beneficiaries aged 65+ years

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)

Procedure CCS	Description
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
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
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 Proc CCS 42- Other OR Rx procedures on respiratory system and mediastinum)
38.18	Endarterectomy leg vessel (from Proc CCS 60- Embolectomy and endarterectomy of lower limbs)
55.03, 55.04	Percutaneous nephrostomy with and without fragmentation (from Proc CCS 103- Nephrotomy and nephrostomy)
94.26, 94.27	Electroshock therapy (from Proc 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
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

Diagnosis CCS	Description
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
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

Diagnosis CCS	Description
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 Dx CCS 97: Peri-; endo-; and myocarditis; cardiomyopathy	
032.82	Diphtheritic myocarditis
036.40	Meningococcal carditis nos
036.41	Meningococcal pericarditis
036.42	Meningococcal endocarditis
036.43	Meningococcal myocarditis
074.20	Coxsackie carditis nos
074.21	Coxsackie pericarditis
074.22	Coxsackie endocarditis
074.23	Coxsackie myocarditis
112.81	Candidal endocarditis
115.03	Histoplasma capsulatum pericarditis
115.04	Histoplasma capsulatum endocarditis
115.13	Histoplasma duboisii pericarditis
115.14	Histoplasma duboisii endocarditis
115.93	Histoplasmosis pericarditis
115.94	Histoplasmosis endocarditis
130.3	Toxoplasma myocarditis
391.0	Acute rheumatic pericarditis
391.1	Acute rheumatic endocarditis
391.2	Acute rheumatic myocarditis
391.8	Acute rheumatic heart disease nec
391.9	Acute rheumatic heart disease nos
392.0	Rheumatic chorea w heart involvement
398.0	Rheumatic myocarditis
398.90	Rheumatic heart disease nos
398.99	Rheumatic heart disease nec
420.0	Acute pericarditis in other disease
420.90	Acute pericarditis nos
420.91	Acute idiopath pericarditis
420.99	Acute pericarditis nec
421.0	Acute/subacute bacterial endocarditis
421.1	Acute endocarditis in other diseases
421.9	Acute/subacute endocarditis nos
422.0	Acute myocarditis in other diseases
422.90	Acute myocarditis nos
422.91	Idiopathic myocarditis
422.92	Septic myocarditis
422.93	Toxic myocarditis
422.99	Acute myocarditis nec
423.0	Hemopericardium
423.1	Adhesive pericarditis
423.2	Constrictive pericarditis
423.3	Cardiac tamponade
429.0	Myocarditis nos
Acute ICD-9 codes within Dx CCS 105: Conduction disorders	

Diagnosis CCS	Description
426.0	Atrioventricular
426.10	Atrioventricular block nos
426.11	Atrioventricular block-1st degree
426.12	Atrioventricular block-mobitz ii
426.13	Atrioventricular block-2nd degree nec
426.2	Left bundle branch hemiblock
426.3	Left bundle branch block nec
426.4	Right bundle branch block
426.50	Bundle branch block nos
426.51	Right bundle branch block/left posterior fascicular block
426.52	Right bundle branch block/left ant fascicular block
426.53	Bilateral bundle branch block nec
426.54	Trifascicular block
426.6	Other heart block
426.7	Anomalous atrioventricular excitation
426.81	Lown-ganong-levine syndrome
426.82	Long qt syndrome
426.9	Conduction disorder nos
Acute ICD-9 codes within Dx CCS 106: Dysrhythmia	
427.2	Paroxysmal tachycardia nos
785.0	Tachycardia nos
427.89	Cardiac dysrhythmias nec
427.9	Cardiac dysrhythmia nos
427.69	Premature beats nec
Acute ICD-9 codes within Dx CCS 108: Congestive heart failure; nonhypertensive	
398.91	Rheumatic heart failure
428.0	Congestive heart failure
428.1	Left heart failure
428.20	Unspecified systolic heart failure
428.21	Acute systolic heart failure
428.23	Acute on chronic systolic heart failure
428.30	Unspecified diastolic heart failure
428.31	Acute diastolic heart failure
428.33	Acute on chronic diastolic heart failure
428.40	Unspec combined syst & dias heart failure
428.41	Acute combined systolic & diastolic heart failure
428.43	Acute on chronic combined systolic & diastolic heart failure
428.9	Heart failure nos
Acute ICD-9 codes within Dx CCS 149: Biliary tract disease	
574.0	Calculus of gallbladder with acute cholecystitis
574.00	Calculus of gallbladder with acute cholecystitis without mention of obstruction
574.01	Calculus of gallbladder with acute cholecystitis with obstruction
574.3	Calculus of bile duct with acute cholecystitis
574.30	Calculus of bile duct with acute cholecystitis without mention of obstruction
574.31	Calculus of bile duct with acute cholecystitis with obstruction
574.6	Calculus of gallbladder and bile duct with acute cholecystitis
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
574.8	Calculus of gallbladder and bile duct with acute and chronic cholecystitis

Diagnosis CCS	Description
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 Dx CCS 152: Pancreatic disorders	
577.0	Acute pancreatitis

APPENDIX B: ADDITIONAL MODEL TESTING RESULTS

Table B.1: Surgery/Gynecology Specialty Cohort Hierarchical Logistic Regression Model Risk Factor Frequencies, Estimates, and Odds Ratios by Sample

Surgery/Gynecology Readmission Rates	Hybrid eHWR Development Sample (N=23,201)				Hybrid eHWR Validation Sample (N=23,490)			
Name	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred
Intercept	-2.573	3.650	---	---	0.168	3.333	---	---
CCDE								
Age	0.029	0.004	1.03(1.02-1.04)	---	0.027	0.003	1.03(1.02-1.03)	---
Systolic Blood Pressure	0.000	0.001	1.00(1.00-1.00)	---	0.001	0.001	1.00(1.00-1.00)	---
Heart Rate	0.006	0.002	1.01(1.00-1.01)	---	0.006	0.002	1.01(1.00-1.01)	---
Respiratory Rate	0.033	0.010	1.03(1.01-1.05)	---	0.029	0.010	1.03(1.01-1.05)	---
Temperature	-0.014	0.037	0.99(0.92-1.06)	---	-0.041	0.034	0.96(0.90-1.03)	---
Weight	0.000	0.001	1.00(1.00-1.00)	---	0.000	0.001	1.00(1.00-1.00)	---
Systolic Blood Pressure Square	0.000	0.000	1.00(1.00-1.00)	---	0.000	0.000	1.00(1.00-1.00)	---
Heart Rate Square	0.000	0.000	1.00(1.00-1.00)	---	0.000	0.000	1.00(1.00-1.00)	---
Temperature Square	-0.069	0.027	0.93(0.89-0.98)	---	0.013	0.023	1.01(0.97-1.06)	---
Temperature Unknown	0.083	0.100	1.09(0.89-1.32)	---	-0.175	0.101	0.84(0.69-1.02)	---
Weight Unknown	-0.025	0.100	0.98(0.80-1.19)	---	0.289	0.090	1.34(1.12-1.59)	---
Condition								
Low frequency conditions	-2.034	0.092	0.13(0.11-0.16)	57.2%	-1.983	0.086	0.14(0.12-0.16)	57.2%
Bunionectomy or repair of toe deformities (CCS 143)	-3.931	0.348	0.02(0.01-0.04)	2.6%	-3.290	0.261	0.04(0.02-0.06)	2.5%
Arthroscopy (CCS 149)	-2.698	0.201	0.07(0.05-0.10)	2.7%	-2.886	0.206	0.06(0.04-0.08)	2.8%
Insertion; replacement; or removal of extracranial ventricular shunt (CCS 2)	-0.968	0.113	0.38(0.30-0.47)	4.4%	-0.989	0.109	0.37(0.30-0.46)	4.2%
Electrographic cardiac monitoring (CCS 203)	-5.075	0.259	0.01(0.00-0.01)	17.2%	-4.752	0.222	0.01(0.01-0.01)	17.1%
Arterial blood gases (CCS 205)	-3.846	0.306	0.02(0.01-0.04)	3.5%	-3.660	0.283	0.03(0.01-0.04)	3.5%
Other diagnostic radiology and related techniques (CCS 226)	-4.092	0.220	0.02(0.01-0.03)	5.7%	-4.235	0.229	0.01(0.01-0.02)	5.6%
Complication of device; implant or graft (CCS 237)	-1.631	0.125	0.20 (0.15-0.25)	4.3%	-1.458	0.118	0.23(0.18-0.29)	4.4%
Complications of surgical procedures or medical care (CCS 238)	Reference	Reference	Reference	2.5%	Reference	Reference	Reference	2.8%
Comorbidity								

Surgery/Gynecology Readmission Rates	Hybrid eHWR Development Sample (N=23,201)				Hybrid eHWR Validation Sample (N=23,490)			
Name	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred
Metastatic cancer/acute leukemia (CC 7)	0.028	0.103	0.97 (0.79-1.18)	5.5%	0.100	0.095	1.11(0.92-1.33)	5.7%
Severe Cancer (CC 8, 9)	0.164	0.088	1.26 (1.06-1.50)	6.3%	0.230	0.085	1.26(1.07-1.49)	6.5%
Other major cancers (CC 10- 12)	-0.139	0.064	0.94 (0.83-1.06)	17.6%	-0.079	0.061	0.92(0.82-1.04)	17.9%
Other hematological disorders (CC 44)	-0.114	0.216	0.87 (0.56-1.35)	0.8%	0.370	0.196	1.45(0.99-2.13)	0.7%
Coagulation defects and other specified hematological disorders (CC 46)	0.177	0.117	1.31 (1.04-1.65)	2.8%	0.100	0.121	1.11(0.87-1.40)	2.5%
Iron deficiency (CC 47)	0.338	0.054	1.48 (1.33-1.64)	40.5%	0.380	0.051	1.46(1.32-1.62)	41.1%
End-stage liver disease (CC 25, 26)	0.258	0.181	1.06 (0.72-1.55)	1.2%	0.414	0.176	1.51(1.07-2.14)	1.1%
Pancreatic disease (CC 32)	0.142	0.119	1.09 (0.86-1.37)	3.0%	0.122	0.116	1.13(0.90-1.42)	2.9%
Dialysis status (CC 130)	0.182	0.177	1.55 (1.11-2.17)	1.0%	0.617	0.165	1.85(1.34-2.56)	1.0%
Acute renal failure (CC 131)	-0.020	0.083	1.01 (0.85-1.19)	9.5%	-0.035	0.080	0.97(0.82-1.13)	9.7%
Transplants (CC 128, 174)	0.226	0.354	1.52 (0.81-2.87)	0.3%	0.813	0.334	2.25(1.17-4.34)	0.2%
Severe Infection (CC 1, 3-5)	0.166	0.196	1.27 (0.88-1.82)	1.0%	0.143	0.180	1.15(0.81-1.64)	1.1%
Other infectious disease & pneumonias (CC 6, 111-	0.066	0.074	1.07 (0.92-1.24)	10.4%	0.174	0.072	1.19(1.03-1.37)	10.3%
Septicemia/shock (CC 2)	-0.205	0.116	0.87 (0.69-1.10)	3.2%	-0.099	0.112	0.91(0.73-1.13)	3.3%
CHF (CC 80)	0.294	0.091	1.16 (0.97-1.39)	6.4%	-0.055	0.092	0.95(0.79-1.13)	6.3%
Coronary atherosclerosis or angina, cerebrovascular disease (CC 81-84, 89, 98, 99, 103-106)	0.314	0.055	1.29 (1.16-1.44)	40.6%	0.285	0.053	1.33(1.20-1.48)	40.3%
Specified arrhythmias (CC 92, 93)	0.051	0.081	1.06 (0.90-1.24)	8.9%	0.120	0.079	1.13(0.97-1.32)	8.9%
Cardiorespiratory failure or cardiorespiratory shock (CC 79)	0.082	0.117	1.14 (0.90-1.43)	3.0%	0.202	0.112	1.22(0.98-1.52)	3.1%
Coronary obstructive pulmonary disease (COPD) (CC 108)	0.105	0.063	1.18 (1.05-1.34)	14.1%	0.228	0.060	1.26(1.12-1.41)	14.3%
Fibrosis of lung or other chronic lung disorders (CC 109)	0.179	0.143	1.04 (0.77-1.39)	1.9%	0.185	0.134	1.20(0.92-1.56)	2.1%
Protein-calorie malnutrition (CC 21)	0.276	0.088	1.08 (0.91-1.29)	5.0%	0.054	0.088	1.06(0.89-1.25)	5.1%
Disorders of fluid, electrolyte, acid-base (CC 22, 23)	0.141	0.072	1.15 (1.00-1.32)	12.4%	0.091	0.070	1.10(0.96-1.26)	12.5%

Surgery/Gynecology Readmission Rates	Hybrid eHWR Development Sample (N=23,201)				Hybrid eHWR Validation Sample (N=23,490)			
Name	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred
Rheumatoid arthritis and inflammatory connective tissue disease (CC 38)	0.154	0.101	1.13 (0.93-1.37)	4.9%	0.064	0.100	1.07(0.88-1.30)	4.9%
Diabetes mellitus (CC 15-20, 119, 120)	0.120	0.054	1.08 (0.97-1.20)	27.8%	0.154	0.053	1.17(1.05-1.30)	26.6%
Ulcers (CC 148, 149)	0.018	0.097	1.03 (0.85-1.25)	4.2%	-0.139	0.097	0.87(0.72-1.05)	4.5%
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177, 178)	-0.071	0.105	0.82 (0.67-1.02)	3.9%	-0.059	0.104	0.94(0.77-1.16)	3.9%
Seizure disorders and convulsions (CC 74)	0.194	0.145	1.13 (0.85-1.51)	1.9%	0.364	0.136	1.44(1.10-1.88)	1.9%
Respirator dependence/tracheostomy status (CC 77)	-0.219	0.463	3.60 (1.33-9.75)	0.1%	0.735	0.487	2.09(0.80-5.42)	0.1%
Drug and alcohol disorders (CC 51, 52)	0.218	0.106	1.28 (1.03-1.57)	3.8%	0.033	0.108	1.03(0.84-1.28)	3.8%
Psychiatric comorbidity (CC 54- 56, 58, 60)	0.129	0.057	1.14 (1.02-1.27)	20.2%	0.106	0.056	1.11(1.00-1.24)	20.5%
Hip fracture/dislocation (CC 158)	0.072	0.170	0.81 (0.57-1.15)	1.3%	-0.459	0.168	0.63(0.45-0.88)	1.5%

Table B.2: Cardiorespiratory Specialty Cohort Hierarchical Logistic Regression Model Risk Factor Frequencies, Estimates, and Odds Ratios by Sample

Cardiorespiratory Readmission Rates	Hybrid eHWR Development Sample (N=9,261)				Hybrid eHWR Validation Sample (N=9,364)			
Name	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred
Intercept	5.746	3.301	---	---	11.238	3.129	---	---
CCDE								
Age	0.007	0.004	1.01 (1.00-1.01)	---	0.002	0.004	1.00(1.00-1.01)	---
Bicarbonate	0.010	0.006	1.01 (1.00-1.03)	---	0.017	0.006	1.02(1.01-1.03)	---
Creatinine	0.140	0.034	1.08 (1.01-1.15)	---	0.093	0.034	1.10(1.03-1.17)	---
Glucose	0.000	0.001	1.00 (1.00-1.00)	---	0.000	0.001	1.00(1.00-1.00)	---
Hematocrit	-0.015	0.006	0.98 (0.97-1.00)	---	-0.017	0.006	0.98(0.97-0.99)	---
Sodium	-0.016	0.006	0.98 (0.97-0.99)	---	-0.018	0.006	0.98(0.97-0.99)	---
Systolic Blood Pressure	-0.005	0.001	1.00 (0.99-1.00)	---	-0.005	0.001	0.99(0.99-1.00)	---
Heart Rate	-0.001	0.001	1.00 (1.00-1.00)	---	0.003	0.001	1.00(1.00-1.01)	---
Oxygen Saturation	0.010	0.005	1.01 (1.00-1.02)	---	0.004	0.005	1.00(0.99-1.01)	---
WBC Count	0.032	0.009	1.03 (1.01-1.04)	---	0.009	0.009	1.01(0.99-1.03)	---
Temperature	-0.061	0.032	0.92 (0.86-0.97)	---	-0.108	0.030	0.90(0.85-0.95)	---
Temperature Unknown	-0.040	0.125	1.03 (0.81-1.30)	---	0.102	0.115	1.11(0.88-1.39)	---
Heart Rate Square	0.000	0.000	1.00 (1.00-1.00)	---	0.000	0.000	1.00(1.00-1.00)	---
WBC Count Square	-0.001	0.001	1.00 (1.00-1.00)	---	0.001	0.001	1.00(1.00-1.00)	---
Temperature Square	0.020	0.012	1.03 (1.01-1.06)	---	0.034	0.011	1.03(1.01-1.06)	---
Condition								
Low frequency conditions	-1.274	0.404	0.28(0.13-0.62)	1.0%	-1.503	0.474	0.22(0.09-0.56)	0.9%
Pulmonary heart disease (CCS 103)	-0.695	0.145	0.50(0.38-0.66)	6.3%	-0.463	0.143	0.63(0.48-0.83)	6.1%
Congestive heart failure; nonhypertensive (CCS 108)	-0.333	0.087	0.72(0.60-0.85)	40.9%	-0.213	0.087	0.81(0.68-0.96)	41.4%
Pneumonia (except that caused by tuberculosis or sexually transmitted disease) (CCS 122)	-0.910	0.100	0.40(0.33-0.49)	21.8%	-0.679	0.099	0.51(0.42-0.62)	21.9%
Chronic obstructive pulmonary disease and bronchiectasis (CCS 127)	-0.594	0.114	0.55(0.44-0.69)	10.8%	-0.516	0.114	0.60(0.48-0.75)	10.5%
Asthma (128)	-0.798	0.142	0.45(0.34-0.59)	7.2%	-0.875	0.143	0.42(0.31-0.55)	7.3%
Respiratory failure; insufficiency; arrest (adult) (CCS 131)	Reference	Reference	Reference	12.0%	Reference	Reference	Reference	11.8%
Comorbidity								
Metastatic cancer/acute leukemia (CC 7)	0.212	0.151	1.24(0.92-1.66)	3.7%	-0.144	0.157	0.87(0.64-1.18)	3.7%
Severe Cancer (CC 8, 9)	0.301	0.120	1.35(1.07-1.71)	5.6%	0.358	0.115	1.43(1.14-1.79)	6.0%

Cardiorespiratory Readmission Rates	Hybrid eHWR Development Sample (N=9,261)				Hybrid eHWR Validation Sample (N=9,364)			
Name	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred
Other major cancers (CC 10- 12)	-0.009	0.093	0.99(0.83-1.19)	9.4%	0.122	0.093	1.13(0.94-1.36)	8.9%
Other hematological disorders (CC 44)	0.223	0.171	1.25(0.89-1.75)	2.2%	0.143	0.166	1.15(0.83-1.60)	2.3%
Coagulation defects and other specified hematological disorders (CC 46)	-0.018	0.100	0.98(0.81-1.20)	7.6%	-0.022	0.099	0.98(0.81-1.19)	7.4%
Iron deficiency (CC 47)	0.001	0.066	1.00(0.88-1.14)	50.4%	0.141	0.066	1.15(1.01-1.31)	50.1%
End-stage liver disease (CC 25, 26)	0.127	0.215	1.14(0.75-1.73)	1.4%	-0.247	0.229	0.78(0.50-1.22)	1.4%
Pancreatic disease (CC 32)	0.221	0.160	1.25(0.91-1.71)	2.4%	-0.056	0.169	0.95(0.68-1.32)	2.5%
Dialysis status (CC 130)	0.116	0.191	1.12(0.77-1.63)	2.1%	0.099	0.191	1.10(0.76-1.61)	2.3%
Acute renal failure (CC 131)	-0.057	0.078	0.94(0.81-1.10)	28.4%	0.184	0.078	1.20(1.03-1.40)	27.8%
Transplants (CC 128, 174)	0.364	0.381	1.44(0.68-3.04)	0.4%	0.376	0.384	1.46(0.69-3.09)	0.4%
Severe Infection (CC 1, 3-5)	0.338	0.192	1.40(0.96-2.04)	1.7%	0.101	0.215	1.11(0.73-1.69)	1.5%
Other infectious disease & pneumonias (CC 6, 111-	-0.083	0.063	0.92(0.81-1.04)	40.1%	0.029	0.063	1.03(0.91-1.16)	39.5%
Septicemia/shock (CC 2)	0.139	0.090	1.15(0.96-1.37)	10.3%	0.072	0.091	1.07(0.90-1.29)	9.8%
CHF (CC 80)	0.108	0.082	1.11(0.95-1.31)	33.4%	0.072	0.083	1.08(0.91-1.27)	33.8%
Coronary atherosclerosis or angina, cerebrovascular disease (CC 81-84, 89, 98, 99, 103-106)	0.177	0.070	1.19(1.04-1.37)	68.1%	0.109	0.069	1.11(0.97-1.28)	67.7%
Specified arrhythmias (CC 92, 93)	0.191	0.075	1.21(1.05-1.40)	30.6%	0.058	0.074	1.06(0.92-1.22)	31.4%
Cardiorespiratory failure or cardiorespiratory shock (CC 79)	0.136	0.076	1.15(0.99-1.33)	21.5%	0.211	0.076	1.23(1.06-1.43)	20.9%
Coronary obstructive pulmonary disease (COPD) (CC 108)	-0.038	0.064	0.96(0.85-1.09)	48.0%	0.089	0.063	1.09(0.97-1.24)	47.6%
Fibrosis of lung or other chronic lung disorders (CC 109)	-0.012	0.101	0.99(0.81-1.20)	7.8%	-0.026	0.096	0.97(0.81-1.18)	8.4%
Protein-calorie malnutrition (CC 21)	0.075	0.087	1.08(0.91-1.28)	10.2%	0.139	0.085	1.15(0.97-1.36)	10.4%
Disorders of fluid, electrolyte, acid-base (CC 22, 23)	0.123	0.069	1.13(0.99-1.29)	29.3%	0.023	0.069	1.02(0.89-1.17)	28.4%
Rheumatoid arthritis and inflammatory connective tissue disease (CC 38)	0.150	0.109	1.16(0.94-1.44)	6.0%	0.175	0.107	1.19(0.97-1.47)	6.0%
Diabetes mellitus (CC 15-20, 119, 120)	0.018	0.064	1.02(0.90-1.16)	40.0%	0.026	0.064	1.03(0.91-1.16)	38.9%
Ulcers (CC 148, 149)	0.330	0.095	1.39(1.15-1.68)	7.1%	0.234	0.093	1.26(1.05-1.52)	7.8%

Cardiorespiratory Readmission Rates	Hybrid eHWR Development Sample (N=9,261)				Hybrid eHWR Validation Sample (N=9,364)			
Name	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177, 178)	0.087	0.103	1.09(0.89-1.34)	6.7%	0.081	0.103	1.08(0.89-1.33)	6.5%
Seizure disorders and convulsions (CC 74)	0.089	0.148	1.09(0.82-1.46)	3.3%	0.159	0.139	1.17(0.89-1.54)	3.6%
Respirator dependence/tracheostomy status (CC 77)	-0.045	0.313	0.96(0.52-1.77)	0.6%	-0.020	0.316	0.98(0.53-1.82)	0.5%
Drug and alcohol disorders (CC 51, 52)	0.114	0.124	1.12(0.88-1.43)	4.7%	0.132	0.124	1.14(0.90-1.45)	4.7%
Psychiatric comorbidity (CC 54-56, 58, 60)	0.146	0.059	1.16(1.03-1.30)	30.1%	0.171	0.059	1.19(1.06-1.33)	30.4%
Hip fracture/dislocation (CC 158)	-0.281	0.196	0.75(0.51-1.11)	2.1%	-0.104	0.180	0.90(0.63-1.28)	2.0%

Table B.3: Cardiovascular Specialty Cohort Hierarchical Logistic Regression Model Risk Factor Frequencies, Estimates, and Odds Ratios by Sample

Cardiovascular Readmission Rates	Hybrid eHWR Development Sample (N=8,108)				Hybrid eHWR Validation Sample (N=8,037)			
Name	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred
Intercept	0.309	2.001	---	---	4.939	1.915	---	---
CCDE								
Age	0.014	0.005	1.01(1.00-1.03)	---	0.008	0.005	1.01(1.00-1.02)	---
Bicarbonate	0.022	0.011	1.02(1.00-1.04)	---	0.009	0.011	1.01(0.99-1.03)	---
Creatinine	0.186	0.043	1.20(1.11-1.31)	---	0.189	0.045	1.21(1.11-1.32)	---
Hematocrit	-0.022	0.009	0.98(0.96-0.99)	---	-0.017	0.009	0.98(0.97-1.00)	---
Potassium	-0.017	0.074	0.98(0.85-1.14)	---	-0.072	0.073	0.93(0.81-1.07)	---
Sodium	-0.022	0.010	0.98(0.96-1.00)	---	-0.036	0.009	0.96(0.95-0.98)	---
WBC Count	0.021	0.016	1.02(0.99-1.05)	---	0.022	0.016	1.02(0.99-1.05)	---
Systolic Blood Pressure	0.002	0.001	1.00(1.00-1.01)	---	0.001	0.001	1.00(1.00-1.00)	---
Heart Rate	0.009	0.002	1.01(1.00-1.01)	---	0.007	0.002	1.01(1.00-1.01)	---
Oxygen Saturation	-0.024	0.013	0.98(0.95-1.00)	---	-0.040	0.012	0.96(0.94-0.98)	---
Respiratory Rate	0.005	0.011	1.01(0.98-1.03)	---	0.018	0.011	1.02(1.00-1.04)	---
Bicarbonate Square	0.003	0.002	1.00(1.00-1.01)	---	0.003	0.002	1.00(1.00-1.01)	---
Potassium Square	0.178	0.078	1.20(1.03-1.39)	---	0.149	0.072	1.16(1.01-1.34)	---
WBC Count Square	0.000	0.002	1.00(1.00-1.00)	---	0.001	0.002	1.00(1.00-1.01)	---
Systolic Blood Pressure Square	0.000	0.000	1.00(1.00-1.00)	---	0.000	0.000	1.00(1.00-1.00)	---
Heart Rate Square	0.000	0.000	1.00(1.00-1.00)	---	0.000	0.000	1.00(1.00-1.00)	---
Condition								
Low frequency conditions	0.052	0.113	1.05(0.84-	22.7%	-0.145	0.113	0.86(0.69-1.08)	21.1%

Cardiovascular Readmission Rates	Hybrid eHWR Development Sample (N=8,108)				Hybrid eHWR Validation Sample (N=8,037)			
Name	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred
			1.31)					
Acute myocardial infarction (CCS 100)	-0.046	0.123	0.95(0.75-1.21)	18.1%	0.024	0.113	1.02(0.82-1.28)	20.6%
Coronary atherosclerosis and other heart disease (CCS 101)	-0.320	0.138	0.73(0.55-0.95)	19.3%	-0.610	0.142	0.54(0.41-0.72)	19.7%
Nonspecific chest pain (CCS 102)	-0.230	0.138	0.79(0.61-1.04)	14.9%	-0.142	0.134	0.87(0.67-1.13)	14.0%
Cardiac dysrhythmias (CCS106)	Reference	Reference	Reference	24.9%	Reference	Reference	Reference	24.6%
Comorbidity								
Metastatic cancer/acute leukemia (CC 7)	0.363	0.258	1.44(0.87-2.38)	1.7%	0.512	0.263	1.67(1.00-2.79)	1.5%
Severe Cancer (CC 8, 9)	0.138	0.187	1.15(0.80-1.66)	3.4%	0.034	0.204	1.03(0.69-1.54)	2.9%
Other major cancers (CC 10-12)	0.022	0.135	1.02(0.78-1.33)	7.8%	-0.094	0.144	0.91(0.69-1.21)	7.0%
Other hematological disorders (CC 44)	0.245	0.261	1.28(0.77-2.13)	1.4%	0.184	0.252	1.20(0.73-1.97)	1.5%
Coagulation defects and other specified hematological disorders (CC 46)	0.375	0.154	1.45(1.08-1.97)	4.2%	-0.023	0.159	0.98(0.72-1.33)	4.6%
Iron deficiency (CC 47)	0.125	0.097	1.13(0.94-1.37)	35.6%	0.149	0.097	1.16(0.96-1.40)	35.1%
End-stage liver disease (CC 25, 26)	0.160	0.337	1.17(0.61-2.27)	0.8%	0.912	0.287	2.49(1.42-4.37)	0.9%
Pancreatic disease (CC 32)	0.665	0.210	1.94(1.29-2.93)	1.9%	0.293	0.213	1.34(0.88-2.04)	2.1%
Dialysis status (CC 130)	-0.139	0.241	0.87(0.54-1.40)	2.2%	-0.355	0.250	0.70(0.43-1.14)	2.0%
Acute renal failure (CC 131)	0.137	0.116	1.15(0.91-1.44)	18.2%	0.258	0.115	1.29(1.03-1.62)	18.1%
Transplants (CC 128, 174)	-0.126	0.443	0.88(0.37-2.10)	0.6%	0.189	0.455	1.21(0.49-2.95)	0.4%
Severe Infection (CC 1, 3-5)	0.107	0.341	1.11(0.57-2.17)	0.9%	0.211	0.345	1.24(0.63-2.43)	0.8%
Other infectious disease & pneumonias (CC 6, 111-	0.332	0.101	1.39(1.14-1.70)	17.2%	0.232	0.101	1.26(1.03-1.54)	17.1%
Septicemia/shock (CC 2)	-0.165	0.163	0.85(0.62-1.17)	4.3%	0.148	0.158	1.16(0.85-1.58)	4.2%
CHF (CC 80)	0.419	0.116	1.52(1.21-1.91)	16.7%	0.170	0.118	1.19(0.94-1.49)	17.8%

Cardiovascular Readmission Rates	Hybrid eHWR Development Sample (N=8,108)				Hybrid eHWR Validation Sample (N=8,037)			
Name	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred
Coronary atherosclerosis or angina, cerebrovascular disease (CC 81-84, 89, 98, 99, 103-106)	-0.151	0.101	0.86(0.71-1.05)	74.2%	0.023	0.101	1.02(0.84-1.25)	74.7%
Specified arrhythmias (CC 92, 93)	0.154	0.110	1.17(0.94-1.45)	19.5%	0.146	0.109	1.16(0.93-1.43)	20.4%
Cardiorespiratory failure or cardiorespiratory shock (CC 79)	0.131	0.136	1.14(0.87-1.49)	6.6%	0.040	0.142	1.04(0.79-1.37)	6.1%
Coronary obstructive pulmonary disease (COPD) (CC 108)	0.194	0.093	1.21(1.01-1.46)	19.5%	0.060	0.093	1.06(0.88-1.27)	19.6%
Fibrosis of lung or other chronic lung disorders (CC 109)	0.418	0.158	1.52(1.12-2.07)	3.8%	0.151	0.169	1.16(0.83-1.62)	3.7%
Protein-calorie malnutrition (CC 21)	0.261	0.157	1.30(0.95-1.77)	3.9%	0.106	0.161	1.11(0.81-1.53)	3.8%
Disorders of fluid, electrolyte, acid-base (CC 22, 23)	-0.112	0.109	0.89(0.72-1.11)	16.7%	0.069	0.108	1.07(0.87-1.32)	16.9%
Rheumatoid arthritis and inflammatory connective tissue disease (CC 38)	0.306	0.141	1.36(1.03-1.79)	5.7%	0.005	0.160	1.00(0.73-1.37)	5.1%
Diabetes mellitus (CC 15-20, 119, 120)	0.228	0.084	1.26(1.07-1.48)	37.7%	0.039	0.083	1.04(0.88-1.22)	37.7%
Ulcers (CC 148, 149)	0.169	0.168	1.18(0.85-1.65)	3.4%	0.290	0.164	1.34(0.97-1.84)	3.6%
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177, 178)	0.238	0.154	1.27(0.94-1.71)	4.6%	0.082	0.159	1.09(0.80-1.48)	4.2%
Seizure disorders and convulsions (CC 74)	-0.170	0.253	0.84(0.51-1.38)	2.3%	0.073	0.229	1.08(0.69-1.69)	2.3%
Respirator dependence/tracheostomy status (CC 77)	-0.395	1.184	0.67(0.07-6.86)	0.1%	-0.725	1.157	0.48(0.05-4.67)	0.1%
Drug and alcohol disorders (CC 51, 52)	-0.104	0.223	0.90(0.58-1.39)	2.4%	0.307	0.188	1.36(0.94-1.96)	2.7%

Cardiovascular Readmission Rates	Hybrid eHWR Development Sample (N=8,108)				Hybrid eHWR Validation Sample (N=8,037)			
Name	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred
Psychiatric comorbidity (CC 54-56, 58, 60)	0.144	0.089	1.15(0.97-1.37)	22.3%	0.152	0.087	1.16(0.98-1.38)	23.1%
Hip fracture/dislocation (CC 158)	0.083	0.339	1.09(0.56-2.11)	0.8%	-0.444	0.377	0.64(0.31-1.34)	0.8%

Table B.4: Neurology Specialty Cohort Hierarchical Logistic Regression Model Risk Factor Frequencies, Estimates, and Odds Ratios by Sample

Neurology Readmission Rates	Hybrid eHWR Development Sample (N=4,400)				Hybrid eHWR Validation Sample (N=4,348)			
Name	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred
Intercept	3.350	2.409	---	---	2.770	2.373	---	---
CCDE								
Age	-0.004	0.006	1.00(0.98-1.01)	---	-0.008	0.006	0.99(0.98-1.00)	---
Creatinine	0.134	0.057	1.14(1.02-1.28)	---	0.273	0.054	1.31(1.18-1.46)	---
Hematocrit	-0.027	0.010	0.97(0.95-0.99)	---	-0.053	0.011	0.95(0.93-0.97)	---
Sodium	-0.037	0.011	0.96(0.94-0.98)	---	0.000	0.011	1.00(0.98-1.02)	---
WBC Count	-0.001	0.018	1.00(0.96-1.03)	---	0.024	0.018	1.02(0.99-1.06)	---
Systolic Blood Pressure	0.000	0.002	1.00(1.00-1.00)	---	-0.002	0.002	1.00(0.99-1.00)	---
Heart Rate	0.010	0.003	1.01(1.00-1.02)	---	0.006	0.003	1.01(1.00-1.01)	---
Oxygen Saturation	-0.015	0.017	0.99(0.95-1.02)	---	-0.035	0.016	0.97(0.94-1.00)	---
Respiratory Rate	0.052	0.015	1.05(1.02-1.08)	---	0.005	0.015	1.00(0.98-1.03)	---
WBC Count Square	0.003	0.002	1.00(1.00-1.01)	---	0.002	0.002	1.00(1.00-1.01)	---
Systolic Blood Pressure Square	0.000	0.000	1.00(1.00-1.00)	---	0.000	0.000	1.00(1.00-1.00)	---
Temperature Square	-0.003	0.024	1.00(0.95-1.04)	---	0.012	0.019	1.01(0.98-1.05)	---
Temperature Unknown	-0.197	0.210	0.82(0.54-1.24)	---	-0.007	0.206	0.99(0.66-1.49)	---
Condition								
Low frequency conditions	0.188	0.099	1.21(0.99-1.46)	49.3%	0.048	0.098	1.05(0.87-1.27)	50.4%
Acute cerebrovascular disease (CCS109)	Reference	Reference	Reference	50.7%	Reference	Reference	Reference	49.6%
Comorbidity								

Neurology Readmission Rates	Hybrid eHWR Development Sample (N=4,400)				Hybrid eHWR Validation Sample (N=4,348)			
Name	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred
Metastatic cancer/acute leukemia (CC 7)	-0.354	0.255	0.70(0.43-1.16)	3.7%	-0.105	0.241	0.90(0.56-1.45)	4.2%
Severe Cancer (CC 8, 9)	0.258	0.206	1.29(0.86-1.94)	4.7%	-0.002	0.219	1.00(0.65-1.53)	4.3%
Other major cancers (CC 10-12)	0.284	0.154	1.33(0.98-1.80)	9.6%	0.183	0.155	1.20(0.89-1.63)	9.6%
Other hematological disorders (CC 44)	0.448	0.345	1.57(0.80-3.08)	1.3%	0.379	0.284	1.46(0.84-2.55)	1.8%
Coagulation defects and other specified hematological disorders (CC 46)	-0.444	0.231	0.64(0.41-1.01)	4.1%	0.446	0.185	1.56(1.09-2.25)	5.2%
Iron deficiency (CC 47)	0.096	0.119	1.10(0.87-1.39)	34.1%	-0.019	0.119	0.98(0.78-1.24)	34.9%
End-stage liver disease (CC 25, 26)	-0.107	0.407	0.90(0.40-2.00)	1.2%	0.811	0.306	2.25(1.24-4.10)	1.5%
Pancreatic disease (CC 32)	0.314	0.305	1.37(0.75-2.49)	1.8%	0.086	0.314	1.09(0.59-2.02)	1.9%
Dialysis status (CC 130)	0.787	0.325	2.20(1.16-4.15)	1.5%	-0.496	0.320	0.61(0.33-1.14)	2.0%
Acute renal failure (CC 131)	-0.111	0.154	0.90(0.66-1.21)	15.6%	0.213	0.145	1.24(0.93-1.64)	16.6%
Transplants (CC 128, 174)	0.391	0.656	1.48(0.41-5.35)	0.3%	0.455	0.597	1.58(0.49-5.08)	0.4%
Severe Infection (CC 1, 3-5)	0.398	0.331	1.49(0.78-2.85)	1.4%	0.374	0.334	1.45(0.75-2.80)	1.4%
Other infectious disease & pneumonias (CC 6, 111-	0.279	0.127	1.32(1.03-1.70)	20.2%	0.192	0.123	1.21(0.95-1.54)	20.5%
Septicemia/shock (CC 2)	0.303	0.190	1.35(0.93-1.97)	5.5%	-0.116	0.203	0.89(0.60-1.32)	5.4%
CHF (CC 80)	0.168	0.155	1.18(0.87-1.60)	13.5%	0.269	0.155	1.31(0.97-1.77)	13.4%
Coronary atherosclerosis or angina, cerebrovascular disease (CC 81-84, 89, 98, 99, 103-106)	0.339	0.111	1.40(1.13-1.75)	57.7%	0.001	0.111	1.00(0.81-1.24)	56.7%
Specified arrhythmias (CC 92, 93)	0.304	0.140	1.35(1.03-1.78)	17.6%	0.182	0.139	1.20(0.91-1.58)	18.1%
Cardiorespiratory failure or cardiorespiratory shock (CC 79)	0.069	0.189	1.07(0.74-1.55)	6.0%	-0.221	0.195	0.80(0.55-1.17)	6.1%

Neurology Readmission Rates	Hybrid eHWR Development Sample (N=4,400)				Hybrid eHWR Validation Sample (N=4,348)			
Name	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred
Coronary obstructive pulmonary disease (COPD) (CC 108)	0.100	0.123	1.10(0.87-1.40)	16.7%	-0.121	0.131	0.89(0.69-1.15)	16.2%
Fibrosis of lung or other chronic lung disorders (CC 109)	-0.296	0.281	0.74(0.43-1.29)	2.7%	0.028	0.259	1.03(0.62-1.71)	2.9%
Protein-calorie malnutrition (CC 21)	0.049	0.174	1.05(0.75-1.48)	7.1%	0.280	0.162	1.32(0.96-1.82)	7.8%
Disorders of fluid, electrolyte, acid-base (CC 22, 23)	-0.110	0.135	0.90(0.69-1.17)	18.9%	-0.002	0.129	1.00(0.77-1.28)	20.5%
Rheumatoid arthritis and inflammatory connective tissue disease (CC 38)	0.206	0.181	1.23(0.86-1.75)	5.6%	-0.265	0.200	0.77(0.52-1.14)	5.9%
Diabetes mellitus (CC 15-20, 119, 120)	0.000	0.105	1.00(0.81-1.23)	34.1%	-0.076	0.105	0.93(0.75-1.14)	34.5%
Ulcers (CC 148, 149)	0.085	0.197	1.09(0.74-1.60)	4.6%	-0.024	0.206	0.98(0.65-1.46)	4.6%
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177, 178)	0.175	0.151	1.19(0.89-1.60)	10.0%	0.081	0.149	1.08(0.81-1.45)	10.6%
Seizure disorders and convulsions (CC 74)	-0.024	0.139	0.98(0.74-1.28)	13.7%	0.031	0.145	1.03(0.78-1.37)	12.2%
Respirator dependence/tracheostomy status (CC 77)	-0.117	0.869	0.89(0.16-4.88)	0.2%	1.622	0.691	5.06(1.31-19.63)	0.3%
Drug and alcohol disorders (CC 51, 52)	-0.026	0.233	0.97(0.62-1.54)	4.3%	0.182	0.221	1.20(0.78-1.85)	3.9%
Psychiatric comorbidity (CC 54-56, 58, 60)	-0.027	0.106	0.97(0.79-1.20)	28.4%	0.081	0.103	1.08(0.89-1.33)	30.0%
Hip fracture/dislocation (CC 158)	-0.004	0.320	1.00(0.53-1.86)	1.6%	-0.083	0.315	0.92(0.50-1.71)	1.8%

Table B.5: Medicine Specialty Cohort Hierarchical Logistic Regression Model Risk Factor Frequencies, Estimates, and Odds Ratios by Sample

Medicine Readmission Rates	Hybrid eHWR Development Sample (N=34,619)				Hybrid eHWR Validation Sample (N=34,574)			
Name	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred
Intercept	4.474	1.570	---	---	5.603	1.549	---	---
CCDE								
Age	-0.001	0.002	1.00(1.00-1.00)	---	-0.003	0.002	1.00(0.99-1.00)	---
Bicarbonate	0.012	0.004	1.01(1.01-1.02)	---	0.015	0.004	1.02(1.01-1.02)	---
Creatinine	0.024	0.014	1.02(1.00-1.05)	---	-0.011	0.014	0.99(0.96-1.02)	---
Glucose	0.000	0.000	1.00(1.00-1.00)	---	0.000	0.000	1.00(1.00-1.00)	---
Hematocrit	-0.014	0.003	0.99(0.98-0.99)	---	-0.015	0.003	0.98(0.98-0.99)	---
Potassium	0.043	0.023	1.04(1.00-1.09)	---	0.039	0.024	1.04(0.99-1.09)	---
Sodium	-0.008	0.003	0.99(0.99-1.00)	---	-0.005	0.003	0.99(0.99-1.00)	---
WBC Count	-0.004	0.004	1.00(0.99-1.00)	---	-0.012	0.004	0.99(0.98-1.00)	---
Systolic Blood Pressure	0.000	0.001	1.00(1.00-1.00)	---	0.000	0.001	1.00(1.00-1.00)	---
Heart Rate	0.001	0.001	1.00(1.00-1.00)	---	0.001	0.001	1.00(1.00-1.00)	---
Respiratory Rate	0.009	0.004	1.01(1.00-1.02)	---	0.014	0.004	1.01(1.01-1.02)	---
Temperature	-0.055	0.015	0.95(0.92-0.98)	---	-0.070	0.015	0.93(0.91-0.96)	---
Potassium Unknown	-0.053	0.073	0.95(0.82-1.09)	---	-0.045	0.074	0.96(0.83-1.10)	---
Temperature Unknown	0.171	0.064	1.19(1.05-1.35)	---	0.012	0.066	1.01(0.89-1.15)	---
Bicarbonate Square	0.000	0.000	1.00(1.00-1.00)	---	0.002	0.000	1.00(1.00-1.00)	---
WBC Count Square	0.000	0.000	1.00(1.00-1.00)	---	0.000	0.000	1.00(1.00-1.00)	---
Systolic Blood Pressure Square	0.000	0.000	1.00(1.00-1.00)	---	0.000	0.000	1.00(1.00-1.00)	---
Heart Rate Square	0.000	0.000	1.00(1.00-1.00)	---	0.000	0.000	1.00(1.00-1.00)	---
Temperature Square	-0.004	0.005	1.00(0.99-1.01)	---	0.001	0.005	1.00(0.99-1.01)	---
Condition								
Low frequency conditions	-0.425	0.107	0.65(0.53-0.81)	33.1%	-0.307	0.108	0.74(0.60-0.91)	32.8%
Aspiration pneumonitis; food/vomitus (CCS 129)	0.326	0.139	1.39(1.06-1.82)	1.8%	0.257	0.143	1.29(0.98-1.71)	1.7%
Intestinal infection (CCS 135)	0.053	0.140	1.05(0.80-1.39)	1.9%	0.384	0.137	1.47(1.12-1.92)	2.0%
Intestinal obstruction without hernia (CCS 145)	-0.066	0.136	0.94(0.72-1.22)	2.6%	0.033	0.135	1.03(0.79-1.35)	2.8%
Diverticulosis and diverticulitis (CCS 146)	-0.490	0.154	0.61(0.45-0.83)	2.1%	-0.566	0.162	0.57(0.41-0.78)	2.0%
Biliary tract disease (CCS 149)	-0.178	0.159	0.84(0.61-1.14)	1.5%	0.001	0.158	1.00(0.73-1.37)	1.5%

Medicine Readmission Rates	Hybrid eHWR Development Sample (N=34,619)				Hybrid eHWR Validation Sample (N=34,574)			
Name	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred
Gastrointestinal hemorrhage (CCS 153)	-0.380	0.130	0.68(0.53-0.88)	3.5%	-0.318	0.131	0.73(0.56-0.94)	3.7%
Other gastrointestinal disorders (CCS 155)	-0.195	0.152	0.82(0.61-1.11)	1.6%	-0.063	0.152	0.94(0.70-1.26)	1.6%
Acute and unspecified renal failure (CCS 157)	-0.200	0.128	0.82(0.64-1.05)	3.3%	0.048	0.128	1.05(0.82-1.35)	3.1%
Urinary tract infections (CCS 159)	-0.426	0.132	0.65(0.50-0.85)	3.7%	-0.340	0.133	0.71(0.55-0.92)	3.7%
Skin and subcutaneous tissue infections (CCS 197)	-0.628	0.155	0.53(0.39-0.72)	2.1%	-0.531	0.154	0.59(0.43-0.80)	2.2%
Septicemia (except in labor) (CCS 2)	0.030	0.108	1.03(0.83-1.27)	23.5%	0.039	0.109	1.04(0.84-1.29)	23.8%
Complication of device; implant or graft (CCS 237)	-0.111	0.119	0.89(0.71-1.13)	4.8%	0.016	0.121	1.02(0.80-1.29)	4.6%
Complications of surgical procedures or medical care (CCS 238)	-0.062	0.132	0.94(0.72-1.22)	2.7%	0.038	0.136	1.04(0.80-1.36)	2.5%
Syncope (CCS 245)	-0.622	0.151	0.54(0.40-0.72)	2.4%	-0.681	0.155	0.51(0.37-0.69)	2.5%
Diabetes mellitus with complications (CCS 50)	-0.340	0.135	0.71(0.55-0.93)	2.6%	-0.265	0.136	0.77(0.59-1.00)	2.6%
Fluid and electrolyte disorders (CCS 55)	-0.411	0.134	0.66(0.51-0.86)	3.1%	-0.075	0.131	0.93(0.72-1.20)	3.2%
Cataract (CCS 86)	-0.930	0.163	0.39(0.29-0.54)	2.2%	-0.688	0.159	0.50(0.37-0.69)	2.2%
Hypertension with complications and secondary hypertension (CCS 99)	Reference	Reference	Reference	1.6%	Reference	Reference	Reference	1.6%
Comorbidity								
Metastatic cancer/acute leukemia (CC 7)	0.032	0.069	1.03(0.90-1.18)	5.0%	-0.063	0.071	0.94(0.82-1.08)	4.9%
Severe Cancer (CC 8, 9)	0.290	0.054	1.34(1.20-1.49)	7.1%	0.338	0.055	1.40(1.26-1.56)	6.9%
Other major cancers (CC 10-12)	0.035	0.045	1.04(0.95-1.13)	12.2%	0.079	0.045	1.08(0.99-1.18)	12.1%
Other hematological disorders (CC 44)	0.327	0.077	1.39(1.19-1.61)	3.0%	0.126	0.080	1.13(0.97-1.33)	2.9%
Coagulation defects and other specified hematological disorders (CC 46)	0.178	0.052	1.19(1.08-1.32)	7.5%	0.166	0.052	1.18(1.07-1.31)	7.5%

Medicine Readmission Rates	Hybrid eHWR Development Sample (N=34,619)				Hybrid eHWR Validation Sample (N=34,574)			
Name	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred
Iron deficiency (CC 47)	0.056	0.036	1.06(0.99-1.13)	52.9%	0.047	0.036	1.05(0.98-1.12)	53.0%
End-stage liver disease (CC 25, 26)	0.315	0.078	1.37(1.18-1.60)	3.0%	0.270	0.076	1.31(1.13-1.52)	3.2%
Pancreatic disease (CC 32)	0.230	0.061	1.26(1.12-1.42)	5.1%	0.199	0.061	1.22(1.08-1.38)	5.2%
Dialysis status (CC 130)	0.059	0.086	1.06(0.90-1.26)	3.3%	0.086	0.085	1.09(0.92-1.29)	3.5%
Acute renal failure (CC 131)	0.080	0.041	1.08(1.00-1.17)	24.3%	0.075	0.041	1.08(0.99-1.17)	24.2%
Transplants (CC 128, 174)	0.177	0.154	1.19(0.88-1.61)	0.7%	0.383	0.141	1.47(1.11-1.93)	0.8%
Severe Infection (CC 1, 3-5)	0.084	0.099	1.09(0.90-1.32)	1.9%	0.096	0.100	1.10(0.91-1.34)	1.8%
Other infectious disease & pneumonias (CC 6, 111-	-0.003	0.035	1.00(0.93-1.07)	34.4%	0.112	0.035	1.12(1.04-1.20)	34.5%
Septicemia/shock (CC 2)	0.005	0.047	1.00(0.92-1.10)	11.4%	0.074	0.046	1.08(0.98-1.18)	11.3%
CHF (CC 80)	0.121	0.043	1.13(1.04-1.23)	19.6%	0.185	0.043	1.20(1.11-1.31)	19.8%
Coronary atherosclerosis or angina, cerebrovascular disease (CC 81-84, 89, 98, 99, 103-106)	0.139	0.034	1.15(1.07-1.23)	61.1%	0.254	0.035	1.29(1.20-1.38)	61.1%
Specified arrhythmias (CC 92, 93)	0.133	0.039	1.14(1.06-1.23)	21.6%	0.092	0.040	1.10(1.01-1.19)	21.5%
Cardiorespiratory failure or cardiorespiratory shock (CC 79)	0.073	0.048	1.08(0.98-1.18)	10.7%	0.021	0.048	1.02(0.93-1.12)	10.9%
Coronary obstructive pulmonary disease (COPD) (CC 108)	0.131	0.034	1.14(1.07-1.22)	23.7%	0.095	0.035	1.10(1.03-1.18)	23.6%
Fibrosis of lung or other chronic lung disorders (CC 109)	0.127	0.064	1.14(1.00-1.29)	4.6%	0.054	0.064	1.06(0.93-1.20)	4.7%

Medicine Readmission Rates	Hybrid eHWR Development Sample (N=34,619)				Hybrid eHWR Validation Sample (N=34,574)			
Name	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred
Protein-calorie malnutrition (CC 21)	0.137	0.042	1.15(1.06-1.24)	13.5%	0.140	0.041	1.15(1.06-1.25)	13.9%
Disorders of fluid, electrolyte, acid-base (CC 22, 23)	0.186	0.037	1.20(1.12-1.30)	28.8%	0.141	0.037	1.15(1.07-1.24)	29.3%
Rheumatoid arthritis and inflammatory connective tissue disease (CC 38)	0.110	0.054	1.12(1.00-1.24)	6.8%	0.026	0.056	1.03(0.92-1.15)	6.6%
Diabetes mellitus (CC 15-20, 119, 120)	0.113	0.034	1.12(1.05-1.20)	38.9%	0.072	0.034	1.07(1.01-1.15)	39.2%
Ulcers (CC 148, 149)	0.154	0.048	1.17(1.06-1.28)	9.0%	0.047	0.049	1.05(0.95-1.15)	9.2%
Hemiplegia, paraplegia, paralysis, functional disability (CC 67-69, 100-102, 177, 178)	0.028	0.050	1.03(0.93-1.13)	8.6%	0.064	0.050	1.07(0.97-1.18)	8.2%
Seizure disorders and convulsions (CC 74)	0.165	0.064	1.18(1.04-1.34)	4.6%	0.020	0.066	1.02(0.90-1.16)	4.6%
Respirator dependence/tracheostomy status (CC 77)	0.282	0.184	1.33(0.92-1.90)	0.4%	0.124	0.191	1.13(0.78-1.65)	0.4%
Drug and alcohol disorders (CC 51, 52)	0.089	0.060	1.09(0.97-1.23)	5.7%	0.121	0.059	1.13(1.00-1.27)	5.9%
Psychiatric comorbidity (CC 54-56, 58, 60)	0.075	0.031	1.08(1.01-1.15)	30.0%	0.116	0.031	1.12(1.06-1.19)	30.1%
Hip fracture/dislocation (CC 158)	0.140	0.083	1.15(0.98-1.35)	2.4%	-0.244	0.090	0.78(0.66-0.94)	2.5%

APPENDIX C: PUBLIC COMMENT SUMMARY REPORT

Measure Name: Hybrid Hospital-Wide Readmission Measure with Claims and Electronic Health Record Data (Hybrid eHWR Measure)
Date of Report: August 28, 2014
Contractor (Measure Developer) Name: Yale New Haven Health Services Corporation/Center for Outcomes Research and Evaluation (YNHHSC/CORE)

INTRODUCTION

Dates of public comment period: Thursday, July 7, 2014 through Friday, August 8, 2014

Website used: https://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/MMS/CallforPublicComment.html

Methods used to notify stakeholders and general public of comment period:
- Email notification to Centers for Medicare and Medicaid Services (CMS) listserv groups including the eMeasures Interest Group (eMIG)
- Email to relevant stakeholders and stakeholder organizations, including:
  - Abt Associates (former CMS contractor for EH eCQMs)
  - Kaiser Permanente of Northern California
  - Health information technology experts from the CCDE Technical Expert Panel
- Posting on CMS Public Comment website

Volume of responses received:
We received comments from 7 commenters during the public comment period; specifically:
- 1 Hospital/health system (Hennepin County Medical Center)
- 1 Health insurance provider (Kaiser Foundation Health Plan, Inc.)
- 1 Health insurance association (America's Health Insurance Plans)
- 1 Hospital association (America's Essential Hospitals)
- 1 EHR vendor (Epic)
- 1 Professional society (The Infectious Diseases Society of America)
- 1 Other (Consultant to CMS and ONC)

STAKEHOLDER COMMENTS—GENERAL

SUMMARY OF GENERAL COMMENTS

Most comments were focused on the hybrid nature of the measure and on the risk-adjustment variables from the electronic health record (EHR) used in the measure. Although most comments did not include statements of support or arguments against the measure, one commenter stated that the work was valuable. Another stated that they "support CMS' efforts in examining new approaches to provide a more accurate assessment and portrayal of services provided by clinicians and hospitals."

Another stated, "We believe it is very important that enriched clinical data from an EHR be used to supplement the clinically limited datasets available from claims."

No specific questions or comments were submitted about the measure cohort, the data source used for measure development and testing, or the measure outcome (all-cause 30-day unplanned readmission). Comments and questions were focused on risk-adjustment, including the core clinical data elements (CCDE) from the electronic health records (EHR), the claims data elements used, and the risk-adjustment methodology. Other comments focused on various aspects of measure implementation, such as how best to communicate the importance of incorporating clinical data into hospital outcome measures, questions about how the measure is related to meaningful use, and concerns about the potential burden on providers who do not have an EHR.

Proposed action:

See proposed action under the measure-specific comment summaries below.

MEASURE-SPECIFIC COMMENT SUMMARIES

Measure Name: Hybrid Hospital-Wide Readmission Measure with Claims and Electronic Health Record Data (Hybrid eHWR Measure)

GENERAL COMMENTS

Three comments supported the measure overall.

Response: CMS thanks the commenters for their support for the current approach.

RISK ADJUSTMENT METHODS AND VARIABLES

One comment requested clarification of the exact time stamp used to identify the time of arrival when extracting the first captured CCDE values. The commenter suggested that a more precise definition be provided in the technical report in order for hospitals to be able to accurately and consistently identify the correct data value.

Response: We recognize that clearly defining the appropriate time stamp for the start of an episode is a critical step for identifying the first-captured vital sign or laboratory test result. The definition currently states, "The time stamp that is captured closest to the moment a patient first reaches the hospital for care." In practice, the time of arrival requires two separate pieces of information: the time stamp associated with the first recorded contact patients have with hospital staff at the start of the episode; and the location where patients first appear (e.g., the emergency department, pre-operative area, inpatient floor or unit). As stated in the CCDE Technical Report (pg. 28), time of arrival stamps were derived from the Patient Management System and corresponded with the time a patient

registered as "arrived" at the hospital. This was when a patient's insurance and contact information were first collected by the hospital administrative staff. This time was chosen because we believed that it would consistently precede capture of any vital signs and laboratory tests. These stamps will likely need to be mapped within a hospital's electronic database separately for each potential arrival location. CMS will develop human and machine readable logic statements to support mapping and extraction of the time stamps needed to identify first captured data values. These standard documents will also be released for public comment.

Two comments were requests for clarification of the exact data value chosen among all possible values for each data element in the CCDE.

Response: For each of the CCDE, the value used in the risk-adjusted models is the first captured value within 2 hours and 24 hours of arrival. For vital signs it is the first value captured in the EHR within 2 hours after a patient is registered as having arrived at the hospital in the patient management system (the patient has "checked in" and first provided their name, demographics, and insurance information to hospital personnel). For laboratory test results it is the first captured value within 24 hours after a patient has registered as having arrived at the hospital. We will clarify this in the final technical report.

One comment was a request that CMS consider including data elements related to medications ordered, administered, and prescribed at discharge in the CCDE for readmission measures. This commenter stated that in a readmission measure, these data elements "may be relevant and contribute to the accuracy of risk adjustments."

Response: Our intention with the approach to risk adjustment is to include factors related to patients' severity of illness prior to and at the start of each hospitalization. The risk-adjustment variables are chosen such that they only capture patients' clinical status before treatment is provided and the effects of that treatment are realized. This approach allows the measure to compare outcomes across hospitals without obscuring potential differences in the care patients receive. This aligns with the approach of other CMS public reported measures. Therefore, we do not include information about medications ordered or administered during or at the conclusion of the hospitalizations. Although such information would likely be predictive of patients' risk of readmission, it also might obscure differences among hospitals in the quality of care they provide and undermine the purpose of the measure.

One comment was a statement that if CMS intends to apply the CCDE to readmission measures in addition to mortality measures, the "reliability testing should be adequate to support validity."

Response: We agree that it is important to establish the reliability of outcome measures when incorporating new risk variables. For this and other outcome measures that are reengineered to include the CCDE, reliability testing will be done using a larger and more representative set of hospitals prior to public reporting.

One comment suggested that the laboratory tests included in the CCDE should be compatible with the specific condition for which the patients were admitted.

Response: For certain conditions, there are specific tests that should be performed routinely upon the start of a hospital encounter, such as troponin values for patients with acute myocardial infarction. The CCDE, however, was developed to include data elements that are routinely captured on nearly all admitted patients

regardless of their principal diagnosis. The intent was to then have a group of data elements that could be applied to cohorts of patients admitted for specific conditions as well as a hospital-wide cohort which encompasses multiple conditions. The expectation is that the CCDE could be augmented by a few data elements relevant to risk adjustment of specific conditions as long as the additional data elements are feasible.

One comment was a statement that a mechanism should exist for sharing lab information across settings to avoid unnecessary repetition of a lab test to satisfy a reporting requirement.

Response: The CCDE was developed to include only data elements that are currently captured in nearly all adult hospitalized patients. The purpose of this selection criterion was to use data that clinicians already capture to avoid influencing or changing the way that hospitals and clinicians care for patients. It is not the intent of this measure to force or encourage clinicians to perform certain tests or capture vital signs in their patients. Participation in this measure will not require hospitals to perform unnecessary or repetitive testing.

We recognize that pre-operative laboratory testing is routinely performed outside of the hospital for patients with planned surgical procedures. Our analyses showed that these data are not consistently transcribed into the inpatient EHR when patients are admitted for surgical procedures. Due to missing data we excluded laboratory test results from risk adjustment of the surgical cohort in the Hybrid eHWR Measure. Ideally, test results could be made available if they were transcribed into the EHR upon admission. Testing should not be repeated unless clinically indicated. CMS will consider ways to support improved data capture and data availability across settings wherever possible.

Two comments stated that for many clinical risk variables listed in the measures specifications tables, the odds ratios from models of readmission were close to 1.0, thus suggesting little predictive value. They also noted that the CMS CCs from claims were most predictive of readmissions.

Response: We used a fixed, common set of variables in each of the 5 specialty cohort models for simplicity and ease of data collection and analysis. In the measure specifications tables in Appendix A, all of these fixed risk-adjustment variables are listed for each specialty cohort regardless of whether they were significant predictors of readmission for the specialty cohort. Thus, several variables that are not significant predictors or only weak predictors of readmission (odds ratio close to 1.0) are included in the models. In addition, some terms were forced into the models. For example, we forced in both the linear term and quadratic terms for several variables in the CCDE at the same time. We also forced in principal discharge diagnosis in our models. This approach is consistent with observing several odds ratios close to 1.0. There is no loss of model performance in including risk factors that have little predictive value. Some of these variables are important for face validity, in that even if they are not predictive, omitting them may raise concerns about the model. This approach does not bias the measure results or the hospital performance scores.

In the Hybrid eHWR Measure the CCs were slightly more predictive of readmission compared with the CCDE. The CCDE, however, were also predictive, and the model that used both comorbidity and the CCDE together showed the best discrimination.

One comment questioned whether the assertion in the technical report that a complication is a condition that occurs as a consequence of care is necessarily true.

Response: A complication is not necessarily or always a consequence of care. Certain complications can

clearly be attributed to poor care. In many instances, however, when a complication occurs, it is impossible to determine definitively whether the complication was a result of the care received or a patient' underlying poor health. In the measure, complications are conditions that are considered likely to have been acquired during the hospitalization. We do not include any data that reflect events that occurred after the start of the hospitalization as risk-adjustment variables in the measure. We also always include readmissions for complications of care following procedures in the measure outcome because we do not consider these readmissions to be planned. A full list of the discharge diagnoses considered complications of care following a procedure can be found in the technical report for the claims-based 2014 Hospital-Wide All-Cause Readmission Measure Updates Report found here: http://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment- Instruments/HospitalQualityInits/Measure-Methodology.html.

One comment was a question about whether any of the CCDE were too highly correlated with one another to be included in the model.

Response: We examined correlation among the variables in the CCDE before developing the risk- adjusted models. This analysis resulted in removal of BUN, chloride, anion gap, hemoglobin, and diastolic blood pressure from the group of CCDE that were considered in the models because they were highly correlated with other data elements. For details see page 15 in the Draft 2014 Reengineered Hospital-Wide All-Cause Unplanned Readmission Measure Report.

Three comments questioned the exclusion of variables that reflect socioeconomic status from risk adjustment of the measure in light of the possible changes to the National Quality Forum (NQF) recommendations regarding the use of these variables in quality measures.

Response: Development of new NQF recommendations regarding socioeconomic status variables is ongoing. This measure is based on the Original Hospital-Wide All-Cause Readmission Measure methodology that did not account for socioeconomic status in risk adjustment. We will consider making an adjustment to this measure when the final recommendations from NQF are released.

STATISTICAL METHODS

One commenter suggested including negative log likelihood estimates and Akaike estimate for model fit in the measures specification tables in Appendix B of the technical report.

Response: We appreciate the suggestion of additional tests to demonstrate model performance. We do not include the negative log likelihood estimates and Akaike Information Criteria estimates because these statistics are only meaningful when comparing two or more models. The tables in Appendix B were used to show the association or effect between the model variables and the outcome of readmission as well as the difference of the effect over three different study samples. For the model performance, we have reported C-statistics, calibration, predictive ability, and chi-square residuals (Tables 3.7 and 3.8). These statistics provide information about model performance and model fit.

One commenter requested that we provide some context for interpreting the Intra-Class Correlation Coefficient (ICC).

Response: For the hospital event rate based on the patient binomial outcomes like readmission (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.

ESPECIFICATION

One comment questioned whether the Hybrid eHWR Measure is an eSpecified version of the original claims-based measure currently in public reporting.

Response: The Hybrid eHWR Measure is not an e-specification of the current Hospital-Wide All-Cause Unplanned Readmission measure. Many of the data elements used to calculate this current measure, including the ICD-9 codes for patients' conditions as well as dates of admission and discharge, will still be collected from patient claims. The only difference between this Hybrid eHWR Measure and the HWR measure is the inclusion of the consideration of EHR data elements (the CCDE) in the risk adjustment model.

One comment was a statement of conditional support of the CCDE. The commenter noted that support depended on whether the EHR software systems used for feasibility testing represent the majority of systems used in hospitals. Support also depended on whether CMS recognizes that a significant number of hospitals do not use these systems.

Response: In testing and reporting on the feasibility of data elements, we sampled a subset of the EHR systems currently in use. The four EHR systems included in testing (Epic, Cerner, Meditech, and Allscripts) are the most common inpatient medical records. Together they are used in approximately 50% of hospitals attesting for Meaningful Use in 2013. We recognize that a substantial portion of hospitals do not use these systems. CMS is developing an implementation strategy that will include ample opportunity for hospitals to test EHR database queries and reporting protocols.

IMPLEMENTATION

One comment was a question about whether the measure will be part of Meaningful Use.

Response: This measure is not a part of Meaningful Use. CMS plans to implement the measure through the Inpatient Quality Reporting Program separate from the Meaningful Use Measures for Eligible Hospitals. Details about the implementation of the measure will be forthcoming.

One comment was a question about how the Hybrid eHWR Measure will be integrated with the current Meaningful Use expectation that clinicians use SNOMED-CT codes rather than ICD-9 or ICD-10 codes to indicate patients' conditions. The commenter also asked whether CMS ever intends to use SNOMED-CT codes rather than ICD9 or ICD-10 billing codes to identify patient's conditions in the Hybrid eHWR Measure.

Response: The Hybrid eHWR Measure does not currently include data on patients' conditions from electronic health records (EHRs), or SNOMED-CT codes. Although CMS would like to incorporate data from EHRs into quality measures wherever possible, the data must meet feasibility criteria in order to be extracted and used in measure calculation (see the CCDE methodology report, page 13). The Technical Expert Panel engaged during the development of the CCDE agreed that data captured in EHRs on patients' principal discharge diagnoses and comorbid conditions did not currently meet these criteria. This was due, in part, to the consensus opinion that clinicians do not currently apply a standard definition to the concept of a principal discharge diagnosis, nor do they consistently capture comorbidity data in structured fields. However, we recognize that current efforts to improve identification and capture of conditions through Meaningful Use might improve the standard use of conditions data over time. Therefore, CMS intends to review the feasibility of these and other types of data elements relevant to outcome measures in the future.

One comment was a statement suggesting that a more compelling argument for using clinical data, instead of being less susceptible to gaming, was that clinicians are the source of clinical data which they derive from direct interaction with patients. Clinicians appreciate and value the accuracy of clinical data, and use it to assess patients' conditions to guide treatment.

Response: We agree that one important advantage to incorporating EHR data into hospital outcome measures is that the data are being recorded by clinicians who are interacting with the patient and who value the accuracy of the data to guide the care they provide.

One comment was a request for clarification about whether hospitals would be required to extract claims data from paper medical records. The commenter expressed concern that this would create an undue burden.

Response: Data about conditions, comorbidities, and readmissions will continue to be derived from inpatient claims and will not be extracted from paper medical records. CMS is developing an implementation plan which will address how hospitals that do not have EHRs can participate in the measure without being subject to undue burden. More information about this plan will be forthcoming.

One comment was a statement that by including data elements related to medications ordered, administered, and prescribed at discharge, CMS could standardize medication data capture and further the relational development of other electronic quality tools targeted at medication management such as real-time clinical decision support.

Response*:* We agree that the medication errors and inappropriate use are an important cause of unplanned readmission. These data elements, however, are not included in the CCDE or in risk- adjustment of the Hybrid eHWR Measure because they represent events that transpire after a patient first presents to the hospital for care and potentially reflect variation in the quality of care patients receive during hospital admissions.

LANGUAGE AND FORMATTING

One comment was a suggestion to add percent to the estimates in table 3.3 of the Hybrid eHWR Measure technical report.

Response: The values in the cells of this table are percentages. We will clarify this in the final report.

One comment suggested including figure 3.1 from the CCDE technical report in the Hybrid eHWR Measure technical report.
Response: We will consider this change.

One comment was a suggestion to add the number of observations in Table 2.1 as a fourth column.

Response: We will take your suggestion under consideration.

PRELIMINARY RECOMMENDATIONS

The measure developers are not recommending any changes to the measure specifications in response to public comments.

OVERALL ANALYSIS OF THE COMMENTS AND RECOMMENDATIONS TO CMS

Feedback on the Hybrid eHWR Measure was constructive and positive. Most commenters focused on the EHR data elements used in risk-adjustment and various aspects of measure implementation.

Many of the issues raised will be clarified with release of the machine and human readable logic for the CCDE, and the implementation plan for CCDE data reporting and Hybrid eHWR Measure implementation.

APPENDIX D: HYBRID eHWR MEASURE TESTING FOR COMBINED (MA+FFS) COHORT

Evaluation of the Impact of Incorporating Medicare Advantage Admissions into the Hybrid Hospital-Wide Readmission Measure
Data Supplement: March 2023

Overview

In this supplemental data, we present the rationale and testing results of integrating MA beneficiaries in the Hybrid Hospital-Wide Readmission (HWR) measure. The only change to the current Hybrid HWR measure is the addition of Medicare Advantage (MA) admissions into the cohort; all other specifications remain the same. The cohort included 11,029,470 eligible inpatient admissions (4,077,633 MA and 6,951,837 Fee-for Service) extracted from the Centers for Medicare & Medicaid Services (CMS) Integrated Data Repository (IDR) for Fee-for-Service (FFS) inpatient claims, hospital-submitted MA inpatient claims, and Medicare Advantage Organization (MAO)-submitted MA inpatient encounter claims. The addition of MA inpatient admissions into the HWR measure improved reliability, improved the precision of measure scores, and led to more hospitals and beneficiaries included in the measure. The mean risk-standardized readmission rate was slightly higher for the combined FFS and MA (FFS+MA) cohort compared to the FFS-only cohort (15.48 versus 15.35% for hospitals with 25 or more admissions in each specialty cohort). Among hospitals with 25 or more FFS admissions, most hospitals remained in their same performance quintile after the addition of MA inpatient admissions, with the greatest shifts seen in hospitals with a high percentage of MA inpatient admissions.

Testing was done in the claims-only, rather than Hybrid version, of the HWR measure due to lack of availability of electronic health record (EHR) data. The hybrid version of the measure is identical to the claims-only version except for the additional core clinical data elements (CCDE) obtained from the EHR used for risk adjustment in addition to the claims-based risk variables. It is very unlikely that the addition of these CCDE risk variables would affect the impact of adding MA data into the hybrid HWR measure. The CCDE were tested within the Kaiser Permanente Northern California (KPNC) patient population, which is almost entirely Medicare Advantage patients. Further, measure scores based using the claims-only data are highly correlated with measure scores adding the CCDE based on initial hybrid voluntary reporting data (2018) and Kaiser Permanente data. In the Kaiser data, the overall correlation of risk-standardized readmission rates (RSRRs) calculated using claims only and claims plus EHR data was 0.99 (please refer to Section 3.6 of this Methodology Report for those results).

Importance of Including MA Beneficiaries in Hospital Outcome Measures
Including MA beneficiaries in CMS hospital outcome measures would help ensure that hospital quality is measured across all Medicare beneficiaries and not just the FFS population. MA beneficiary enrollment has been rapidly expanding as a share of Medicare beneficiaries. In 2022, nearly 48% of the eligible Medicare beneficiaries – or 28 million people – were covered by Medicare Advantage plans.[11] The Congressional Budget Office projects that by 2030, 62% of beneficiaries will be covered by MA plans. MA coverage also varies across counties and states (ranging between one to 59%) with lower enrollment in rural states.[12] Consequently, using FFS-only beneficiaries exclude a large segment of the focus population for CMS quality measures, which are intended to reflect the health of all Medicare beneficiaries.

Inclusion of MA beneficiaries has several important benefits for the reliability and validity of the hospital outcome measures. The addition of MA beneficiaries to the cohort would significantly increase the size of the measure's cohort,

enhance the reliability of the measure scores, lead to more hospitals receiving results, and increase the chance of identifying meaningful differences in quality for some low-volume hospitals. Moreover, this update would address stakeholder concerns about differences in quality for MA and FFS beneficiaries.[11, 13]

The addition of MA inpatient admissions also allows for inclusion in the measure of beneficiaries who switch between FFS and MA. CMS's claims-based readmission measures can require enrollment in FFS Part A and Part B for the 12 months prior to the date of admission and Part A during the index admission and at least one month after discharge. Currently, for the beneficiaries that switch from MA to FFS plans each year during the open enrollment period, their admissions are excluded from the cohort if disenrollment occurs in the 12 months prior to the date of admission. Similarly, beneficiaries that switch from FFS to MA in the month following index admission will also be excluded from the measure cohort.

Objectives of Current Analysis

We assessed the impact of incorporating MA inpatient admissions into the CMS claims-based FFS Hospital-Wide Readmission (HWR) measure. Given that the only difference between the Hybrid HWR and the claim-based HWR measures is the addition of core clinical data elements (CCDE) obtained from the electronic health record (EHR), the impact of the addition of MA inpatient admissions into the Hybrid measure is expected to be comparable to the findings presented herein. We assessed differences in 30-day observed readmission rates and prevalence of demographic and claims-based risk-adjustment variables for MA versus FFS admissions. We then assessed RSRRs for a combined FFS+MA cohort as compared to the FFS-only cohort, overall and by five specialty cohorts at the patient and hospital level. Changes in hospital performance quintiles and signal-to-noise ratio reliability and test-retest reliability for the HWR measure were assessed after the addition of MA admissions to the FFS-only cohort.

Methods

Data Sources

We used the Integrated Data Repository (IDR) to extract inpatient claims data for FFS-only, hospital-submitted MA, and MAO-submitted MA inpatient claims. Only inpatient data is used for risk adjustment of the HWR measure. We downloaded claims data with claim through date (CLM_THRU_DT) in the years of 2017, 2018, and 2019 for the Medicare Fee for Service (FFS) and Medicare Advantage (MA) Plans based on the following claim types (CLM_TYPE_CD):

- 60 for FFS inpatient admissions,
- 62/63/64 for hospital-submitted MA inpatient admissions, and
- 4011/4041 for MAO-submitted MA inpatient admissions.

We determined the impact of adding MA inpatient data to the FFS-only HWR measure. Using IDR data, we followed the methodology for the current FFS-only HWR measure for cohort inclusion/exclusion criteria, risk factors derivation from inpatient claims diagnoses during the 12 months prior to admission or present at index admission, outcome definitions, and measure score calculation. After adding the MA beneficiaries, the enrollment requirement was updated to 12 months FFS or MA enrollment prior to the index admission and 30 days after index admission. Information on the claims-based HWR measure methodology, including measure specifications and calculation methodology, can be found in Section 2 and Appendices A and D in the 2020 HWR measure updates and specifications report on QualityNet at: (https://qualitynet.cms.gov/) > Hospitals – Inpatient > Measures > Claims-Based Measures > Readmission Measures > Learn More > Resources > Archived Measure Methodology.

To create the combined FFS+MA cohort, we chose to combine the MAO-submitted and hospital-submitted MA admission claims. First, while most hospitals submit MA inpatient claims, not all hospitals are required to submit claims

for MA beneficiaries (i.e., those that do not receive disproportionate-share hospital or medical education payments from Medicare), so MAO-submitted claims capture additional admissions not found in the hospital-submitted claims. However, there are benefits in including the hospital-submitted claims. A small proportion of admissions were only found in the hospital-submitted claims, and hospital-submitted claims are timelier than MAO-submitted claims, which is advantageous for reporting deadlines for CMS hospital outcome measures. Further, unlike MAO-submitted claims which are associated with a National Provider Identifier (NPI), hospital-submitted claims are already associated with a CMS Certification Number (CCN) used to identify hospitals in the CMS outcome measures. Therefore, if an admission was found in both datasets, we used the claim found in the hospital-submitted data. For a small portion of admissions with only MAO-submitted claims, we used IDR provider history data to map NPI to CCN.

The cohort tested included hospital admissions with discharge dates from July 2018 to June 2019, mimicking the CMS reporting year data period, including both FFS and MA data. The risk-adjustment data were derived from both FFS and MA inpatient claims one year prior to and during the index claims. The HWR cohort included 11,029,470 eligible admissions (4,077,633 MA and 6,951,837 FFS). We calculated measure results for the combined FFS+MA admissions and compared to the results for FFS-only admissions. We compared observed readmission rates between MA and FFS admissions in the five specialty cohorts including Cardiorespiratory, Cardiovascular, Medicine, Surgery, and Neurology. We then examined risk variable prevalence in MA and FFS admissions. We compared model performance metrics, c-statistic and Predictive Ability, in each specialty cohort between FFS+MA versus FFS-only admissions using patient-level logistic regression models.

We used hierarchical logistic models with a random effect for hospitals to calculate hospital-level standardized readmission ratios and risk-standardized readmission rates (SRRs and RSRRs) for each specialty cohort and then calculated the hospital-level measure score RSRRs in the overall cohort. We repeated the above analyses with FFS-only claims and compared the number of hospitals, number of admissions, and RSRRs from FFS-only and combined FFS+MA data. We also calculated test-retest reliability for the total cohort and signal-to-noise reliability (STNR) for each of the 5 specialty cohorts based on between hospital variance and hospital volume. In general, the higher the volume or between hospital variance, the higher the STNR.

To assess the overall impact of adding MA data to hospital measure scores, we examined shifts in hospital RSRR quintiles in the FFS-only cohort versus the combined FFS+MA cohort among hospitals with 25 or more FFS admissions. To examine the associations between hospital characteristics and the addition of MA data, we first examined quintile shifts in hospital RSRR by quintiles of the proportion of hospital MA admissions and by quintiles of overall hospital volume. We also calculated the change of RSRR, defined as the difference between RSRRs using FFS+MA and FFS-only data for hospitals. For example, if the hospital RSRR was 15% using FFS-only and 15.5% using FFS+MA data, the change of RSRR was 0.5%. We then calculated the correlation coefficient between change of RSRR with hospital proportion of MA admissions and with hospital volume of MA admissions.

Results

Admission volume, observed readmission rate, and demographic and risk-adjustment variables
For the July 1, 2018 – June 30, 2019 dataset, there were 11,029,470 overall admissions in the combined FFS+MA cohort. The addition of MA data added 4,077,633 additional eligible admissions to the cohort (Table D.1). The observed (unadjusted) 30-day readmission rate for the combined FFS+MA cohort was 15.48% (Table D.1). The observed readmission rate was slightly higher among MA beneficiaries compared to FFS beneficiaries (15.72% versus 15.35%, for a difference of 0.37%). Yet, prevalence of comorbidities was generally lower among MA beneficiaries as compared to FFS (Table D.2).

Table D.1: Number of Admissions and Observed 30-Day Readmission Rate (RR) in the Study Cohort for the July 1, 2018 – June 30, 2019 Reporting Period, MA admissions versus FFS Admissions, Overall and by Specialty cohort

Specialty Cohort	FFS+MA (N)	FFS+MA RR (%)	MA (N)	MA RR (%)	FFS (N)	FFS RR (%)	FFS RR - MA RR (%)
Overall	11,029,470	**15.48**	4,077,633	**15.72**	6,951,837	**15.35**	-0.37
Cardiorespiratory	1,306,739	18.42	476,597	18.67	830,142	18.27	-0.40
Cardiovascular	1,158,878	14.53	440,788	14.90	718,090	14.29	-0.61
Medicine	5,306,659	17.74	1,949,773	18.02	3,356,886	17.57	-0.45
Neurology	645,101	12.94	247,361	13.45	397,740	12.63	-0.82
Surgical	2,612,093	10.49	963,114	10.56	1,648,979	10.45	-0.11

Table D.2: Number and Prevalence of Demographic and Risk-Adjustment Variables in the Study Cohort for the July 1, 2018 – June 30, 2019 Reporting Period, MA admissions versus FFS Admissions

Description	FFS+MA, n (Total N=11,029,470)	FFS+MA (%)	MA, n (Total N=4,077,633)	MA (%)	FFS, n (Total N=6,951,837)	FFS (%)	%FFS - %MA
Demographics							
Age, mean (SD)	77.66	8.15	77.32	7.86	77.86	8.31	0.55
Risk Variables							
Metastatic cancer/acute leukemia (CC 8)	387,327	3.51	136,660	3.35	250,667	3.61	0.25
Severe Cancer (CC 9, 10)	587,156	5.32	206,319	5.06	380,837	5.48	0.42
Other cancers (CC 11-14)	726,388	6.59	260,895	6.40	465,493	6.70	0.30
Severe hematological disorders (CC 46)	88,842	0.81	29,312	0.72	59,530	0.86	0.14
Coagulation defects and other specified hematological disorders (CC 48)	427,044	3.87	147,051	3.61	279,993	4.03	0.42
Iron deficiency or other unspecified anemia and blood disease (CC 49)	4,441,522	40.27	1,582,949	38.82	2,858,573	41.12	2.30
End-stage liver disease (CC 27, 28)	300,296	2.72	112,428	2.76	187,868	2.70	-0.05
Pancreatic disease (CC 34, 36)	633,290	5.74	216,518	5.31	416,772	6.00	0.69
Dialysis status (CC 134)	189,442	1.72	54,422	1.33	135,020	1.94	0.61
Acute renal failure (CC 135-140)	3,866,945	35.06	1,425,848	34.97	2,441,097	35.11	0.15
Transplants (CC 132, 186)	84,275	0.76	22,155	0.54	62,120	0.89	0.35
Severe Infection (CC 1, 3-6)	122,558	1.11	43,832	1.07	78,726	1.13	0.06
Other infectious disease & pneumonias (CC 7, 114-116)	1,989,439	18.04	676,909	16.60	1,312,530	18.88	2.28
Septicemia/shock (CC 2)	722,481	6.55	244,358	5.99	478,123	6.88	0.89
CHF (CC 85)	1,967,563	17.84	688,258	16.88	1,279,305	18.40	1.52
Coronary atherosclerosis or angina, cerebrovascular disease (CC 86-89, 102, 105-109)	5,010,738	45.43	1,802,070	44.19	3,208,668	46.16	1.96
Specified arrhythmias (CC 96, 97)	1,877,253	17.02	627,875	15.40	1,249,378	17.97	2.57
Cardiorespiratory failure or cardiorespiratory shock (CC 84)	1,165,410	10.57	404,634	9.92	760,776	10.94	1.02
Coronary obstructive pulmonary disease (COPD) (CC 111)	2,859,202	25.92	1,050,950	25.77	1,808,252	26.01	0.24

Description	FFS+MA, n (Total N=11,029,470)	FFS+MA (%)	MA, n (Total N=4,077,633)	MA (%)	FFS, n (Total N=6,951,837)	FFS (%)	%FFS - %MA
Fibrosis of lung or other chronic lung disorders (CC 112)	317,368	2.88	111,656	2.74	205,712	2.96	0.22
Protein-calorie malnutrition (CC 21)	1,182,355	10.72	417,123	10.23	765,232	11.01	0.78
Disorders of fluid, electrolyte, acid-base (CC 23, 24)	2,316,613	21.00	785,254	19.26	1,531,359	22.03	2.77
Rheumatoid arthritis and inflammatory connective tissue disease (CC 40)	587,349	5.33	199,193	4.89	388,156	5.58	0.70
Diabetes mellitus (CC 17-19, 122, 123)	4,210,807	38.18	1,635,742	40.11	2,575,065	37.04	-3.07
Ulcers (CC 157-161)	529,873	4.80	184,435	4.52	345,438	4.97	0.45
Hemiplegia, paraplegia, paralysis, functional disability (CC 70,71, 73,74, 103,104, 189,190)	498,498	4.52	168,402	4.13	330,096	4.75	0.62
Seizure disorders and convulsions (CC 79)	439,808	3.99	150,421	3.69	289,387	4.16	0.47
Respirator dependence/tracheostomy status (CC 82)	29,887	0.27	9,784	0.24	20,103	0.29	0.05
Drug and alcohol disorders (CC 54, 55)	329,407	2.99	124,296	3.05	205,111	2.95	-0.10
Psychiatric comorbidity (CC 57-59, 61, 63)	2,957,433	26.81	1,031,480	25.30	1,925,953	27.70	2.41
Hip fracture/dislocation (CC 170)	164,253	1.49	52,733	1.29	111,520	1.60	0.31

Model Performance

C-statistics and predictive ability for the combined FFS+MA cohort versus FFS-only are presented in Table D.3. The c-statistics for the combined cohort ranged from 0.60 – 0.69 for each of the five specialty cohorts and were similar to the FFS-only cohort. Predictive ability was also similar between the combined FFS+MA and FFS-only cohorts.

Table D.3: Predictive Ability and C-Statistics for Admission-Level Models for the Combined FFS+MA Cohort and in the FFS-Only Cohort by Specialty Cohort, Reporting Period July 1, 2018-June 30, 2019

Specialty Cohort	Combined FFS+MA Cohort		FFS-Only Cohort	
	Predictive Ability % (lowest decile – highest decile)	c-statistic	Predictive Ability % (lowest decile – highest decile)	c-statistic
Cardiorespiratory	10.5 – 28.6	0.60	10.3 – 28.6	0.60
Cardiovascular	8.0 – 25.6	0.62	7.3 – 25.7	0.63
Medicine	9.6 – 29.2	0.61	9.2 – 29.3	0.62
Neurology	7.9 – 22.4	0.60	6.7 – 22.5	0.62
Surgical	2.3 - 24	0.69	2.2 - 24	0.70

Measure Reliability

Signal-to-noise reliability (STNR) for the measure score including MA admissions (FFS+MA) and without including MA admissions (FFS-only) for the five specialty cohorts is noted in Table D.4. Between hospital variance ranged from 0.024-0.034 across specialty cohorts for the combined FFS+MA cohort, and was similar for the FFS-only cohort. Median STNR, calculated based on between hospital variance and hospital volume, for the combined FFS+MA cohort was higher than for the FFS-only cohort among each of the specialty cohorts. Test-retest reliability for the overall cohort was 0.780 in the combined FFS+MA cohort versus 0.725 in the FFS-only cohort.

Table D.4: Signal-to-Noise Reliability (STNR) and Between Hospital Variance for Hospitals in the Combined FFS+MA Cohort and in the FFS-Only Cohort in the July 1, 2018 – June 30, 2019 Reporting Period (for hospitals with 25 or more admissions)

Specialty Cohort	Combined FFS+MA Cohort					FFS-only Cohort				
	N1*	Median	25% Q1	75% Q3	Between Hospital Variance	N2*	Median	25% Q1	75% Q3	Between Hospital Variance
Cardiorespiratory	4,043	0.643	0.424	0.803	0.029	3,886	0.543	0.360	0.721	0.029
Cardiovascular	2,858	0.667	0.401	0.809	0.025	2,602	0.544	0.317	0.705	0.021
Medicine	4,328	0.822	0.538	0.935	0.026	4,242	0.735	0.471	0.892	0.024
Neurology	2,539	0.631	0.424	0.775	0.034	2,265	0.549	0.382	0.703	0.035
Surgical	3,286	0.762	0.519	0.887	0.024	3,165	0.663	0.425	0.828	0.023

*N1: Number of hospitals with at least 25 FFS+MA admissions; N2: number of hospitals with at least 25 FFS admissions.

Risk-Standardized Readmission Rates

Tables D.5 and D.6 present distribution of hospital volume, SRR, and RSRR for all hospitals (Table D.5) and for hospitals with 25 or more eligible admissions within each specialty cohort, the cutoff used for public reporting of the HWM measure (Table D.6). For each specialty cohort, and for the combined HWR cohort, numbers of hospitals and admissions were higher in the combined FFS+MA data compared to the FFS-only data for all hospitals. With the addition of MA data, 127 additional hospitals were included in the measure (including all hospitals) (Table D.5). In hospitals with 25 or more admissions, the addition of MA data resulted in 63 additional hospitals (Table D.6). Total risk-standardized readmission rates were slightly higher for the FFS+MA cohort compared to the FFS-only cohort (15.48% versus 15.35% both for all hospitals and for hospitals with 25 or more admissions. This trend was seen across all specialty cohorts (Tables D.5 and D.6).

Table D.5: Hospital Volume, Standardized Readmission Ratio (SRR), and Risk-Standardized Readmission Rate (RSRR) for Combined FFS+MA Cohort and for FFS- Only Cohort in the July 1, 2018 – June 30, 2019 Reporting Period, Overall and by Specialty Cohort, for all hospitals

Specialty Cohort	Value	Combined FFS+MA Cohort						FFS-Only Cohort					
		Number of hospitals	Mean	Std Dev	25% Q1	Median	75% Q3	Number of hospitals	Mean	Std Dev	25% Q1	Median	75% Q3
Cardio-respiratory	Hospital Volume	4,586	285	328	56	157	423	4,479	185	207	45	106	261
	SRR	4,586	1.00	0.09	0.95	0.99	1.05	4,479	1.00	0.08	0.95	0.99	1.04
	RSRR	4,586	**18.47%**	1.66%	17.46%	**18.31%**	19.30%	4,479	**18.31%**	1.5%	17.42%	**18.16%**	19.05%
Cardio-vascular	Hospital Volume	4,391	264	394	12	80	382	4,290	167	249	10	50	237
	SRR	4,391	1.00	0.07	0.97	1.00	1.03	4,290	1.00	0.06	0.98	1.00	1.03
	RSRR	4,391	**14.55%**	1.03%	14.12%	**14.49%**	14.98%	4,290	**14.31%**	0.8%	13.97%	**14.26%**	14.66%
Medicine	Hospital Volume	4,742	1,119	1531	103	445	1,681	4,617	727	968	89	304	1,059
	SRR	4,742	1.00	0.10	0.95	0.99	1.05	4,617	1.00	0.09	0.95	1.00	1.05
	RSRR	4,742	**17.80%**	1.81%	16.78%	**17.64**%	18.69%	4,617	**17.62%**	1.66%	16.71%	**17.49%**	18.44%
Neurology	Hospital Volume	4,333	148.88	224	9	46	206	4,224	94	140	8	31	125
	SRR	4,333	1.00	0.08	0.97	0.99	1.03	4,224	1.00	0.07	0.97	0.99	1.03
	RSRR	4,333	**12.97%**	1.03%	12.50%	**12.87%**	13.33%	4,224	**12.66%**	0.91%	12.25%	**12.56%**	12.98%
Surgical	Hospital Volume	3,995	654	942	54	281	861	3,909	422	624	41	176	534
	SRR	3,995	1.00	0.08	0.96	1.00	1.04	3,909	1.00	0.07	0.96	1.00	1.03
	RSRR	3,995	**10.52%**	0.8%	10.05%	**10.45%**	10.90%	3,909	**10.47%**	0.77%	10.07%	**10.42%**	10.82%
Total*	Hospital Volume	4,782	2,306	3,232	203	863	3,359	4,655	1,493	2,057	172	593	2,091
	SRR	4,782	1.00	0.08	0.95	0.99	1.04	4,655	1.00	0.08	0.96	0.99	1.03
	RSRR	4,782	**15.48%**	1.28%	14.79%	**15.40%**	16.06%	4,655	**15.35%**	1.15%	14.74%	**15.26%**	15.86%

*Includes all specialty cohorts

Table D.6: Hospital Volume, Standardized Readmission Ratio (SRR), and Risk-Standardized Readmission Rate (RSRR) for Combined FFS+MA Cohort and for FFS-Only Cohort in the July 1, 2018 – June 30, 2019 Reporting Period, Overall and by Specialty Cohort, for hospitals with 25 or more admissions in the corresponding specialty cohort

Specialty Cohort	Value	Combined FFS+MA Cohort						FFS-Only Cohort					
		Number of hospitals	Mean	Std Dev	25% Q1	Median	75% Q3	Number of hospitals	Mean	Std Dev	25% Q1	Median	75% Q3
Cardio-respiratory	Hospital Volume	4,043	322	333	83	203	460	3,886	212	210	64	135	294
	SRR	4,043	1.0036	0.10	0.94	0.99	1.06	3,886	1.00	0.09	0.95	0.99	1.05
	RSRR	4,043	**18.49%**	1.75%	17.34%	**18.30%**	19.45%	3,886	**18.33%**	1.59%	17.31%	**18.17%**	19.17%
Cardio-vascular	Hospital Volume	2,858	401	430	89	267	562	2,602	270	274	71	183	365
	SRR	2,858	1.0020	0.09	0.95	1.00	1.05	2,602	1.00	0.07	0.96	1.00	1.04
	RSRR	2,858	**14.55%**	1,26%	13.78%	**14.48%**	15.28%	2,602	**14.30%**	1.01%	13.68%	**14.26%**	14.87%
Medicine	Hospital Volume	4,328	1225	1561	149	592	1840	4,242	790	985	122	380	1129
	SRR	4,328	1.0041	0.11	0.94	0.99	1.06	4,242	1.00	0.10	0.95	1.00	1.06
	RSRR	4,328	**17.81%**	1.89%	16.67%	**17.64%**	18.80%	4,242	**17.63%**	1.72%	16.61%	**17.50%**	18.54%
Neurology	Hospital Volume	2,539	248	248	72	167	337	2,265	168	156	59	116	226
	SRR	2,539	1.0054	0.10	0.94	0.99	1.06	2,265	1.00	0.09	0.95	0.99	1.05
	RSRR	2,539	**13.01%**	1.31%	12.16%	**12.87%**	13.74%	2,265	**12.68%**	1.20%	11.94%	**12.56%**	13.30%
Surgical	Hospital Volume	3,286	793	984	148	440	1074	3,165	519	657	104	277	677
	SRR	3,286	1.0027	0.09	0.95	0.99	1.05	3,165	1.00	0.08	0.95	1.00	1.05
	RSRR	3,286	**10.52%**	0.96%	9.93%	**10.43%**	11.05%	3,165	**10.48%**	0.85%	9.96%	**10.41%**	10.95%
Total*	Hospital Volume	4,563	2,417	3,269	253	995	3,546	4,500	1544	2073	200	650	2172
	SRR	4,563	1.0000	0.08	0.95	0.99	1.04	4,500	1.00	0.08	0.96	0.99	1.04
	RSRR	4,563	**15.48%**	1.31%	14.74%	**15.38%**	16.11%	4,500	**15.35%**	1.17%	14.71%	**15.25%**	15.89%

*Includes all specialty cohorts

Change in Hospital Performance

Table D.7 shows the quintile shifts in RSRR across hospitals in the combined MA+FFS cohort as compared to the FFS only cohort in hospitals with at least 25 FFS admissions. As a percentage of MA patients, correlations between quintiles ranged from 0.81-0.99. As a percentage of overall hospital volume, correlations between quintiles ranged from 0.89-0.94. After the addition of MA admissions to the FFS-only HWR measure, about two thirds (66.9%) of hospitals remained in their same performance quintile, and 95.4% remained within +/- 1 quintile. The correlation between hospital RSRRs was 0.92. As hospitals' percent of MA admissions increased, fewer hospitals remained within the same performance quintile (83.7% among hospitals in the lowest quintile of percent MA admissions; 54.7% of hospitals in the highest quintile of percent of MA admissions). As hospital volume increased, trends in RSRR shifts were not as marked (74.5% of hospitals in lowest volume quintile remained in same RSRR performance quintile; 65.9% of hospitals in highest volume quintile). We found a weak but statistically significant correlation between change of RSRR and proportion of MA admissions (0.055, $p<0.01$), and also a weak but statistically significant correlation between change of RSRR and hospital volume (0.050, $p<0.01$).

Table D.7: Shifts in RSRR quintiles comparing FFS-only cohort to the combined FFS+MA cohort, by quintiles of hospitals' percent of MA admissions and total (MA and FFS) admission volume for hospitals with 25 or more FFS admissions (N = 4,500)

Description	Same quintile	+1 quintile	Correlation
Overall	66.91%	95.42%	0.92
By Percent of MA admissions			
Q1: 0.00% - 12.51%	83.67%	99.89%	0.99
Q2: 12.51% - 23.37%	71.89%	98.78%	0.96
Q3: 23.39% - 32.39%	65.11%	96.33%	0.93
Q4: 32.41% - 44.01%	59. 22%	94.22%	0.91
Q5: 44.03% - 95.88%	54.67%	87.89%	0.81
By MA+FFS Admission Volume			
Q1: 25 - 198 admissions	74.53%	99.00%	0.93
Q2: 199 - 583 admissions	67.00%	95.78%	0.89
Q3: 584 - 1842 admissions	62.49%	94.67%	0.94
Q4: 1844 - 4321 admissions	64.67%	94.11%	0.90
Q5: 4325 - 40801 admissions	65.89%	93.56%	0.90

Summary: Integrating MA Data into the HWR Measure

Using data from July 1, 2018 – June 30, 2019, we calculated results from the MA claims to compare to the FFS-only results. The inclusion of MA admissions added 127 hospitals and more than four million admissions to the HWR cohort during the data period tested. When considering only hospitals with 25 or more eligible admissions, the cutoff used for public reporting of the HWR measure, the inclusion of MA data resulted in 63 additional hospitals in the measure. Observed (unadjusted) readmission within 30 days was higher for MA-only admissions than for FFS-only admissions (15.72 versus 15.35%), with comorbidities generally lower among MA beneficiaries. The mean risk-standardized readmission rate was slightly higher for the combined FFS+MA cohort compared to the FFS-only cohort (15.48 versus 15.35% for hospitals with 25 or more admissions). This trend was seen across all specialty cohorts. Test-retest

reliability for the combined FFS+MA cohort was higher than for the FFS-only cohort (0.780 versus 0.725 among hospitals with 25 or more admissions). After the addition of MA admissions to the FFS-only HWR measure and among hospitals with 25 or more FFS admissions, about two thirds (67%) of hospitals remained in their same performance quintile, and 95% remained within +/- one quintile. The correlation between hospital RSRRs was 0.92.

The addition of MA admissions into the CMS HWR measure improved reliability, improved the precision of measure scores, and led to more hospitals and beneficiaries included in the measure. Most hospitals remained in their same performance quintile after the addition of MA admissions, with the greatest shifts seen in hospitals with a high percentage of MA admissions. The inclusion of MA beneficiaries into the claims-based HWR measure addresses stakeholder concerns about differences in quality for MA and FFS beneficiaries by ensuring hospital outcomes are measured across all Medicare beneficiaries.

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