Draft 2014 Reengineered Hospital-Wide All-Cause Unplanned Readmission Measure: Claims and EHR Data Hybrid

(Version 1.0)

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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) measure[1]. 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 investigating whether the CCDE can be used to enhance the HWR measure risk-adjustment methodology.

Version 1.0 of the CCDE consists of patients' gender, age, weight, the first set of vital signs captured within 2 hours of the start of the episode of care, and the results of the first complete blood count and basic chemistry panel drawn within 24 hours of the start of the episode of care[2]. Preliminary work had established that the CCDE could be used to risk adjust measures of 30-day mortality across a variety of common and costly medical conditions[2]. 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.

To reengineer the original HWR measure, we considered a hybrid approach that links the patient-level EHR data to 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 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 tested these two models with the understanding that these 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 the 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 Hospital-Wide All-Cause Unplanned Readmission Hybrid eMeasure (HWR eMeasure).

1.2 RATIONALE FOR REENGINEERING

The increased use of EHRs by hospitals provides 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 provides an opportunity to align the measure with clinical decision support systems that many providers utilize to alert care teams about patients at increased risk of poor outcomes, such as readmission, in real time during the inpatient stay[5]. Utilizing the same variables that are used to support clinical decision-making to calculate hospital performance would be clinically sensible and cost effective, as it reduces the burden of EHR data mapping and extraction required for quality reporting. In addition, 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.

In our previous work, CORE demonstrated that models of 30-day mortality that include the CCDE as predictor variables perform better than models that include only comorbidity information from claims data[2]. This was true across a variety of common and costly medical conditions such as acute myocardial infarction, heart failure, pneumonia, and stroke. By reengineering the HWR measure into a hybrid measure that uses claims and EHR data, we have an opportunity to demonstrate the utility of the CCDE for risk adjustment of readmission measures.

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.

2. METHODOLOGY

2.1 DATA SOURCE

All data used to develop the HWR eMeasure 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. The original HWR measure is specified for patients enrolled in Medicare Fee-For-Service (FFS). Kaiser's members do not participate in the FFS

program.

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 HWR eMeasure. 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 too 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.

The following inclusion criteria would be applied in a Medicare fee-for-service (FFS) population according to the original HWR measure methodology, but did not apply to the KPNC patient population: 1) Enrolled in Medicare fee-for-service (FFS); 2) Enrolled in Part A for the 12 months prior to and including the date of the index admission; and, 3) Discharged from non-federal acute care hospitals because federal status does not apply to any KPNC hospitals.

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.

The following exclusion criteria from the original HWR measure methodology would be applied in a Medicare FFS population but did not apply to the KPNC patient population: 1) Admitted to Prospective

Payment System (PPS)-exempt cancer hospitals because admissions to such hospitals were not included in the KPNC dataset; and, 2) Without at least 30 days of post-discharge enrollment in Medicare FFS.

Transfers Between Hospitals

The HWR eMeasure 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 categories using the Agency for Healthcare Research & Quality (AHRQ) Clinical Classification Software (CCS). In addition, procedure codes associated with each admission were aggregated into 231 mutually exclusive AHRQ procedure

categories. The AHRQ CCS 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 HWR eMeasure 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 was the only component of the HWR eMeasure that differed 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. 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.14).

- For service mix, the principal discharge diagnoses documented in the inpatient claims during the index admissions are used.

Refer to Table A.8 for the list of service mix risk-adjustment variables, which are common to each specialty cohort, and Table A.9, Table A.10, Table A.11, Table A.12, and Table A.13 for case mix risk-adjustment variables used in each specialty cohort. The original HWR measure 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 Respecified HWR eMeasure

The risk-adjustment variables included in the development and testing of the HWR eMeasure 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 enhance 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 more parsimonious eMeasure which included only the CCDE with no service mix adjustment. A simpler model might be easier to calculate with very few variables and could align more closely with EHR-based clinical decision support tools designed to predict patients' risk of readmission in real time. We realized 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 HWR eMeasure risk-adjustment methodology, 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:*
    - 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; and,
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.

Feasibility of the CCDE

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. The data elements in the CCDE were selected because they meet the following feasibility criteria: (1) obtained consistently under current clinical practice, (2) captured with a standard definition across providers and care settings, and (3) entered in a structured field to reduce the burden of extraction and ensure consistent reporting[2].

The CCDE is a set of 21 data elements that consists of patients' age, gender, weight, 6 vital signs captured in the EHR within the first 2 hours of arrival at the hospital, and 13 laboratory test results captured within the first 24 hours of arrival at the hospital (Table 2.1). 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: Core Clinical Data Elements (CCDE)

Clinical Data Elements	Units of Measurement	Timing of First Capture
Patient Characteristics		
Age	Years	---
Gender	Male or female	---
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
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

Clinical Data Elements	Units of Measurement	Timing of First Capture
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

Data Element Preparation

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

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

Because each of the CCDE is a set of continuous variables with the exception of gender, we examined the plots for each of the remaining 15 Winsorized data elements against the logit of the unplanned readmission outcome within each specialty cohort to ensure that the relationships conformed to clinical expectations. For example, we anticipated that within the adult population increasing age in years would have a linear relationship with greater risk of unplanned readmission. However, some data elements, such as temperature, were expected to predict greater risk of readmission at very low and very high values and to have little predictive value within the physiologically normal range. Data elements that, upon visual inspection, appeared to have a linear relationship with the outcome were included in risk adjusted regression models without transformation. For data elements with more complex relationships with the outcome, such as temperature we tested two approaches to data transformation, quadratic functions and spline terms.

We sought to select 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.

2.5 MODEL SPECIFICATION AND VALIDATION

To develop the HWR eMeasure, 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 model based on discrimination in terms of the C-statistic. The two models with lower discrimination were discarded. We completed measure development and testing only for the best-performing model containing the CCDE.

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

Specifically, for a given specialty cohort, we estimated a hierarchical logistic regression model as follows. Let Y_{ij} denote the outcome (equal to 1 if patient *i* is readmitted within 30 days, zero otherwise) for a patient in cohort C $\subseteq$ {1.,,,.5 at hospital *j*; $\mathbf{Z_{ij}}$ denotes a set of risk factors. Let *M* denote the total number of hospitals and m_j the number of index patient stays in hospital *j*. We assume the outcome is related linearly to the covariates via a logit function with dispersion:

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

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

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

Hospital performance assessment

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

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

$$pred_{Cj} = \Sigma \text{logit}^{-1}(\alpha_j + \boldsymbol{\beta}^*\mathbf{Z}_{ij}) \quad (2)$$

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

$$exp_{Cj} = \Sigma \text{logit}^{-1}(\mu + \boldsymbol{\beta}^*\mathbf{Z}_{ij}) \quad (3)$$

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

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

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 $C \subseteq \{1,\ldots,5\}$, 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 $SRR_{cj} = 1$. Then, calculate the volume-weighted logarithmic mean:

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

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 ($RSRR_j$)**.

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

We completed hierarchical modeling and calculated measure results for the best-performing model containing the CCDE, which we will refer to as the HWR eMeasure, and the original HWR model. Assessment of the HWR eMeasure performance included model calibration (to assess over-fitting), discrimination in terms of predictive ability (wide range in the distribution of model results), and distribution of model residuals. These analyses were done in the development, validation, and testing (2012) sample. 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.

To assess the internal consistency of the overall composite score and specialty cohort scores for the best-performing model, we will calculate the weighted correlations among specialty cohorts, the correlation between each specialty cohort SRR with the composite SRR, and the Cronbach's coefficient α to assess the overall internal consistency.

2.6 MEASURE TESTING

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 HWR eMeasure 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].

We considered all measure testing as preliminary due to the small sample of hospitals in the KPNC database and the lack of diversity within the integrated network of KPNC hospitals. Establishing 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 HWR EMEASURE AND ORIGINAL HWR MEASURE RESULTS

We compared the results of the original HWR measure with the results of the reengineered HWR eMeasure 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 HWR Cohort in 2010-2012 KPNC Dataset

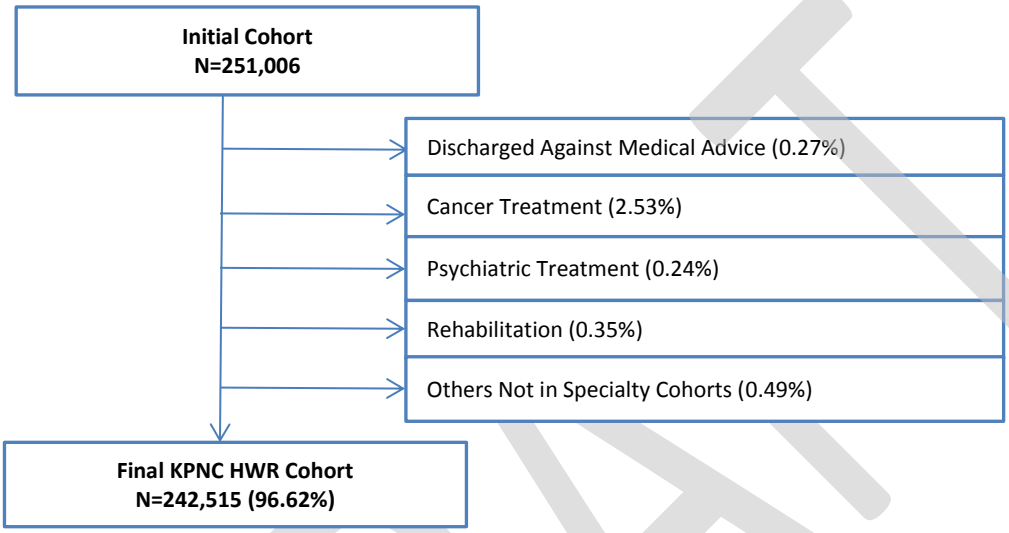


Table 3.1: Index Admissions by Specialty Cohort

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	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. 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: Rates of Capture of CCDE in Specified Timeframes by Specialty Cohort and Data Sample

	Development Sample	Validation Sample	2012 Sample
Heart rate			
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			
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			
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			
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*			
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			
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			
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			
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			
Surgery/Gynecology	79.4	80.1	78.6
Cardiorespiratory	98.5	98.4	98.9
Cardiovascular	95.3	95.3	94.9

* Capture for weight is within the first 24 hours of admission because it is not likely to change substantially during that timeframe.

	Development Sample	Validation Sample	2012 Sample
Neurology	97.8	97.8	97.9
Medicine	97.4	97.4	97.8
Potassium			
Surgery/Gynecology	70.6	71.1	70.0
Cardiorespiratory	96.8	96.5	97.1
Cardiovascular	93.6	93.6	93.5
Neurology	96.1	95.9	95.8
Medicine	95.6	95.6	95.8
Sodium			
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			
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			
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			
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 percentile-99th percentile)

	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)

	Development Sample	Validation Sample	2012 Sample
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)
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 (^{o}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)

[†] Weight in the KPNC system was collected and exported in ounces and then converted to pounds.

	Development Sample	Validation Sample	2012 Sample
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)
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 logisitic 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-Statistic Comparisons across 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 HWR eMeasure. 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 HWR eMeasure 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 HWR eMeasure are shown in Table 3.6.

Table 3.6: SRR & RSRR Distribution by Specialty Cohort for the HWR eMeasure (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 HWR eMeasure

Examination of the performance of the HWR eMeasure 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). 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

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

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

Distribution of Model Residuals (%)	HWR eMeasure Development Sample	HWR eMeasure Validation Sample	HWR eMeasure 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%

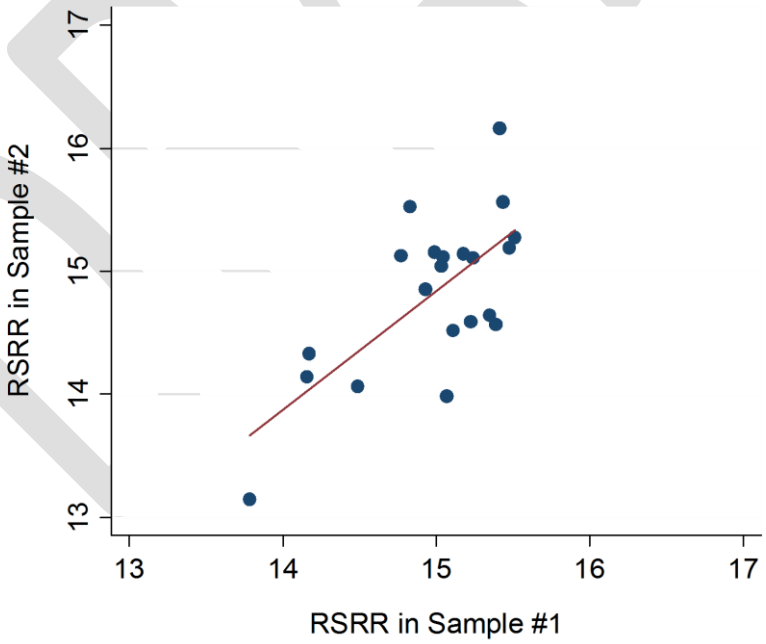
Distribution of Model Residuals (%)	HWR eMeasure Development Sample	HWR eMeasure Validation Sample	HWR eMeasure 2012 Sample
[2+	7.1%	7.3%	7.2%
Neurology			
<-2	0.0%	0.0%	0.0%
[-2,0	87.2%	86.8%	88.1%
[0,2]	4.4%	4.9%	4.0%
[2+	8.4 %	8.3%	7.9%
Medicine			
<-2	0.0%	0.0%	0.0%
[-2,0	81.6%	81.8%	83.3%
[0,2]	9.2%	9.1%	7.7%
[2+	9.2%	9.1%	9.0%

3.5 MEASURE TESTING

Reliability of Measure Components and Results

When comparing the hospitals' RSRRs in the development and validation samples for the HWR eMeasure, 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 HWR EMEASURE RESULTS

The original HWR measure was also calculated to compare with the HWR eMeasure results.
The standardized risk ratios and risk standardized readmission rates were highly correlated between

the two models (Table 3.9). Ranking of hospitals based on the composite RSRRs differed only slightly by measure. Ranking tended to shift up or down by one or two positions on the list (Table 3.10).

Table 3.9: Correlation of Original HWR and HWR eMeasure 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 3.10: Hospital Rankings by Risk Model Approach (Development Sample)

Hospital ID	Original HWR		HWR eMeasure	
	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 Hospital-Wide All-Cause Unplanned Readmission measure to include clinical data from patients' EHRs to adjust for the risk of readmission. We used a 3-year dataset to develop and evaluate a statistical model of all-cause unplanned readmission. The dataset consisted of all acute-care hospital admissions to the 21 hospitals in the KPNC network for patients who were 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 HWR eMeasure represents and important innovation in hospital outcome measures in two areas.

- It responds to the preference of many providers and other stakeholders that physiological clinical data be used to adjust for patient-level factors in hospital outcome measures. By including the CCDE into the risk adjustment methodology, we have taken the first step toward outcome measures that rely, on physiological information captured in real time. This is the same data that clinicians use to assess how sick their patients are and to guide their treatment plans. This alignment tends to make sense to providers and gives face validity to the measures, and might eventually lead to measures that can be reported in real-time.
- It provides new efficiencies in measure development and implementation. The use of the CCDE across multiple measures can potentially simplify risk-adjustment strategies. The CCDE are a small manageable number of variables that can be applied across condition cohorts and outcomes (although some variables will be more and less important for specific models). If developers begin with these CCDE, even if there is a need to add a few additional data elements, we can greatly reduce the time and efforts involved in measure development and improve harmonization.
- It provides protection against purposeful gaming of data or non-purposeful temporal fluctuations in the use of specific ICD9/ICD10 codes. The use of data captured in real-time only to support patients' treatment are far less susceptible to gaming or coding drift because their definitions are standard and capture remains uniform and static over patients and over time. They are conceptually and temporally removed from the incentives that drive billing coding.

Thus, the use of the CCDE in the HWR eMeasure represents a first step toward developing more valid, efficient, and harmonized quality measurement system. The reengineered eMeasure also performed well. The model showed greater discrimination and yielded similar measure results compared with the original measure.

Measure testing and validation for this measure is preliminary at this stage due to the small, homogenous set of hospitals used for measure development. As yet there is no national test bed that includes both claims and EHR data from a broad and diverse set of hospitals for full measures testing.

The National Quality Forum (NQF) has created a process by which measure developers can obtain a temporary approval of new measures that rely on EHR data. This allows such measures to be implemented so that the necessary data can be collected from hospitals. Once these data are collected full scale measure testing can be completed.

Implementation of the HWR eMeasures will require a novel and somewhat complex implementation system including converting the CCDE into standard formats (value sets and measure logic, such as HQMF), communicating via implementation guides for providers and certification steps for vendors, determining the proper reporting period and frequency, putting into place the infrastructure to receive and audit data. Implementation also presents some additional challenges in that it requires reporting the CCDE on the broad cohort of all adult inpatient admissions uncoupled with an actual measure to ensure that the CCDE can be applied to an all-payer population, to multiple condition cohorts, and measure outcomes. It also requires that some claims data be submitted within CCDE data files to support linking with separate vital statistics claims data files for measure calculation.

It will be critical to consider and create strategies for these challenges in order to implement the CCDE and any measures that incorporate the CCDE in risk adjustment.

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 best alternative choice for the new hybrid HWR eMeasures. Although our results indicate that the CCDE, by itself, is not as predictive of readmission as are claims data describing patients' comorbidities, under some circumstances there might be uses for more parsimonious models, such as, the *CCDE alone* and the *CCDE with principal discharge diagnosis* models. More parsimonious models are simpler to understand and calculate and, where they used with the CCDE, better harmonized with the physiological data clinicians are using. It is possible that additional clinical data captured in EHRs could be included in future versions of the CCDE to improve the performance of one of these more parsimonious models. However, any new clinical data elements would have to be feasible for extraction. Future version of the CCDE will ultimately have to improve discrimination, reliability, and validity over existing models.

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 than 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 likely occurred as 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.
- *Expected readmissions:* The number of readmissions expected based on average hospital performance with a given hospital's case mix.
- *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: ORIGINAL HWR MEASURE SPECIFICATIONS AND PLANNED READMISSION ALGORITHM

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

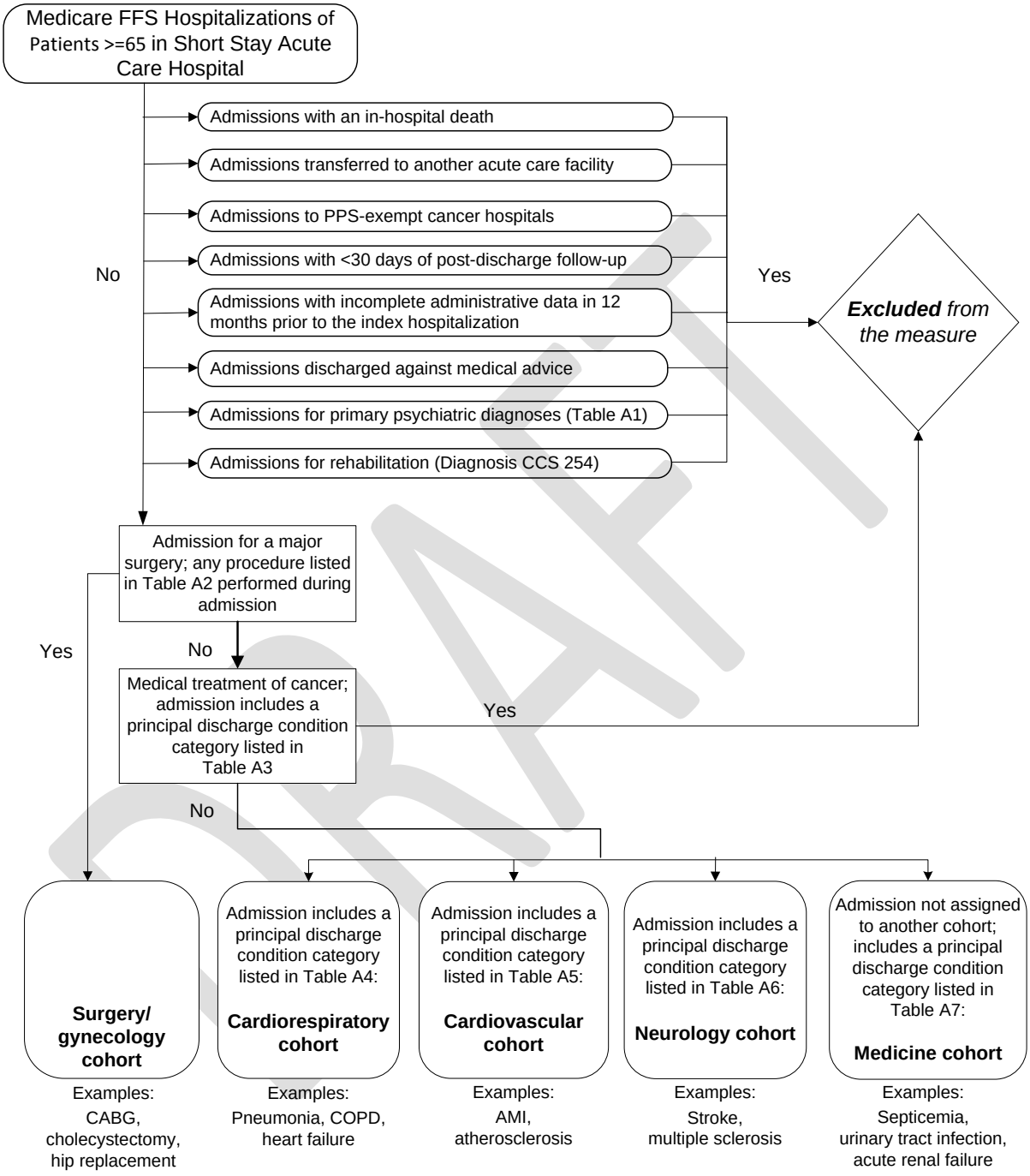


Table A.1: Psychiatric Discharge Diagnosis Categories Excluded from the Measure

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
51	Endarterectomy; vessel of head and neck

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

AHRQ Procedure CCS	Description
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
136	Artificial rupture of membranes to assist delivery

AHRQ Procedure CCS	Description
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
24	Cancer of breast

AHRQ Diagnosis CCS	Description
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
104	Other and ill-defined heart disease

AHRQ Diagnosis CCS	Description
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
47	Other and unspecified benign neoplasm

AHRQ Diagnosis CCS	Description
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
137	Diseases of mouth; excluding dental

AHRQ Diagnosis CCS	Description
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
204	Other non-traumatic joint disorders

AHRQ Diagnosis CCS	Description
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
661	Substance-related disorders

AHRQ Diagnosis CCS	Description
663	Screening and history of mental health and substance abuse codes

Risk Adjustment

Table A.8: Principal Discharge Diagnosis Risk Variables Common to All HWR 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: Comorbidity Indicators for Medicine Specialty Cohort

Variable	Description
CCS 1	Tuberculosis
CCS 2	Septicemia (except in labor)
CCS 3	Bacterial infection; unspecified site
CCS 4	Mycoses
CCS 5	HIV infection

Variable	Description
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 46	Benign neoplasm of uterus
CCS 47	Other and unspecified benign neoplasm
CCS 48	Thyroid disorders
CCS 49	Diabetes mellitus without complication
CCS 50	Diabetes mellitus with complications
CCS 51	Other endocrine disorders
CCS 52	Nutritional deficiencies
CCS 53	Disorders of lipid metabolism
CCS 54	Gout and other crystal arthropathies
CCS 55	Fluid and electrolyte disorders
CCS 57	Immunity disorders
CCS 58	Other nutritional; endocrine; and metabolic disorders
CCS 59	Deficiency and other anemia
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 84	Headache; including migraine
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 98	Essential hypertension
CCS 99	Hypertension with complications and secondary hypertension
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 123	Influenza
CCS 124	Acute and chronic tonsillitis
CCS 126	Other upper respiratory infections
CCS 129	Aspiration pneumonitis; food/vomitus
CCS 130	Pleurisy; pneumothorax; pulmonary collapse
CCS 132	Lung disease due to external agents

Variable	Description
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 152	Pancreatic disorders (not diabetes)
CCS 151	Other liver diseases
CCS 153	Gastrointestinal hemorrhage
CCS 154	Noninfectious gastroenteritis
CCS 155	Other gastrointestinal disorders
CCS 156	Nephritis; nephrosis; renal sclerosis
CCS 157	Acute and unspecified renal failure
CCS 158	Chronic renal failure
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 174	Female infertility
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)

Variable	Description
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 214	Digestive congenital anomalies
CCS 215	Genitourinary congenital anomalies
CCS 217	Other congenital anomalies
CCS 225	Joint disorders and dislocations; trauma-related
CCS 226	Fracture of neck or femur (hip)
CCS 228	Skull and face fractures
CCS 229	Fracture of upper limb
CCS 230	Fracture of lower limb
CCS 231	Other fractures
CCS 232	Sprains and strains
CCS 234	Crushing injury or internal injury
CCS 235	Open wounds of head; neck; and trunk
CCS 236	Open wounds of extremities
CCS 237	Complication of device; implant or graft
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 nonmedicinal substances
CCS 244	Other injuries and conditions due to external causes
CCS 245	Syncope
CCS 246	Fever of unknown origin
CCS 247	Lymphadenitis
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 255	Administrative/social admission
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

Variable	Description
CCS 661	Substance-related disorders
CCS 663	Screening and history of mental health and substance abuse codes

Table A.10: Comorbidity Indicators for Surgery/Gynecology Specialty Cohort

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

Variable	Description
CCS 43	Malignant neoplasm without specification of site
CCS 44	Neoplasms of unspecified nature or uncertain behavior
CCS 45	Maintenance chemotherapy; radiotherapy
CCS 46	Benign neoplasm of uterus
CCS 47	Other and unspecified benign neoplasm
CCS 48	Thyroid disorders
CCS 49	Diabetes mellitus without complications
CCS 50	Diabetes mellitus with complications
CCS 51	Other endocrine disorders
CCS 52	Nutritional deficiencies
CCS 53	Disorders of lipid metabolism
CCS 54	Gout and other crystal arthropathies
CCS 55	Fluid and electrolyte disorders
CCS 57	Immunity disorders
CCS 58	Other nutritional; endocrine; and metabolic disorders
CCS 59	Deficiency and other anemia
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

Variable	Description
CCS 101	Coronary atherosclerosis and other heart disease
CCS 102	Nonspecific chest pain
CCS 103	Pulmonary heart disease
CCS 104	Other and ill-defined heart disease
CCS 105	Conduction disorders
CCS 106	Cardiac dysrhythmias
CCS 107	Cardiac arrest and ventricular fibrillation
CCS 108	Congestive heart failure; non-hypertensive
CCS 109	Acute cerebrovascular disease
CCS 110	Occlusion or stenosis of precerebral arteries
CCS 111	Other and ill-defined cerebrovascular disease
CCS 112	Transient cerebral ischemia
CCS 113	Late effects of cerebrovascular disease
CCS 114	Peripheral and visceral atherosclerosis
CCS 115	Aortic; peripheral; and visceral artery aneurysms
CCS 116	Aortic and peripheral arterial embolism or thrombosis
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

Variable	Description
CCS 148	Peritonitis and intestinal abscess
CCS 149	Biliary tract disease
CCS 151	Other liver diseases
CCS 152	Pancreatic disorders (not diabetes)
CCS 153	Gastrointestinal hemorrhage
CCS 154	Noninfectious gastroenteritis
CCS 155	Other gastrointestinal disorders
CCS 156	Nephritis; nephrosis; renal sclerosis
CCS 157	Acute and unspecified renal failure
CCS 158	Chronis kidney disease
CCS 159	Urinary tract infections
CCS 160	Calculus of urinary tract
CCS 161	Other diseases of kidney and ureters
CCS 162	Other diseases or bladder and urethra
CCS 163	Genitourinary symptoms and ill-defined conditions
CCS 164	Hyperplasia of prostate
CCS 165	Inflammatory conditions of male genital organs
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

Variable	Description
CCS 225	Joint disorders and dislocations; trauma-related
CCS 226	Fracture of neck or femur (hip)
CCS 227	Spinal cord injury
CCS 228	Skull and face fractures
CCS 229	Fracture of upper limb
CCS 231	Other fractures
CCS 234	Crushing injury or internal injury
CCS 236	Open wounds of extremities
CCS 237	Complication of device; implant or graft
CCS 230	Fracture of lower limb
CCS 232	Sprains and strains
CCS 233	Intracranial injury (CCS 233)
CCS 235	Open wounds of head; neck; and trunk
CCS 238	Complications of surgical procedures or medical care
CCS 239	Superficial injury; contusion
CCS 240	Burns
CCS 241	Poisoning by psychotropic agents
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.11: Comorbidity Indicators for Cardiovascular Specialty Cohort

Variable	Description
CCS 96	Heart valve disorders
CCS 97	Peri-; endo-; and myocarditis; cardiomyopathy (except that caused by tuberculosis or sexually transmitted disease)
CCS 100	Acute myocardial infarction
CCS 101	Coronary atherosclerosis and other heart disease
CCS 102	Nonspecific chest pain
CCS 104	Other and ill-defined heart disease
CCS 105	Conduction disorders
CCS 106	Cardiac dysrhythmias
CCS 107	Cardiac arrest and ventricular fibrillation

Variable	Description
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 213	Cardiac and circulatory congenital anomalies

Table A.12: Comorbidity Indicators for Cardiorespiratory Specialty Cohort

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

Table A.13: Comorbidity Indicators for Neurology Specialty Cohort

Variable	Description
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 85	Coma; stupor; and brain damage
CCS 95	Other nervous system disorders
CCS 109	Acute cerebrovascular disease
CCS 110	Occlusion or stenosis of precerebral arteries
CCS 111	Other and ill-defined cerebrovascular disease
CCS 112	Transient cerebral ischemia
CCS 113	Late effects of cerebrovascular disease
CCS 216	Nervous system congenital anomalies
CCS 227	Spinal cord injury
CCS 233	Intracranial injury

Table A.14: 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

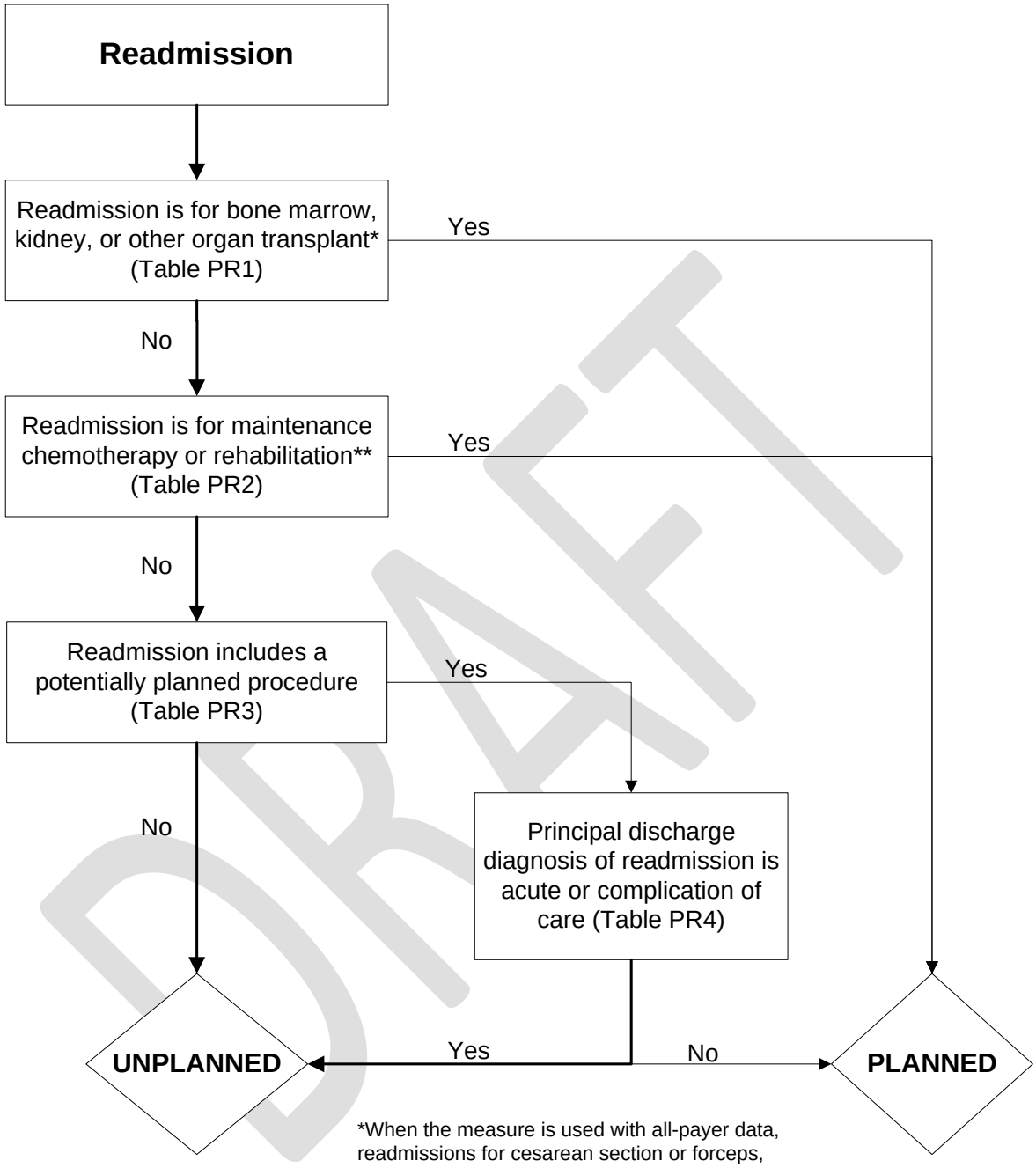
Variable	Description
CC 48	Delirium and Encephalopathy
CC 75	Coma, Brain Compression/Anoxic Damage
CC 77	Respirator Dependence/Tracheostomy Status
CC 78	Respiratory Arrest
CC 79	Cardio-Respiratory Failure and Shock
CC 80	Congestive Heart Failure
CC 81	Acute Myocardial Infarction
CC 82	Unstable Angina and Other Acute Ischemic Heart Disease
CC 92	Specified Heart Arrhythmias
CC 93	Other Heart Rhythm and Conduction Disorders
CC 95	Cerebral Hemorrhage
CC 96	Ischemic or Unspecified Stroke
CC 97	Precerebral Arterial Occlusion and Transient Cerebral Ischemia
CC 100	Hemiplegia/Hemiparesis
CC 101	Diplegia (Upper), Monoplegia, and Other Paralytic Syndromes
CC 102	Speech, Language, Cognitive, Perceptual
CC 104	Vascular Disease with Complications
CC 105	Vascular Disease
CC 106	Other Circulatory Disease
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

Outcome Criteria for HWR Measure

1. **30-day time frame**
   Rationale: Outcomes occurring within 30 days of discharge can be influenced by hospital care and the early transition to the outpatient setting. The use of the 30-day time frame is a clinically meaningful period for hospitals to collaborate with their communities to reduce readmissions.
2. **All-cause unplanned 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 – HWR 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

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

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

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

Diagnosis CCS	Description
423.3	Cardiac tamponade
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

Diagnosis CCS	Description
574.60	Calculus of gallbladder and bile duct with acute cholecystitis without mention of obstruction
574.61	Calculus of gallbladder and bile duct with acute cholecystitis with obstruction
574.8	Calculus of gallbladder and bile duct with acute and chronic cholecystitis
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	HWR eMeasure Development Sample (N=23,201)				HWR eMeasure Validation Sample (N=23,490)			
Name	**Estimate**	**Standard Error**	**OR (LOR-UOR)**	**Frequency Occurred**	**Estimate**	**Standard Error**	**OR (LOR-UOR)**	**Frequency Occurred**
Intercept	-2.573	3.650	---	---	0.168	3.333	---	---
CCDE								
Age	0.029	0.004	1.03(1.02-1.04)	---	0.027	0.003	1.03(1.02-1.03)	---
Systolic Blood Pressure	0.000	0.001	1.00(1.00-1.00)	---	0.001	0.001	1.00(1.00-1.00)	---
Heart Rate	0.006	0.002	1.01(1.00-1.01)	---	0.006	0.002	1.01(1.00-1.01)	---
Respiratory Rate	0.033	0.010	1.03(1.01-1.05)	---	0.029	0.010	1.03(1.01-1.05)	---
Temperature	-0.014	0.037	0.99(0.92-1.06)	---	-0.041	0.034	0.96(0.90-1.03)	---
Weight	0.000	0.001	1.00(1.00-1.00)	---	0.000	0.001	1.00(1.00-1.00)	---
Systolic Blood Pressure Square	0.000	0.000	1.00(1.00-1.00)	---	0.000	0.000	1.00(1.00-1.00)	---
Heart Rate Square	0.000	0.000	1.00(1.00-1.00)	---	0.000	0.000	1.00(1.00-1.00)	---
Temperature Square	-0.069	0.027	0.93(0.89-0.98)	---	0.013	0.023	1.01(0.97-1.06)	---
Temperature Unknown	0.083	0.100	1.09(0.89-1.32)	---	-0.175	0.101	0.84(0.69-1.02)	---
Weight Unknown	-0.025	0.100	0.98(0.80-1.19)	---	0.289	0.090	1.34(1.12-1.59)	---
Condition								
Low frequency conditions	-2.034	0.092	0.13(0.11-0.16)	57.2%	-1.983	0.086	0.14(0.12-0.16)	57.2%
Bunionectomy or repair of toe deformities (CCS 143)	-3.931	0.348	0.02(0.01-0.04)	2.6%	-3.290	0.261	0.04(0.02-0.06)	2.5%
Arthroscopy (CCS 149)	-2.698	0.201	0.07(0.05-0.10)	2.7%	-2.886	0.206	0.06(0.04-0.08)	2.8%
Insertion; replacement; or removal of extracranial ventricular shunt (CCS 2)	-0.968	0.113	0.38(0.30-0.47)	4.4%	-0.989	0.109	0.37(0.30-0.46)	4.2%
Electrographic cardiac monitoring (CCS 203)	-5.075	0.259	0.01(0.00-0.01)	17.2%	-4.752	0.222	0.01(0.01-0.01)	17.1%
Arterial blood gases (CCS 205)	-3.846	0.306	0.02(0.01-0.04)	3.5%	-3.660	0.283	0.03(0.01-0.04)	3.5%
Other diagnostic radiology and related techniques (CCS 226)	-4.092	0.220	0.02(0.01-0.03)	5.7%	-4.235	0.229	0.01(0.01-0.02)	5.6%
Complication of device; implant or graft (CCS 237)	-1.631	0.125	0.20 (0.15-0.25)	4.3%	-1.458	0.118	0.23(0.18-0.29)	4.4%
Complications of surgical procedures or medical care	Reference	Reference	Reference	2.5%	Reference	Reference	Reference	2.8%

Surgery/Gynecology Readmission Rates	HWR eMeasure Development Sample (N=23,201)				HWR eMeasure Validation Sample (N=23,490)			
Name	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred
(CCS 238)								
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-	0.066	0.074	1.07 (0.92-1.24)	10.4%	0.174	0.072	1.19(1.03-1.37)	10.3%
Septicemia/shock (CC 2)	-0.205	0.116	0.87 (0.69-1.10)	3.2%	-0.099	0.112	0.91(0.73-1.13)	3.3%
CHF (CC 80)	0.294	0.091	1.16 (0.97-1.39)	6.4%	-0.055	0.092	0.95(0.79-1.13)	6.3%
Coronary atherosclerosis or angina, cerebrovascular disease (CC 81-84, 89, 98, 99, 103-106)	0.314	0.055	1.29 (1.16-1.44)	40.6%	0.285	0.053	1.33(1.20-1.48)	40.3%
Specified arrhythmias (CC 92, 93)	0.051	0.081	1.06 (0.90-1.24)	8.9%	0.120	0.079	1.13(0.97-1.32)	8.9%
Cardiorespiratory failure or cardiorespiratory shock (CC 79)	0.082	0.117	1.14 (0.90-1.43)	3.0%	0.202	0.112	1.22(0.98-1.52)	3.1%
Coronary obstructive pulmonary disease (COPD) (CC 108)	0.105	0.063	1.18 (1.05-1.34)	14.1%	0.228	0.060	1.26(1.12-1.41)	14.3%

Surgery/Gynecology Readmission Rates	HWR eMeasure Development Sample (N=23,201)				HWR eMeasure Validation Sample (N=23,490)			
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)	0.179	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	HWR eMeasure Development Sample (N=9,261)				HWR eMeasure Validation Sample (N=9,364)			
Name	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred
Intercept	5.746	3.301	---	---	11.238	3.129	---	---
CCDE								
Age	0.007	0.004	1.01 (1.00-1.01)	---	0.002	0.004	1.00(1.00-1.01)	---
Bicarbonate	0.010	0.006	1.01 (1.00-1.03)	---	0.017	0.006	1.02(1.01-1.03)	---
Creatinine	0.140	0.034	1.08 (1.01-1.15)	---	0.093	0.034	1.10(1.03-1.17)	---
Glucose	0.000	0.001	1.00 (1.00-1.00)	---	0.000	0.001	1.00(1.00-1.00)	---
Hematocrit	-0.015	0.006	0.98 (0.97-1.00)	---	-0.017	0.006	0.98(0.97-0.99)	---
Sodium	-0.016	0.006	0.98 (0.97-0.99)	---	-0.018	0.006	0.98(0.97-0.99)	---
Systolic Blood Pressure	-0.005	0.001	1.00 (0.99-1.00)	---	-0.005	0.001	0.99(0.99-1.00)	---
Heart Rate	-0.001	0.001	1.00 (1.00-1.00)	---	0.003	0.001	1.00(1.00-1.01)	---
Oxygen Saturation	0.010	0.005	1.01 (1.00-1.02)	---	0.004	0.005	1.00(0.99-1.01)	---
WBC Count	0.032	0.009	1.03 (1.01-1.04)	---	0.009	0.009	1.01(0.99-1.03)	---
Temperature	-0.061	0.032	0.92 (0.86-0.97)	---	-0.108	0.030	0.90(0.85-0.95)	---
Temperature Unknown	-0.040	0.125	1.03 (0.81-1.30)	---	0.102	0.115	1.11(0.88-1.39)	---
Heart Rate Square	0.000	0.000	1.00 (1.00-1.00)	---	0.000	0.000	1.00(1.00-1.00)	---
WBC Count Square	-0.001	0.001	1.00 (1.00-1.00)	---	0.001	0.001	1.00(1.00-1.00)	---
Temperature Square	0.020	0.012	1.03 (1.01-1.06)	---	0.034	0.011	1.03(1.01-1.06)	---
Condition								
Low frequency conditions	-1.274	0.404	0.28(0.13-0.62)	1.0%	-1.503	0.474	0.22(0.09-0.56)	0.9%
Pulmonary heart disease (CCS 103)	-0.695	0.145	0.50(0.38-0.66)	6.3%	-0.463	0.143	0.63(0.48-0.83)	6.1%
Congestive heart failure; nonhypertensive (CCS 108)	-0.333	0.087	0.72(0.60-0.85)	40.9%	-0.213	0.087	0.81(0.68-0.96)	41.4%
Pneumonia (except that caused by tuberculosis or sexually transmitted disease) (CCS 122)	-0.910	0.100	0.40(0.33-0.49)	21.8%	-0.679	0.099	0.51(0.42-0.62)	21.9%
Chronic obstructive pulmonary disease and bronchiectasis (CCS 127)	-0.594	0.114	0.55(0.44-0.69)	10.8%	-0.516	0.114	0.60(0.48-0.75)	10.5%
Asthma (128)	-0.798	0.142	0.45(0.34-0.59)	7.2%	-0.875	0.143	0.42(0.31-0.55)	7.3%

Cardiorespiratory Readmission Rates	HWR eMeasure Development Sample (N=9,261)				HWR eMeasure 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	HWR eMeasure Development Sample (N=9,261)				HWR eMeasure 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	HWR eMeasure Development Sample (N=8,108)				HWR eMeasure Validation Sample (N=8,037)			
Name	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred
Intercept	0.309	2.001	---	---	4.939	1.915	---	---
CCDE								
Age	0.014	0.005	1.01(1.00-1.03)	---	0.008	0.005	1.01(1.00-1.02)	---
Bicarbonate	0.022	0.011	1.02(1.00-1.04)	---	0.009	0.011	1.01(0.99-1.03)	---
Creatinine	0.186	0.043	1.20(1.11-1.31)	---	0.189	0.045	1.21(1.11-1.32)	---
Hematocrit	-0.022	0.009	0.98(0.96-0.99)	---	-0.017	0.009	0.98(0.97-1.00)	---
Potassium	-0.017	0.074	0.98(0.85-1.14)	---	-0.072	0.073	0.93(0.81-1.07)	---
Sodium	-0.022	0.010	0.98(0.96-1.00)	---	-0.036	0.009	0.96(0.95-0.98)	---
WBC Count	0.021	0.016	1.02(0.99-1.05)	---	0.022	0.016	1.02(0.99-1.05)	---
Systolic Blood Pressure	0.002	0.001	1.00(1.00-1.01)	---	0.001	0.001	1.00(1.00-1.00)	---
Heart Rate	0.009	0.002	1.01(1.00-1.01)	---	0.007	0.002	1.01(1.00-1.01)	---
Oxygen Saturation	-0.024	0.013	0.98(0.95-1.00)	---	-0.040	0.012	0.96(0.94-0.98)	---
Respiratory Rate	0.005	0.011	1.01(0.98-1.03)	---	0.018	0.011	1.02(1.00-1.04)	---
Bicarbonate Square	0.003	0.002	1.00(1.00-1.01)	---	0.003	0.002	1.00(1.00-1.01)	---
Potassium Square	0.178	0.078	1.20(1.03-1.39)	---	0.149	0.072	1.16(1.01-1.34)	---
WBC Count Square	0.000	0.002	1.00(1.00-1.00)	---	0.001	0.002	1.00(1.00-1.01)	---
Systolic Blood Pressure Square	0.000	0.000	1.00(1.00-1.00)	---	0.000	0.000	1.00(1.00-1.00)	---
Heart Rate Square	0.000	0.000	1.00(1.00-1.00)	---	0.000	0.000	1.00(1.00-1.00)	---
Condition								
Low frequency conditions	0.052	0.113	1.05(0.84-1.31)	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								
Metastatic cancer/acute	0.363	0.258	1.44(0.87-2.38)	1.7%	0.512	0.263	1.67(1.00-2.79)	1.5%

Cardiovascular Readmission Rates	HWR eMeasure Development Sample (N=8,108)				HWR eMeasure Validation Sample (N=8,037)			
Name	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred
leukemia (CC 7)								
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%
Fibrosis of lung or other chronic lung disorders (CC	0.418	0.158	1.52(1.12-2.07)	3.8%	0.151	0.169	1.16(0.83-1.62)	3.7%

Cardiovascular Readmission Rates	HWR eMeasure Development Sample (N=8,108)				HWR eMeasure Validation Sample (N=8,037)			
Name	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred
109)								
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	HWR eMeasure Development Sample (N=4,400)				HWR eMeasure 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	HWR eMeasure Development Sample (N=4,400)				HWR eMeasure 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	HWR eMeasure Development Sample (N=4,400)				HWR eMeasure 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	HWR eMeasure Development Sample (N=34,619)				HWR eMeasure 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	HWR eMeasure Development Sample (N=34,619)				HWR eMeasure Validation Sample (N=34,574)			
Name	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred
Gastrointestinal hemorrhage (CCS 153)	-0.380	0.130	0.68(0.53-0.88)	3.5%	-0.318	0.131	0.73(0.56-0.94)	3.7%
Other gastrointestinal disorders (CCS 155)	-0.195	0.152	0.82(0.61-1.11)	1.6%	-0.063	0.152	0.94(0.70-1.26)	1.6%
Acute and unspecified renal failure (CCS 157)	-0.200	0.128	0.82(0.64-1.05)	3.3%	0.048	0.128	1.05(0.82-1.35)	3.1%
Urinary tract infections (CCS 159)	-0.426	0.132	0.65(0.50-0.85)	3.7%	-0.340	0.133	0.71(0.55-0.92)	3.7%
Skin and subcutaneous tissue infections (CCS 197)	-0.628	0.155	0.53(0.39-0.72)	2.1%	-0.531	0.154	0.59(0.43-0.80)	2.2%
Septicemia (except in labor) (CCS 2)	0.030	0.108	1.03(0.83-1.27)	23.5%	0.039	0.109	1.04(0.84-1.29)	23.8%
Complication of device; implant or graft (CCS 237)	-0.111	0.119	0.89(0.71-1.13)	4.8%	0.016	0.121	1.02(0.80-1.29)	4.6%
Complications of surgical procedures or medical care (CCS 238)	-0.062	0.132	0.94(0.72-1.22)	2.7%	0.038	0.136	1.04(0.80-1.36)	2.5%
Syncope (CCS 245)	-0.622	0.151	0.54(0.40-0.72)	2.4%	-0.681	0.155	0.51(0.37-0.69)	2.5%
Diabetes mellitus with complications (CCS 50)	-0.340	0.135	0.71(0.55-0.93)	2.6%	-0.265	0.136	0.77(0.59-1.00)	2.6%
Fluid and electrolyte disorders (CCS 55)	-0.411	0.134	0.66(0.51-0.86)	3.1%	-0.075	0.131	0.93(0.72-1.20)	3.2%
Cataract (CCS 86)	-0.930	0.163	0.39(0.29-0.54)	2.2%	-0.688	0.159	0.50(0.37-0.69)	2.2%
Hypertension with complications and secondary hypertension (CCS 99)	Reference	Reference	Reference	1.6%	Reference	Reference	Reference	1.6%
Comorbidity								
Metastatic cancer/acute leukemia (CC 7)	0.032	0.069	1.03(0.90-1.18)	5.0%	-0.063	0.071	0.94(0.82-1.08)	4.9%
Severe Cancer (CC 8, 9)	0.290	0.054	1.34(1.20-1.49)	7.1%	0.338	0.055	1.40(1.26-1.56)	6.9%
Other major cancers (CC 10-12)	0.035	0.045	1.04(0.95-1.13)	12.2%	0.079	0.045	1.08(0.99-1.18)	12.1%
Other hematological disorders (CC 44)	0.327	0.077	1.39(1.19-1.61)	3.0%	0.126	0.080	1.13(0.97-1.33)	2.9%
Coagulation defects and other	0.178	0.052	1.19(1.08-1.32)	7.5%	0.166	0.052	1.18(1.07-1.31)	7.5%

Medicine Readmission Rates	HWR eMeasure Development Sample (N=34,619)				HWR eMeasure Validation Sample (N=34,574)			
Name	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred
specified hematological disorders (CC 46)								
Iron deficiency (CC 47)	0.056	0.036	1.06(0.99-1.13)	52.9%	0.047	0.036	1.05(0.98-1.12)	53.0%
End-stage liver disease (CC 25, 26)	0.315	0.078	1.37(1.18-1.60)	3.0%	0.270	0.076	1.31(1.13-1.52)	3.2%
Pancreatic disease (CC 32)	0.230	0.061	1.26(1.12-1.42)	5.1%	0.199	0.061	1.22(1.08-1.38)	5.2%
Dialysis status (CC 130)	0.059	0.086	1.06(0.90-1.26)	3.3%	0.086	0.085	1.09(0.92-1.29)	3.5%
Acute renal failure (CC 131)	0.080	0.041	1.08(1.00-1.17)	24.3%	0.075	0.041	1.08(0.99-1.17)	24.2%
Transplants (CC 128, 174)	0.177	0.154	1.19(0.88-1.61)	0.7%	0.383	0.141	1.47(1.11-1.93)	0.8%
Severe Infection (CC 1, 3-5)	0.084	0.099	1.09(0.90-1.32)	1.9%	0.096	0.100	1.10(0.91-1.34)	1.8%
Other infectious disease & pneumonias (CC 6, 111-	-0.003	0.035	1.00(0.93-1.07)	34.4%	0.112	0.035	1.12(1.04-1.20)	34.5%
Septicemia/shock (CC 2)	0.005	0.047	1.00(0.92-1.10)	11.4%	0.074	0.046	1.08(0.98-1.18)	11.3%
CHF (CC 80)	0.121	0.043	1.13(1.04-1.23)	19.6%	0.185	0.043	1.20(1.11-1.31)	19.8%
Coronary atherosclerosis or angina, cerebrovascular disease (CC 81-84, 89, 98, 99, 103-106)	0.139	0.034	1.15(1.07-1.23)	61.1%	0.254	0.035	1.29(1.20-1.38)	61.1%
Specified arrhythmias (CC 92, 93)	0.133	0.039	1.14(1.06-1.23)	21.6%	0.092	0.040	1.10(1.01-1.19)	21.5%
Cardiorespiratory failure or cardiorespiratory shock (CC 79)	0.073	0.048	1.08(0.98-1.18)	10.7%	0.021	0.048	1.02(0.93-1.12)	10.9%
Coronary obstructive pulmonary disease (COPD) (CC 108)	0.131	0.034	1.14(1.07-1.22)	23.7%	0.095	0.035	1.10(1.03-1.18)	23.6%
Fibrosis of lung or other chronic lung disorders (CC 109)	0.127	0.064	1.14(1.00-1.29)	4.6%	0.054	0.064	1.06(0.93-1.20)	4.7%
Protein-calorie malnutrition (CC 21)	0.137	0.042	1.15(1.06-1.24)	13.5%	0.140	0.041	1.15(1.06-1.25)	13.9%
Disorders of fluid, electrolyte, acid-base (CC 22, 23)	0.186	0.037	1.20(1.12-1.30)	28.8%	0.141	0.037	1.15(1.07-1.24)	29.3%
Rheumatoid arthritis and inflammatory connective	0.110	0.054	1.12(1.00-1.24)	6.8%	0.026	0.056	1.03(0.92-1.15)	6.6%

Medicine Readmission Rates	HWR eMeasure Development Sample (N=34,619)				HWR eMeasure Validation Sample (N=34,574)			
Name	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred	Estimate	Standard Error	OR (LOR-UOR)	Frequency Occurred
tissue disease (CC 38)								
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%