

**Hybrid Hospital-Wide Readmission Measure with Electronic Health
Record Extracted Risk Factors
(Version 1.1)**

Submitted By

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1. INTRODUCTION

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 [electronic health records \(EHRs\)](#) could be used to reengineer and enhance the Hospital-Wide All-Cause Unplanned Readmission (HWR) measure¹. Under contract with CMS, CORE had previously identified a set of [core clinical data elements](#) (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 care². 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 [eSpecified](#), 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 stay⁵. 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.

Inclusion and Exclusion Criteria

The inclusion and exclusion criteria for [index admissions](#), 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 ([Table A.1](#)).
- **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 ([Table A.3](#)). 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 [Medicare fee-for-service \(FFS\)](#) population, refer to [Appendix A](#).

Transfers between Hospitals

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.

Development and Testing Samples

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.

Specialty Cohort Assignment

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).

Risk-Adjustment Variables Tested in the Hybrid eHWR Measure

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:*
 - Service mix: Agency for Healthcare Research and Quality (AHRQ) [Clinical Classification Software](#) (CCS) categories for patients' principal discharge diagnoses ([Appendix A](#))
 - Case mix: CMS [Condition Categories \(CCs\)](#) for patients' [comorbidities](#) captured during hospitalizations in the 12 months prior to and including the index admission ([Table A.8](#))
2. *CCDE with Original HWR (Hybrid eHWR):*
 - Service mix: Agency for Healthcare Research and Quality (AHRQ) Clinical Classification Software (CCS) categories for patients' principal discharge diagnoses
 - Case mix: 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:*
 - Service mix: Agency for Healthcare Research and Quality (AHRQ) Clinical Classification Software (CCS) categories for patients' principal discharge diagnoses
 - Case mix: CCDE only
4. *CCDE Alone:*
 - Service mix: None
 - Case mix: 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 reporting².

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 |
| 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 analysis².

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 i^{th} 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 hospitals⁸. 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:

$$\begin{aligned} \text{logit}(\text{Prob}(Y_{ij} = 1)) &= \alpha_j + \boldsymbol{\theta}^* \mathbf{Z}_{ij} + \varepsilon_{ii} \\ \alpha_j &= \mu + \omega_j ; \omega_j \sim N(0, \tau^2) \end{aligned} \tag{1}$$

where $\mathbf{Z}_{ij} = (Z_1, Z_2, \dots, Z_k)$ 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 $C=1, \dots, 5$ at hospital j , we used

$$\text{pred}_{cj} = \sum \text{logit}^{-1}(\alpha_j + \boldsymbol{\theta}^* \mathbf{Z}_{ij}) \quad (2)$$

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

$$\text{exp}_{cj} = \sum \text{logit}^{-1}(\mu + \boldsymbol{\theta}^* \mathbf{Z}_{ij}) \quad (3)$$

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

$$\text{SRR}_{cj} = \text{pred}_{cj} / \text{exp}_{cj} \quad (4)$$

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 $C \subseteq \{1, \dots, 5\}$, 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 $\text{SRR}_{cj} = 1$. Then, calculate the volume-weighted logarithmic mean:

$$\text{SRR}_j = \exp((\sum m_{cj} \log(\text{SRR}_{cj})) / \sum m_{cj}) \quad (5)$$

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)**.

$$\text{RSRR}_j = \text{SRR}_j * \bar{Y} \quad (6)$$

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 agreement¹⁰.

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

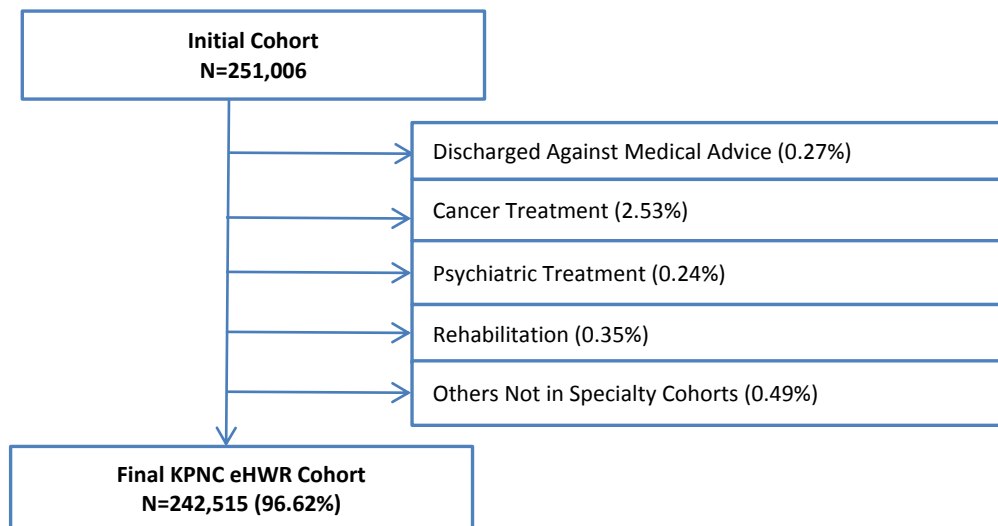


Table 3.1: Index Admissions by Specialty Cohort

| 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

| | 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 |

| | Development Sample | Validation Sample | 2012 Sample |
|---------------------------------------|--------------------|-------------------|-------------|
| 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 |
| 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 |

| | Development Sample | Validation Sample | 2012 Sample |
|---------------------------------|--------------------|-------------------|-------------|
| 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)

| | 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) |
| Medicine | 84 (47-146) | 84 (47-145) | 85 (48-147) |
| Systolic Blood Pressure (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) |

| | Development Sample | Validation Sample | 2012 Sample |
|--|--------------------|-------------------|-------------------|
| 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 (°F) | | | |
| 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) |
| White Blood Cell 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) |
| 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) |

* Weight in the KPNC system was collected and exported in ounces and then converted to pounds.

| | Development Sample | Validation Sample | 2012 Sample |
|-----------------------------|--------------------|-------------------|------------------|
| 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/L) | | | |
| 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)

| | 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

| | Hybrid eHWR Development Sample | Hybrid eHWR Validation Sample | Hybrid eHWR 2012 Sample |
|--|--------------------------------|-------------------------------|-------------------------|
| Calibration (γ_0, γ_1) | | | |
| 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% |

| Distribution of Model Residuals (%) | Hybrid eHWR Development Sample | Hybrid eHWR Validation Sample | Hybrid eHWR 2012 Sample |
|-------------------------------------|--------------------------------|-------------------------------|-------------------------|
| Medicine | | | |
| <-2 | 0.0% | 0.0% | 0.0% |
| [-2,0 | 81.6% | 81.8% | 83.3% |
| [0,2] | 9.2% | 9.1% | 7.7% |
| [2+ | 9.2% | 9.1% | 9.0% |

3.5 MEASURE TESTING

Reliability of Measure Components and Results

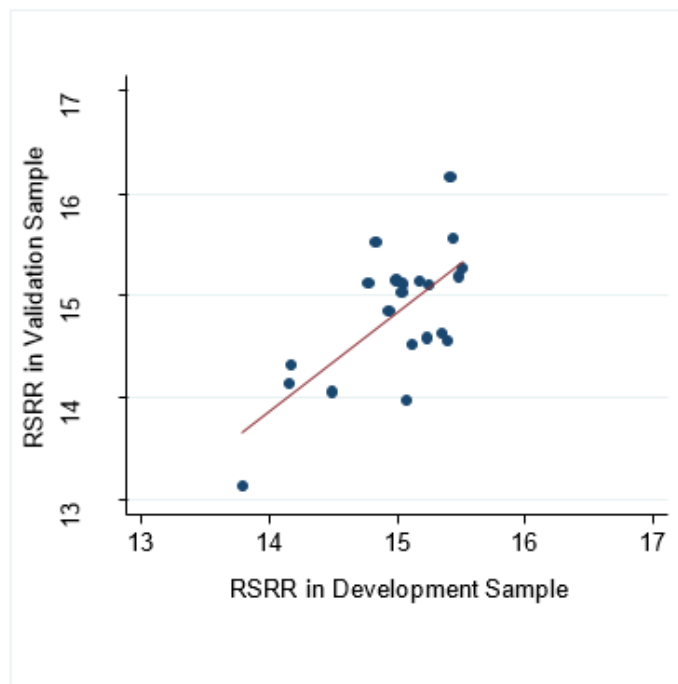
The internal consistency among SRRs for the specialty cohorts was high as indicated by the Cronbach's α of 0.83 for both the Hybrid eHWR measure as well as the Original HWR measure ([Table 3.9](#)) indicating an excellent internal consistency among the SRRs for the five specialty cohorts.

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)

| | 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.

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7. APPENDICES

APPENDIX A: HYBRID eHWR MEASURE SPECIFICATIONS FOR MEDICARE FFS POPULATION

Cohort

Inclusion Criteria for HWR Measure

1. Enrolled in Medicare FFS

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

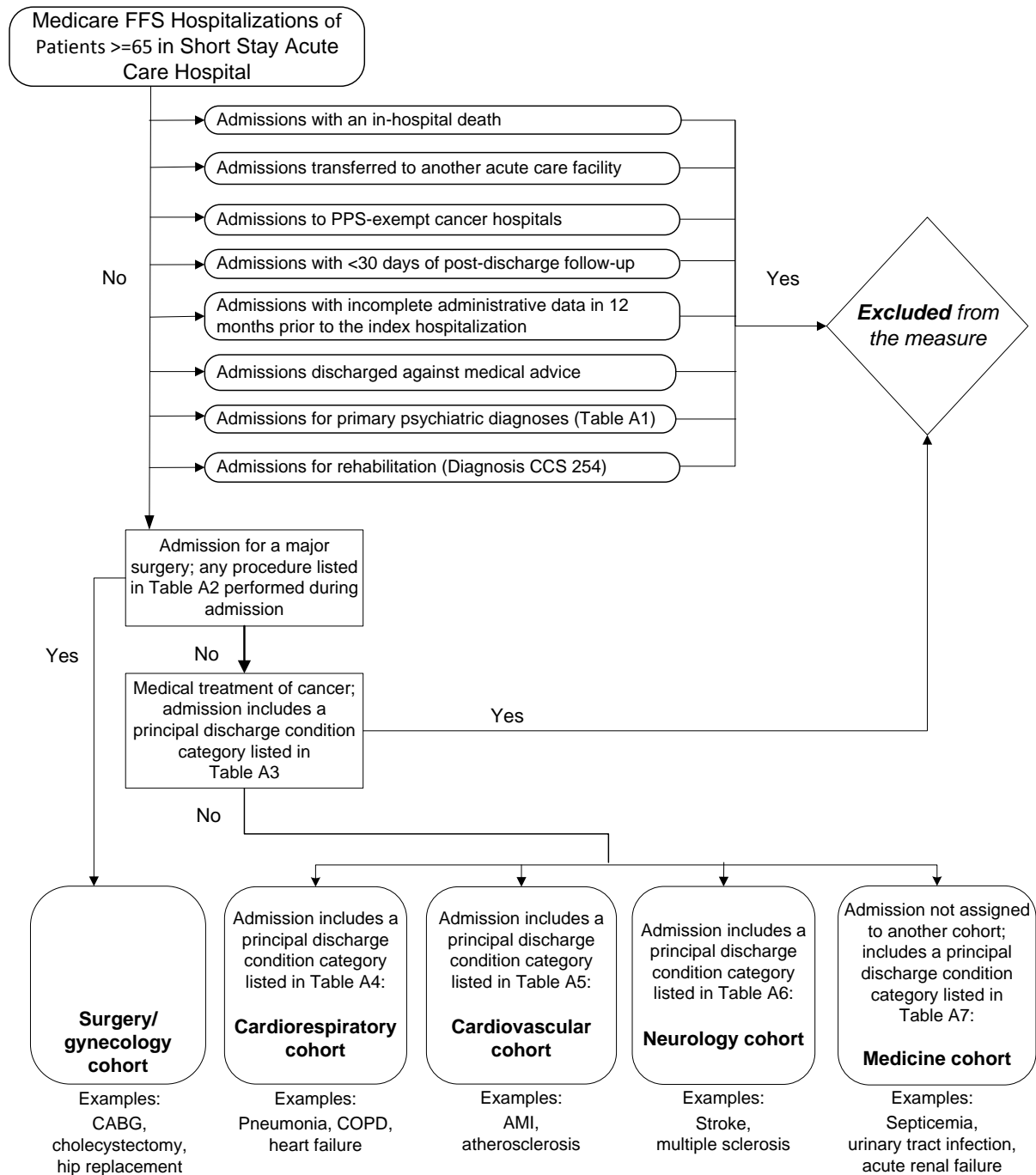


Table A.1: Psychiatric Discharge Diagnosis Categories Excluded from the Measure

| 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 |

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

| AHRQ Procedure CCS | Description |
|--------------------------|---|
| 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 |
| 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 |

| AHRQ Procedure CCS | Description |
|--------------------------|---|
| 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 |
| 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 |

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 |

| AHRQ Diagnosis CCS | Description |
|--------------------------|---|
| 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 |
| 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 |

| AHRQ Diagnosis CCS | Description |
|-----------------------|---|
| 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 |
| 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 |

| AHRQ Diagnosis CCS | Description |
|-----------------------|---|
| 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 |
| 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 |

| AHRQ Diagnosis CCS | Description |
|-----------------------|--|
| 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 |
| 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 |

| AHRQ Diagnosis CCS | Description |
|-----------------------|---|
| 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 |
| 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 |

| AHRQ Diagnosis CCS | Description |
|-----------------------|--|
| 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 |

| Variable | Description |
|----------|--|
| 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 |
| 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 |

| Variable | Description |
|----------|--|
| 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 |
| 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 |

| Variable | Description |
|----------|--|
| 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 |
| 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 |

| Variable | Description |
|----------|--|
| 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 |
| 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 |

| Variable | Description |
|----------|---|
| 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 |
| 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 |

| Variable | Description |
|----------|--|
| CC 95 | Cerebral Hemorrhage |
| CC 96 | Ischemic or Unspecified Stroke |
| CC 97 | Precerebral Arterial Occlusion and Transient Cerebral Ischemia |
| CC 100 | Hemiplegia/Hemiparesis |
| CC 101 | Diplegia (Upper), Monoplegia, and Other Paralytic Syndromes |
| CC 102 | Speech, Language, Cognitive, Perceptual |
| CC 104 | Vascular Disease with Complications |
| CC 105 | Vascular Disease |
| CC 106 | Other Circulatory Disease |
| CC 111 | Aspiration and Specified Bacterial Pneumonias |
| CC 112 | Pneumococcal Pneumonia, Emphysema, Lung Abscess |
| CC 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 time frame

Rationale: Outcomes occurring within 30 days of discharge can be influenced by hospital care and the early transition to outpatient settings. The use of the 30-day time frame is a clinically meaningful period for hospitals to collaborate with their communities to reduce readmissions.

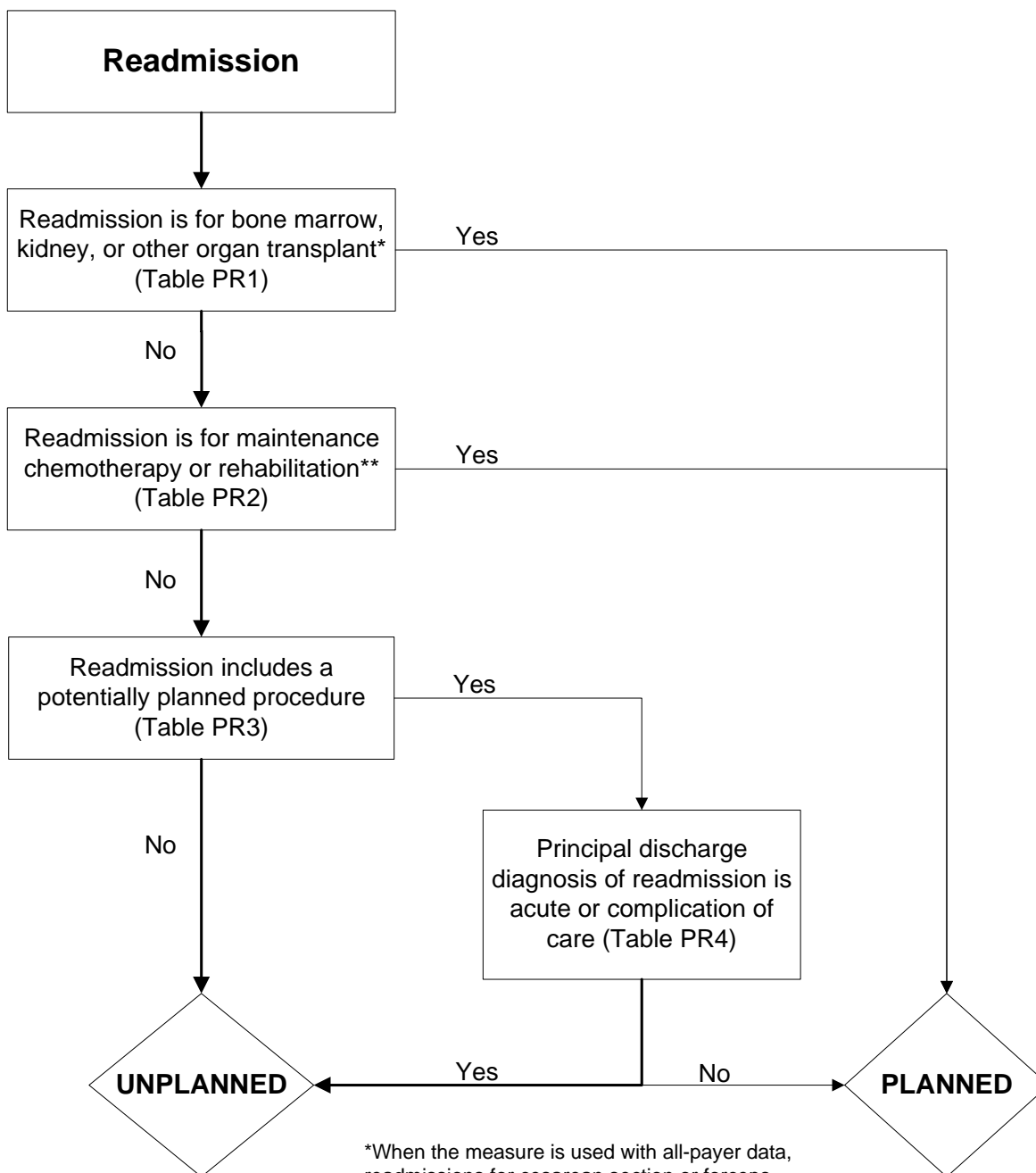
2. All-cause readmission

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



*When the measure is used with all-payer data, readmissions for cesarean section or forceps, vacuum, or breech delivery are considered planned

**When the measure is used with all-payer data, readmissions for forceps or normal delivery are considered planned

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 |

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 |

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 |

[†] 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.

[‡] 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.

[§] 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.

^{**} 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.

| Procedure CCS | Description |
|--|--|
| 55 | Peripheral vascular bypass |
| 56 | Other vascular bypass and shunt; not heart |
| 59 | Other OR procedures on vessels of head and neck |
| 62 | Other diagnostic cardiovascular procedures |
| 66 | Procedures on spleen |
| 67 | Other therapeutic procedures; hemic and lymphatic system |
| 74 | Gastrectomy; partial and total |
| 78 | Colorectal resection |
| 79 | Local excision of large intestine lesion (not endoscopic) |
| 84 | Cholecystectomy and common duct exploration |
| 85 | Inguinal and femoral hernia repair |
| 86 | Other hernia repair |
| 99 | Other OR gastrointestinal therapeutic procedures |
| 104 | Nephrectomy; partial or complete |
| 106 | Genitourinary incontinence procedures |
| 107 | Extracorporeal lithotripsy; urinary |
| 109 | Procedures on the urethra |
| 112 | Other OR therapeutic procedures of urinary tract |
| 113 | Transurethral resection of prostate (TURP) |
| 114 | Open prostatectomy |
| 119 | Oophorectomy; unilateral and bilateral |
| 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 |

| Diagnosis CCS | Description |
|--|--|
| 661 | Substance-related disorders |
| 662 | Suicide and intentional self-inflicted injury |
| 663 | Screening and history of mental health and substance abuse codes |
| 670 | Miscellaneous disorders |
| ICD-9 codes | Description |
| Acute ICD-9 codes within 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 capssulatum 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 |

| Diagnosis CCS | Description |
|---|---|
| 429.0 | Myocarditis nos |
| Acute ICD-9 codes within Dx CCS 105: Conduction disorders | |
| 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 |

| Diagnosis CCS | Description |
|--|---|
| 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 |
| 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) | | | |
|---|--|----------------|------------------|-----------------------|---|----------------|-----------------|-----------------------|
| | 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% |

| 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 |
| Complications of surgical procedures or medical care (CCS 238) | Reference | Reference | Reference | 2.5% | Reference | Reference | Reference | 2.8% |
| Comorbidity | | | | | | | | |
| 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, 111-113) | 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% |

| 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 |
| 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% |
| 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 Name | Hybrid eHWR Development Sample (N=9,261) | | | | Hybrid eHWR Validation Sample (N=9,364) | | | |
|---|---|----------------|------------------|--------------------|--|----------------|-----------------|--------------------|
| | 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% |

| 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 |
| 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% |
| 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% |

| 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 |
| 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% |
| 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 Name | Hybrid eHWR Development Sample (N=8,108) | | | | Hybrid eHWR Validation Sample (N=8,037) | | | |
|---|---|----------------|-----------------|--------------------|--|----------------|-----------------|--------------------|
| | 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(0.84-1.31) | 22.7% | -0.145 | 0.113 | 0.86(0.69-1.08) | 21.1% |
| 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 | | | | | | | | |

| 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 |
| 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% |
| 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% |

| 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 |
| 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% |
| 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 | | | | | | | | |
| 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% |

| 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 |
| 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% |
| 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% |

| 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 |
| 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% |

| 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 |
| 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% |
| 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, 111-112) | -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% |
| 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% |

| 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 |
| 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 eQMs)
 - 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.