# Measure Methodology Report:
# Hospital-Wide, 30-Day, All-Cause Unplanned Readmission (HWR) Rate for the Merit-Based Incentive Payment System (MIPS) Groups

**Submitted by:**

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# Acknowledgements

# Table of Contents

# List of Tables

# List of Figures

# Executive Summary

In 2017, the Centers for Medicare & Medicaid Services (CMS) contracted with Yale New Haven Health Services Corporation – Center for Outcomes Research and Evaluation (CORE) to develop an eligible clinician- and/or eligible clinician group-level outcome measure that reflects the quality of care for patients discharged from acute care hospital stays. Specifically, CMS asked CORE to adapt its existing hospital-level measure, "Hospital-wide All-cause Unplanned Readmission Measure (HWR)," which is currently publicly reported, for use in assessing individual eligible clinicians or eligible clinician groups participating in the Merit-based Incentive Payment System (MIPS). Measure development has benefited from close stakeholder engagement, including a nationally convened Technical Expert Panel (TEP) and a public comment period. This measure fills an important gap by creating a mechanism for shared accountability across healthcare providers for readmitted patients. It will provide clinicians and patients with greater information and transparency to continue to improve patient care quality and outcomes.

The outcome is readmission within 30 days of discharge from an admission; planned readmissions are excluded from this outcome. For this measure, each admission is attributed to up to three healthcare providers. One is the provider who filed a claim for the 'discharge procedure' for the patient; conceptually, this clinician is measured because they have some responsibility for the transition of the patient to non-acute settings. Second is the provider who, during the inpatient stay, billed the most patient-facing charges; conceptually, this clinician has the most responsibility for the care of patients during their stay, and may also be the discharge clinician. A third provider is one that provides the plurality of outpatient primary care during the 12 months prior to the admission, as measured by a plurality of primary care services; conceptually, a primary care provider may manage the transition from acute to non-acute care and participate in decisions to return to acute care. All admissions assigned to a clinician are attributed to the clinician's group; all admissions assigned to a group are used to construct a single measure score for that group, regardless of the reason the admission was attributed. The measure has been tested for eligible clinician groups, defined here by eligible clinicians who use the same Taxpayer Identification Number (TIN).

To compare readmission performance across eligible clinician groups, the measure accounts for differences in patient characteristics (i.e., patient case mix) as well as differences in the services and procedures offered by clinician groups (i.e., provider service mix). The overall risk-adjusted readmission rate (RARR) is derived from the weighted geometric mean of five statistical models built for groups of admissions that are clinically related: cardiorespiratory, cardiovascular, medicine, neurology, and surgery/gynecology. We did not reselect risk variables used in the hospital-level measure, as the patient-level risk prediction is the same regardless of the attribution.

Using our development data for the purpose of measure testing, we found 55,593 eligible clinician groups had at least 25 admissions attributed by one or more attribution rule. The RARRs for these sets of providers had a mean [range] of 15.4% [7.0% – 25.1%] for eligible clinician groups; 11.6% of eligible clinician groups were statistically significantly better or worse than the national observed readmission rate.

In summary, this report details the approach and methods for re-specifying the HWR measure, currently reported within the Inpatient Quality Reporting (IQR) program, for use among MIPS eligible clinician groups. It presents a conceptual framework for the three attribution rules and provides a revised methodology for constructing risk-adjusted scores for the providers measured by these rules. Finally, it

demonstrates the feasibility, variability, reliability, and validity of measuring MIPS eligible clinician groups. The MIPS HWR measure has the potential to illuminate differences in quality, inform patient choice, drive quality improvement, and enhance care coordination. In a formal survey of the TEP, 70% agreed the measure scores were valid and useful measures of quality of care.

# 1. INTRODUCTION

## 1.1 Overview of Measure Development

In 2017, the Centers for Medicare & Medicaid Services (CMS) contracted with Yale New Haven Health Services Corporation – Center for Outcomes Research and Evaluation (CORE) to develop an eligible clinician outcome measure that reflects the quality of care for patients discharged from acute care hospital stays. Specifically, CMS asked CORE to adapt its existing publicly reported hospital-level measure, "Hospital-wide All-cause Unplanned Readmission Measure (HWR)," which is currently reported within the Inpatient Quality Reporting (IQR) program,[1] for use in assessing eligible clinicians and/or eligible clinician groups participating in the Merit-based Incentive Payment System (hereinafter, MIPS HWR measure).

Readmission after discharge has been recognized for over a decade as both a quality and a resource concern. We detail the evidence supporting readmission as a quality indicator below. Jencks et al. estimated that readmissions within 30 days of discharge cost Medicare more than $17 billion annually.[2] A 2006 Commonwealth Fund report estimated if national readmission rates were lowered to the levels achieved by the top-performing regions, Medicare would save $1.9 billion annually.[3] Consequently, there has been a national effort to address rates of readmission for patients of all ages and conditions. As a part of this effort, CMS publicly reports risk-standardized hospital-wide, all-cause readmission rates using a measure which includes most hospital discharges.[1]

The existing hospital-level HWR measure, which provides a broad assessment of the quality of care at hospitals, reflects in part the quality of clinician care in the hospital, in that inpatient clinicians are integral to inpatient care and the transition to an outpatient setting. This measure also may reflect the quality of primary care, in that primary care clinicians may influence whether patients return to an acute care setting. It is thus meaningful to adapt the hospital-level HWR measure for use in assessing the quality of clinician group care. The adapted measure is intended for use in MIPS, part of the Quality Payment Program (QPP), to assess the performance of eligible clinician groups. There is currently a re-specified version of the hospital-level HWR measure in use under MIPS, referred to as the All-Cause Readmission (ACR) measure, which attributes readmissions solely to the primary outpatient physician that provides the plurality of care during the 12-month measurement period. Where relevant, we drew from the ACR measure. However, we used the original hospital-level HWR measure as the foundation for our development work because that version has been most rigorously tested and vetted. Our measure development work focused on redefining and improving the attribution approach for an eligible clinician group-level measure.

In this technical report, we provide detailed information on the development of a MIPS HWR measure. Briefly, we re-specified the hospital-level HWR measure, which was designed to capture unplanned readmissions within 30 days of discharge, to assign outcomes to inpatient and outpatient eligible clinician groups. In alignment with the hospital-level HWR measure, the MIPS HWR measure complies with accepted standards for outcome measure development, including appropriate risk adjustment, testing, and transparency of specifications. From the cohort, we exclude admissions for which we have insufficient data for risk adjustment, admissions for patients who leave against medical advice, admissions for medical cancer treatment, or for conditions that are not typically cared for in short-stay acute care hospitals, and admissions to Prospective Payment System (PPS)-exempt cancer hospitals. Consistent with the hospital-level HWR measure, the MIPS HWR measure does not count planned

readmissions in the measure outcome, since they do not represent a quality signal. Consistent with the hospital-level HWR, admissions are assigned to one of five specialty cohorts: 1) cardiorespiratory, 2) cardiovascular, 3) medicine, 4) neurology, and 5) surgery/gynecology. Separate risk adjustment models are estimated for each specialty cohort. To accommodate the attribution of each admission to multiple eligible clinicians, we modified the statistical model and construction of the summary score used in the original hospital-level HWR. Specifically, instead of using mixed-effects models to directly estimate eligible clinician group effects, we used logistic regression models to construct standardized readmission ratios (SRRs) for each specialty cohort and applied a post-estimation method to adjust these for between-provider variation. These adjusted SRRs are then combined across specialty cohorts to produce a single risk-adjusted readmission rate (RARR). We did not reselect risk variables used in the hospital-level measure, as the patient-level risk prediction is the same regardless of the attribution.

## 1.2 Hospital-Wide Readmission as a Clinician Quality Indicator

Hospital readmission, for any reason, is disruptive to patients and caregivers, costly to the healthcare system, and puts patients at additional risk of hospital-acquired infections and complications. Readmissions are also a major source of patient and family stress and may contribute substantially to loss of functional ability, particularly in older patients. Some readmissions are unavoidable and result from inevitable progression of disease or worsening of chronic conditions. However, readmissions may also result from poor quality of care or inadequate transitional or post-discharge care. Transitional care includes effective discharge planning, transfer of information at the time of discharge, patient assessment and education, and coordination of care and monitoring in the post-discharge period. Numerous studies have found an association between quality of inpatient or transitional care and early (typically 30-day) readmission rates for a wide range of conditions.[4–11]

Randomized controlled trials have shown that improvement in the following areas can directly reduce readmission rates: quality of care during the initial admission; improvement in communication with patients, their caregivers, and their clinicians; patient education; pre-discharge assessment; and coordination of care after discharge.[12–20] Successful randomized trials have reduced 30-day readmission rates by 20–40%.[21] Widespread application of these clinical trial interventions to general practice has also been encouraging. Since 2008, 14 Medicare Quality Improvement Organizations have been funded to focus on care transitions by applying lessons learned from clinical trials. Several have been notably successful in reducing readmissions within 30 days.[22] Many of these study interventions involved enhanced clinician involvement and indicate a key role for clinicians in reducing readmissions. Further, analyses CORE performed pre-development of this measure support variation in clinician group-level performance on 30-day readmissions for patients with acute myocardial infarction (AMI).

Despite these demonstrated successful interventions, the overall national readmission rate remains high, with a 30-day readmission following over 15% of discharges. Readmission rates also vary widely across institutions.[23–25] Moreover, we show below that RARRs vary from 7%–25% for eligible clinician groups for 2015–16. Both the high baseline rate and the variability across eligible clinician groups speak to the need for a quality measure to prompt greater care improvement. Given that studies have shown readmissions within 30 days to be related to quality of care, that interventions, including those utilizing clinicians, have been able to reduce 30-day readmission rates for a variety of specific conditions, and that high and variable clinician-level readmission rates indicate opportunity for improvement, we sought to develop an eligible clinician group-level measure of all-cause, all-condition 30-day unplanned readmission.

## 1.3 Quality Payment Program Background

In April 2015, Congress passed the Medicare Access and CHIP Reauthorization Act (MACRA), which marked a milestone in moving from paying clinicians based on volume of services towards paying clinicians for value of care. MACRA laid forth two pathways for physicians and other clinicians participating in CMS's QPP: 1) the MIPS or 2) an Advanced Alternative Payment Model (APM). This work is informed by and focuses on several aspects of MIPS requirements including identification of eligible clinician groups, importance of outcome measures, attribution of hospital outcomes to clinicians, and alignment between federal programs.

### 1.3.1    Eligible Clinicians and Eligible Clinician Groups

The first aspect of MIPS which informs this work involves defining eligible clinicians and eligible clinician groups. CMS has identified a set of clinicians based on Medicare provider specialty codes and Medicare Part B volume requirements for participation under MIPS. The types of MIPS eligible clinicians include physicians, physician assistants, nurse practitioners, clinical nurse specialists, and certified registered nurse anesthetists who bill under Medicare Part B (81 FR 77036).[26] CMS describes clinicians who participate in MIPS as MIPS eligible clinicians. MIPS eligible clinicians may participate as a single clinician (identified by a unique combination of Taxpayer Identification Number [TIN] and National Provider Identifier [NPI] numbers), as a group (TIN with two or more clinicians), or as a virtual group (two or more TINs of solo practitioners and small groups of fewer than ten clinicians). CMS uses at least one outcome measure (or other high priority measure) to assess the quality of care provided by MIPS eligible clinicians who choose full participation in MIPS to achieve higher payment adjustments (82 FR 30028).[27] CMS decided to propose and implement this measure at the eligible clinician group level, therefore all remaining analyses and discussion are presented for eligible clinician groups.

### 1.3.2    Outcome Measures

As part of MIPS, eligible clinicians and eligible clinician groups fully participating in MIPS must report at least six quality measures or a complete specialty measure set. Of these six, one measure must be an outcome measure. If no outcome measure is available, eligible clinicians and eligible clinician groups must select another high-priority measure in its place. If fewer than six outcome measures are available, eligible clinicians and eligible clinician groups must report on all those available in the measure set. In addition, currently, eligible clinician groups with at least 16 NPIs and 200 cases will automatically receive a score for the MIPS ACR measure, which this measure was adapted from and intended to replace with the same reporting requirements. Placing importance on outcome measures and in alignment with statutory requirements, CMS indicated its plans to increase the requirements for outcome measure reporting over time as more outcome measures become available for MIPS reporting (81 FR 77101, 82 FR 30097).[28,29] [29,30]

### 1.3.3    Existing MIPS Attribution Approaches

An important consideration for measure development is the attribution used by existing outcome measures under MIPS. CMS has published beneficiary assignment methods for MIPS ACR and total per capita cost measures. The attribution methodology is adopted from the Value Modifier (VM) program, which uses outpatient claims to identify a primary outpatient provider during a 12-month performance period. Specifically, the two-step attribution methodology for the VM All-Cause Readmission measure

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assigns beneficiaries first to clinicians based on plurality of charges for delivery of primary care services by primary care physicians or, secondly, to the specialist with a plurality of charges for such services if no primary care physicians provided such services in the 12-month performance period. For the total per capita cost measure in MIPS, CMS modified the algorithm by removing the skilled nursing facility codes from the list of qualifying primary care services used for attribution (79 FR 67960 through 67964, 81 FR 77131).[31] The current MIPS ACR measure builds on this precedent by attributing the readmission outcome to the outpatient primary care clinician. However, the measure detailed in this report revises the VM approach to identify the outpatient primary care eligible clinician group who has billed the plurality of primary care services during the 12 months prior to the index admission that qualifies for measure inclusion as one of three attributable eligible clinician groups.

Hospital Quality as a Proxy for Clinician Group Quality in MIPS
In the program's first year (2019 MIPS payment year), CMS introduced its consideration to allow facility-based clinicians to use their institutions' quality and/or cost scores as a proxy for MIPS eligible clinician group's quality and/or cost performance scores (81 FR 77127).[31] CMS believes providing this option to clinicians will allow for clinicians to be assessed along the lines of the facilities in which they work and minimize reporting burden (82 FR 53753).[32] For the 2021 MIPS payment year, CMS has proposed adopting measures from the Fiscal Year 2020 Hospital Value-based Purchasing Program for facility-based measurement under MIPS (83 FR 35960).[33] Attribution of a facility-based clinician would be to the hospital at which the facility-based clinician provides services to the most Medicare patients, and attribution of facility-based groups would be the hospital at which the plurality of facility-based clinicians were attributed. In contrast to facility-based measures, this measure would be aligned with, but not identical to, the original hospital-level measure. Specifically, the measure is aligned with the hospital-level HWR measure in cohort, outcome, and risk adjustment but differs in attribution to eligible clinician groups, rather than hospitals, and measure calculation to accommodate the multiple attribution approach to up to three clinician groups. This measure was developed with input from a diverse Technical Expert Panel (TEP) that included patients and clinicians to ensure the measure is as meaningful as possible to all stakeholders.

### 1.3.4    Measure Alignment

Finally, one of CMS's priorities in implementing MACRA is to align quality measures across federal programs, such as MIPS and Advanced APMs, settings, and payers. In November 2017, CMS finalized using benchmarks for MIPS quality measures for calculation of APMs (82 FR 53698).[32] CMS' future policies in this area will be important in guiding the attribution of patient health outcomes to clinicians participating in the QPP via MIPS or Advanced APM pathways. In consideration of these aspects of MIPS, we applied a formal strategy, outlined below, for adapting hospital-level inpatient measures for use in measuring clinicians.

### 1.4 Approach to Measure Development

The CORE Project Team consisted of a multidisciplinary group of individuals with expertise in measure development, health services research, clinical medicine, statistics, and measurement methodology. We developed this measure in consultation with national guidelines for publicly reported outcome measures, followed guidance set forth by the CMS Measure Management System Guidance, the National Quality Forum (NQF), and articulated in the American Heart Association scientific statement,

"Standards for Statistical Models Used for Public Reporting of Health Outcomes."[34,35] Following these standards has ensured a transparent process and comprehensive expert input throughout development.

The development process relied on the input of a TEP and other external stakeholders. As part of the process, we identified five key principles, as outlined below in section 1.4.2, to guide re specification of hospital measures for measuring clinician quality; a sixth principle was added by the TEP. We formulated a strategy for identifying and evaluating attribution rules that aligned with these principles.

### 1.4.1 Expert and Stakeholder Input

As part of measure development, CORE obtained input from persons and families, clinical and technical experts, and other stakeholders. As part of CMS's commitment to incorporating views of persons and families, CORE hosted two listening sessions to obtain feedback from persons and families about clinician quality measurement. The goal of the sessions was to obtain input from persons and families regarding quality measurement at the clinician and clinician group level and attribution of selected outcomes to clinicians. We provided participants with the project's background and presented three scenarios for discussion. As part of these sessions, participants provided input for various scenarios, including to whom patient readmission should be attributed for patients discharged from the hospital. Feedback focused on concerns about holding clinicians accountable for events beyond their control and about identifying the true causes of adverse outcomes. As is standard with all measure development processes, CORE also convened, through a public process, and obtained input from a national TEP throughout measure development. The TEP consisted of clinicians, patient advocates, and other stakeholders (see Appendix A for roster). The TEP provided input on approaches to measure re-specification including attribution and risk-adjustment methodology.

Finally, as part of the measure development process and in alignment with CMS Measure Management System guidance,[36, 40] we sought comments from the public on the measure concept and all specifications as outlined in this report. Comments received addressed the general utility of the measure, the extent to which face validity results sufficiently validate the measure, the attribution to multiple clinician groups, and the risk adjustment approach including the addition of social risk factors to the risk model. No changes were made to this report based on the comments received.

### 1.4.2 Key Principles Driving Attribution Identification and Evaluation

As part of this development process, we identified five key principles to guide re-specification of hospital measures for measuring clinician groups' (and individual clinicians, although not ultimately for this measure) quality and added a sixth identified by the TEP. Our approach to identifying and evaluating attribution rules reflects a set of principles that we derived from prior work on hospital measurement, policy goals, consultation with our TEP, the context of adapting existing measures, and the common features of those measures. Notably, these principles are specific to hospital measure re-specification and may not be applicable to attribution in general. In this section, we state these six principles explicitly and describe how they proscribed and informed our choices and findings.

Principle #1: Attribution is Specific to the Measure Outcome
Throughout this document, attribution refers to the assignment of the outcome of a patient episode of care to one or more clinicians for the purpose of assessing clinician quality. Attribution, therefore, is specific to the outcome. For example, when a patient is admitted for elective surgery, it may be most

sensible to attribute any complications of that surgery to the surgeon, but any post-discharge readmission to the clinician who discharged the patient. For this measure, we considered attribution to clinician groups who might plausibly influence the transition of care from hospital to the outpatient setting, or who might influence the decision of patients to return to the hospital within 30 days.

Principle #2: Adapted Measures Should Align with Original Hospital-Level Measures
Our goal was to adapt the patient cohort, outcome, and risk-adjustment strategy that had been previously specified for hospital measurement for use in measuring clinicians. We took as a principle that an adapted measure should align, to the degree practical, with the existing measure. We only considered attribution approaches that could be implemented using the same data sources that are used to measure hospitals, with the same cohort and outcome definitions. The risk-adjustment variables and models would be, when practical, similar to those used for hospital-level measures. Thus, for the current measure, we adopted the original outcome, the five 'specialty cohorts' for classifying patients, and the existing set of risk factors from the hospital-level measure. We verified model performance using this approach.

Principle #3: Clinician Quality Reflects Hospital Quality
This measure was originally developed to measure hospital quality. When measuring performance, it may be possible (if technically challenging) to isolate the components of quality at the group and hospital levels. However, just as hospital quality measurement inherently reflects contributions from clinical staff, hospital systems, and community resources, we adopted the analogous principle here, that clinician performance measurement also reflects other factors, including hospital quality. Therefore, just as with CMS's hospital measures, we did not try to separate these effects when measuring clinician performance. From the perspective of the patient, this means that when comparing providers, the performance reflects the hospital or outpatient environment in which the clinician practices. From the perspective of the policymaker, this principle means that clinicians are held accountable in part for the quality of the hospital environment in which they treat patients. Since these individuals are perhaps best placed to identify systemic opportunities for improvement, this approach can drive improvement throughout the system of care.

Principle #4: Inpatient Outcomes May Be Most Reasonably Attributed to Inpatient Clinicians
We identified candidate attribution rules using four sources: 1) a literature review/environmental scan; 2) current CMS policies; 3) TEP and other expert input; and 4) claims patterns for measured patients. A hierarchy that arose from TEP input allowed us to identify key candidate attribution rules:

- Hospital clinicians generally play the most important role in outcomes after admission.

- The most central hospital clinicians depend in large part on the condition/procedure and outcome.

- Clinicians caring for patients before and after an admission may also play a role in post-admission outcomes.

Finally, we only considered attribution to the types of clinicians that are eligible for the QPP. Currently, the types of clinicians who qualify for participation are physicians, physician assistants, nurse practitioners, clinical nurse specialists, and certified registered nurse anesthetists; this list may be expanded over time as directed by MACRA. However, based upon strong TEP input regarding the role of the outpatient primary care provider in supporting the transition to the outpatient setting, we did not

limit ourselves to inpatient providers. The measure presented here attributes the readmission outcome to two inpatient providers and an outpatient provider; these provider categories, especially the inpatient provider categories, may overlap.

Principle # 5: Attribution Should Align with Policy Goals

Consistent with guidelines on attribution published by the NQF, we adopted the principle that the choice of attribution rule should be ultimately determined by policy goals and informed by clinical sensibility and empirical findings.[37] Thus, while empirical findings may illuminate what is feasible and practical, they cannot determine what is "right" or "appropriate." For example, empirical results may indicate that a readmission outcome after a surgical procedure can be feasibly attributed to either the surgeon or the Discharge Clinician but cannot determine that one is "better" or "more sensible" than the other. The choice between the two attribution rules will need to be based on clinical and policy considerations.

Principle #6: Attribution Should Consider the Potential for Unintended Consequences

We prioritize the goal of improving patient care. One implication of prioritizing patient care is that we considered the incentives created or modified by each candidate attribution rule. An attribution rule could conceivably create lines of responsibility that result in a tradeoff between better patient care and better clinician scores. For example, any rule that can be manipulated after admission, allowing clinicians to avoid attribution of a patient's outcome once they have provided care for that patient, could create incentives for a clinician to 'shift' patients with poorer prognoses to another clinician, resulting in perhaps worse care for the patient but better measure scores for the first clinician. Therefore, we articulate potential unintended consequences for each candidate attribution rule.

These six principles provide a framework for thinking about the attribution of inpatient outcomes in a way consistent with CMS's policies and goals. They are broad enough to identify all candidate attribution rules that are plausible and clinically meaningful, while narrow enough to avoid spurious analyses and findings.

### 1.4.3 Strategy for Adapting Inpatient Outcome Measures to Apply to Eligible Clinician Groups

Prior to adapting the MIPS HWR measure, we developed a general strategy for re-specifying existing hospital-level inpatient outcome measures to apply to eligible clinicians and eligible clinician groups (although ultimately only to eligible clinician groups for this measure). This strategy consists of: 1) systematically identifying candidate attribution rules; 2) evaluating the candidate attribution rules using standardized criteria; and 3) reviewing the findings with the TEP and CMS to inform the choice of final attribution rules. The overall process for identifying, testing, and selecting algorithms ("attribution rules") for assigning patient outcomes to clinicians consists of three key steps:

1. Identify candidate attribution rules: Use literature and related publications, existing policies, claims patterns, and stakeholder (clinician, patient, and other expert) input to identify a preliminary set of candidate attribution rules for the measure under consideration. Descriptive data on claims patterns may also inform this set of candidate attribution rules. The aim of this step is to identify a set of attribution rules that are feasible, meaningful, and policy relevant.

2. Implement candidate attribution rules on a common dataset and evaluate key characteristics of each: For each candidate attribution rule, empirically evaluate the face validity, ability to differentiate among providers, reliability and sample size, and overlap with other candidate attribution rules. We compared results to that of a random attribution as an additional validity check.

3. Use TEP input and policy considerations to select a final attribution rule: We presented the results of the evaluation to stakeholders for their input. Specifically, we held an in-person meeting of our nationally convened TEP that includes representation from a broad group of providers and patients. We presented the candidate attribution rules and results to the TEP to obtain their input. We then obtained CMS input and brought the final attribution rules back to the TEP for their assessment.

## 1.5 Aims of the Measure

The primary objective of this work was the development of a hospital-wide, all-condition and all-cause, 30-day readmission measure for clinicians and/or clinician groups that:

- Captures differences in readmissions experienced by patients who were discharged alive from an inpatient stay.

- Adjusts for clinician case mix.

- Assesses the relative performance of clinicians and/or clinician groups.

- Aligns with CMS's existing hospital-level hospital-wide readmission measure, as appropriate.

- Provides targets to clinicians and/or clinician groups for efforts to improve the quality of care.

Based upon diverse stakeholder input, the final measure ultimately presented in this report attributes readmissions to clinician groups only.

# 2. METHODS

## 2.1 Overview

This measure reports the clinician group-level RARR of unplanned readmissions within 30 days of hospital discharge for any condition or procedure. The measure comprises a single summary score, derived from the results of five different models, one for each of the following <u>specialty cohorts</u>: medicine, surgery/gynecology, cardiorespiratory, cardiovascular, and neurology, each of which will be described in greater detail below. The measure uses one year of data to assess clinician group performance, as well as one prior year of data to determine risk factors and attribution.

Consistent with the IQR HWR measure, we created five major specialty cohorts based on organization of care and assigned each admission to a specialty cohort using principal discharge diagnosis and procedure codes. First, admissions that included major surgical procedures (regardless of diagnosis code) were assigned to the surgery/gynecology cohort. Then, we assigned the remaining patients to the other four specialty cohorts. We built a separate model for each of the five specialty cohorts. As risk adjustment relates to the patient-level risk of the measure outcome, we adopted the risk factors in the hospital model and evaluated the resulting risk model performance.

To accommodate attribution of each admission to multiple eligible clinicians, we modified the statistical modeling approach and construction of the summary score used in the IQR HWR measure. Specifically, instead of using mixed-effects models to estimate clinician group effects directly, we used logistic regression models to construct SRRs for each specialty cohort and applied a post-estimation method to adjust these for between clinician group variation. These adjusted SRRs are then combined across specialty cohorts for each eligible clinician group to produce a single RARR.

We summarized the RARRs for eligible clinician groups and evaluated the reliability and validity of the measure results. We also assessed the reliability and performance of the five specialty cohort models.

## 2.2 Data Sources

For measure development and testing, we used Medicare administrative claims and enrollment information for patients with admissions between July 1, 2015 and June 30, 2017.

- *Medicare Part A inpatient data* — contain final action claims data submitted by inpatient hospital providers for <u>Medicare fee-for-service (FFS)</u> beneficiaries for reimbursement of facility costs. Information in this file includes International Classification of Diseases (ICD)-9/10 diagnosis codes, ICD-9/10 procedure codes, dates of service, hospital provider ID, and beneficiary demographic information. These data were used to identify index admissions, readmissions, and <u>comorbidities</u> for risk adjustment. These data also were used for identifying inpatient providers. MIPS HWR risk-adjustment models use only inpatient claims data (historical and current). Primarily this is to align with the existing IQR HWR measure. Outpatient data were used for attribution, which is done separately from risk adjustment.

- *Medicare Enrollment Database* — contains Medicare beneficiary demographic, benefit/coverage, and vital status information. These data were used to determine Fee-for-Service (FFS) enrollment and post-discharge mortality status.

- *Medicare Part B claim line data from Integrated Data Repository (IDR)* — contain final action claims data for the physician services (regardless of setting) during the index admission, outpatient care, services, and supplies for Medicare FFS beneficiaries. Each claim line in the file includes details of services rendered, the identity of the rendering clinician, and the payment the clinician received for each line of service. These data were used to identify clinicians who billed for care of the patient during the index inpatient stay and 12 months prior the admission date.

- *Provider Enrollment, Chain and Ownership System (PECOS) file for clinician specialty from IDR* — contains physician and non-physician specialties for NPIs. We used the PECOS file to match the specialties for NPIs in outpatient facilities (Federally Qualified Health Center [FQHC], Critical Access Hospital [CAH], and Rural Health Clinic [RHC]].

- *Electing Teaching Amendment (ETA) hospital-related files and Accountable Care Organization attestation file* — provides information related to identify eligible outpatient facility and clinicians for Outpatient Primary Care Provider (PCP).

- *Medicare outpatient data from FQHCs, CAHs, RHCs, and ETAs* — contains 100% Part B claims for each calendar year from institutional outpatient providers. Examples of institutional outpatient providers include hospital outpatient departments, RHCs, renal dialysis facilities, outpatient rehabilitation facilities, comprehensive outpatient rehabilitation facilities, and community mental health centers. The file includes facility charge amounts. We used these data to identify the PCP facility and clinician. The eligible facility is treated as an eligible clinician group, and its CMS Certification Number (CCN) is treated as same as the identification number for the eligible clinician groups.

For measure development and testing, we created and used data between July 1, 2015 through June 30, 2017 as follows:

- To test patient-level model reliability, we used data from July 1, 2015 through June 30, 2016. We randomly split the one year of data into two equal samples (Development Sample and Validation Sample) and compared model performance in both samples.

- To test patient-level model validity/reliability from a temporal perspective, we used data from July 1, 2016 through June 30, 2017 (Temporal Validation Sample) and compared results to those from July 1, 2015 through June 30, 2016.

- To test measure score signal-to-noise reliability, we used a one-year sample from July 1, 2015 through June 30, 2016 (Medicare Full Sample).

- To assess model performance, calculate measure scores, and calculate performance category results for eligible clinician groups, we used a one-year sample (July 1, 2015 through June 30, 2016, or Medicare Full Sample). This reflects the amount of data (one year) that would be used to calculate the measure under MIPS.

## 2.3   Cohort Definition

In general, we adopted the same cohort definition as the IQR HWR measure.[38] Our guiding principle for defining eligible admissions remained that the measure should capture unplanned readmissions for as many admissions as possible across a maximum number of eligible clinician groups. Therefore, we included all admissions except those for which full data were not available or for which 30-day readmission cannot reasonably be considered a signal of quality of care.

### 2.3.1   Grouping Patients into Clinically Coherent Discharge Condition Categories

We adopted the approach of the hospital-level HWR measure, and aggregated ICD-10 codes into clinically coherent condition categories using the Agency for Healthcare Research and Quality (AHRQ) Clinical Classification Software (CCS). The CCS grouping system is well-known and widely used; it is based on the principal diagnosis and not on complications or events that occur during admission (unlike the Medicare Severity Diagnosis Related Groups [MS-DRGs]); and it was developed using Healthcare Cost and Utilization Project data (unlike CMS Condition Category groups [CMS-CCs]), making it more applicable to all-payer data.[39] The AHRQ CCS has been used by managed care plans, insurers, and researchers for a variety of functions, such as assessing resource use, predicting future expenses, comparing procedure or condition rates among payers or hospitals, or profiling patients. We used AHRQ CCS versions 2017.1 and 2017.2, in which there are a total of 285 mutually exclusive AHRQ condition categories, most of which are single, homogenous diseases such as pneumonia or acute myocardial infarction. Some are aggregates of conditions, such as "other bacterial infections." Mental health and substance abuse categories are included. In addition, AHRQ provides 231 mutually exclusive procedure categories to group procedures a patient might have had during admission; these procedure groups are used to identify patients with major procedures for assignment to the surgery/gynecology cohort, and to risk adjust outcomes for the patients in that specialty cohort. To enhance the CCSs for use within measurement, CORE slightly modifies the CCSs based on thorough clinical review.

### 2.3.2   Inclusion Criteria

Admissions are eligible for inclusion in the measure if:

1. Patient is 65 years of age or older.
   **Rationale:** Younger Medicare patients represent a distinct population with dissimilar characteristics and outcomes.

2. Patient survives admission.
   **Rationale:** Patients who die during the initial admission cannot be readmitted.

3. Patient is discharged home or to a non-acute setting.
   **Rationale:** In an episode of care in which a patient is transferred among hospitals, responsibility for the readmission is assigned to the final discharging hospital. Therefore, intermediate admissions within a single episode of care are not eligible for inclusion.

4. Patient is continuously enrolled in FFS Medicare for the 12 months prior to the index admission and 30 days after discharge.
   **Rationale:** This is necessary to ensure full data for risk adjustment, attribution, and outcome determination.

These inclusion criteria are consistent with existing CMS publicly reported measures for readmission.

### 2.3.3 Exclusion Criteria

We then applied several exclusion criteria to the measure population ("starting cohort").

1. Patients discharged against medical advice (AMA) are excluded.
   **Rationale:** Clinicians have limited opportunity to implement high quality care.

2. Admissions for patients to a PPS-exempt cancer hospital are excluded.
   **Rationale:** These hospitals care for a unique population of patients that cannot reasonably be compared to the patients admitted to other hospitals.

3. Admissions primarily for medical treatment of cancer are excluded.
   **Rationale:** These admissions have a very different mortality and readmission profile than the rest of the Medicare population (higher rates of planned readmissions and higher rates of competing mortality), and outcomes for these admissions do not correlate well with outcomes for other admissions. Patients with cancer who are admitted for other diagnoses or for surgical treatment of their cancer remain in the measure. See Appendix B for excluded CCS.

4. Admissions primarily for psychiatric disease are excluded.
   **Rationale:** Patients admitted principally for psychiatric treatment are typically cared for in separate psychiatric centers which are not comparable to acute care hospitals. See Appendix B for excluded CCSs.

5. Admissions for "rehabilitation care; fitting of prostheses; and adjustment devices" (CCS 254) are excluded.
   **Rationale:** These admissions are not typically admitted to an acute care hospital for acute care.

6. Patient cannot be attributed to a clinician group.
   **Rationale:** Only patients with adequate claims for attribution should be included in the measure.

7. Patient is not continuously enrolled in Medicare Part A FFS for at least 30 days following discharge from the index admission.
   **Rationale:** The 30-day readmission outcome cannot be assessed in this group since claims data are used to determine whether a patient was readmitted.

Note that a readmission within 30-days will also be eligible as an index admission if it meets all other eligibility criteria. This allows our measure to capture repeated readmissions for the same patient, whether with the same clinician(s) or not. Since there are few patients with multiple admissions in the same year in the same specialty cohort, it is difficult to model the within-patient variance; thus, we chose to treat these multiple admissions as statistically independent.

### 2.3.4 Specialty Cohorts

Consistent with the hospital-level measure, we organized admissions in the total cohort into five mutually exclusive specialty cohorts: 1) cardiorespiratory, 2) cardiovascular, 3) medicine, 4) neurology, and 5) surgery/gynecology. By grouping patients with similar conditions, we improve risk adjustment.

We refer to these specialty cohorts as "specialty cohorts," a term which refers to the principal discharge diagnosis, not the specialty of the clinicians caring for the patients. We estimated a separate risk model for each specialty cohort. We used the same approach to define the specialty cohorts as the IQR HWR measure; please refer to that underline measure methodology report for additional information regarding measure development decisions and details. (See Appendix C, Table C2, for a specific list of conditions in each specialty cohort).[40]

Logically, admissions are first assigned to the surgery/gynecology specialty cohort, according to whether a major procedure is performed. Those not assigned to this specialty cohort are then assigned to one of the other four specialty cohorts based on the primary discharge diagnosis. Thus, we describe the surgery/gynecology specialty cohort first, followed by the others.

Surgery/Gynecology
This cohort includes admissions likely cared for by surgical or gynecologic teams. To be confident that these patients were cared for by surgical or gynecologic teams, we used AHRQ *procedure* categories (rather than AHRQ condition categories) to identify these patients. A patient could only be assigned to the surgery/gynecology specialty cohort if they underwent a major surgical procedure. We reviewed the list of AHRQ procedure categories and identified those which could typically result in surgical or gynecological teams caring for the patient. Minor procedures that would not have required a patient to be on the surgical service were not included in the list (for example, breast biopsy). Procedures that would generally accompany other, more major, procedures were also not included in the list on the assumption that patients undergoing these procedures would also undergo another procedure on the list (for example, intraoperative cholangiogram). The full list of procedures assigned to the surgery/gynecology specialty cohort is summarized in Appendix C, Table C1. Any eligible admission during which a major surgical procedure from the final list was performed was assigned to the surgery/gynecology specialty cohort.

After assigning patients to the surgery/gynecology specialty cohort, we then used the principal discharge diagnosis AHRQ CCS to assign remaining index admissions to one of the other four specialty cohorts, as described below. This approach is consistent with the IQR HWR measure. The AHRQ discharge condition categories for the non-surgical groups are shown in Appendix C, Table C2.

Cardiorespiratory
This cohort includes several conditions with very high readmission rates — pneumonia, chronic obstructive pulmonary disease, and heart failure — as well as admissions for other condition categories related to these three conditions (asthma, acute bronchitis, pulmonary heart disease, cystic fibrosis, and respiratory failure). We combined these patients into a single specialty cohort because patients with these diseases are often clinically indistinguishable, are typically treated by the same care teams, and are often simultaneously treated for several of these diagnoses. Although patients with heart failure may be cared for by a separate cardiac or cardiovascular team, they are also often cared for by general medicine teams.

Cardiovascular
This cohort includes cardiovascular condition categories, such as acute myocardial infarction, that in large hospitals might be cared for by a separate cardiac or cardiovascular team.

<u>Neurology</u>
This cohort includes neurologic condition categories such as stroke that in large hospitals might be cared for by a separate neurology team.

<u>Medicine</u>
This cohort includes all non-surgical patients who were not assigned to any of the specialty cohorts.

## 2.4 Outcome Definition

The <u>outcome</u> for this measure is unplanned all-cause 30-day readmission. We define a readmission as a subsequent inpatient admission to any acute care facility which occurs within 30 days of the discharge date of an eligible index admission. Any readmission is eligible to be counted as an outcome, except those that are considered planned.

### 2.4.1 Planned Readmissions

Only unplanned readmissions were counted as outcomes. To align with our data years we used the planned readmission algorithm version 4.0 to classify readmissions as planned or unplanned.[41] Implementation with more recent data would use the most recent version of the planned readmission algorithm.

### 2.4.2 All-cause Readmission

As with the IQR HWR measure, we defined the outcome as "all-cause" unplanned readmissions rather than readmissions related to the previous admission for multiple reasons. First, from the patient perspective, readmission for any reason is likely to be an undesirable outcome of care. Furthermore, readmission for any reason exposes the patient to risks associated with admission, such as iatrogenic errors. Second, there is no reliable way to determine whether a readmission is related to the previous admission based on the documented cause of readmission. For example, a stroke patient who develops aspiration pneumonia may ultimately be readmitted for respiratory distress. It would be inappropriate to treat this readmission as unrelated to the care the patient received for stroke. Third, the range of potentially avoidable readmissions also includes those not directly related to the index condition category, such as those resulting from medication reconciliation errors, poor communication at discharge, or inadequate follow-up post-discharge. Creating a comprehensive list of potentially avoidable readmissions related to the previous admission's condition category would be arbitrary and, ultimately, challenging to implement. Fourth, all existing CMS readmission measures report all-cause readmission, making this approach consistent with existing measures. Fifth, research shows that readmission reduction interventions can reduce all-cause readmission, not only condition-specific readmission. Finally, defining the outcome as all-cause readmissions may encourage hospitals to implement broader initiatives aimed at improving the overall care within the hospital and transitions from the hospital setting instead of limiting the focus to a narrow set of condition-specific approaches.

## 2.5 Attribution to Multiple Clinician Groups

Attribution of the outcome is the critical difference between MIPS HWR measure and the IQR HWR measure. While a hospital discharge can be unambiguously assigned to the facility which bills for the discharge, there is more uncertainty when assigning a discharge to a clinician. A critical and novel aspect

of MIPS HWR measure is that it attributes each outcome to potentially three distinct eligible clinician groups (Section 2.5.2), each identified by care provided by an individual eligible clinician in that eligible clinician group. Conceptually, this "multiple attribution" is consistent with the recognition that patient readmission can be influenced by multiple key providers; attribution to multiple providers was strongly endorsed by a large majority of the TEP.

We used the key principles, TEP input, and internal clinical experience to develop a set of potential candidate clinicians for attribution. These included eligible clinicians identified on the hospital claim (e.g., the attending clinician), and those identified through carrier claims and outpatient claims (Section 2.2). All candidate approaches were identified using claims data, and all were identified using the principles outlined in Section 1.4.2. We then used the strategy described in Section 1.4.3 to finalize the set of attribution rules. Appendix D documents attribution rules that were evaluated and ultimately excluded, along with the reason they were not adopted.

### 2.5.1   Eligible Clinician Group (TIN)

In order to assign attribution to multiple eligible clinician groups, first we identified 'eligible clinicians' using unique combinations of NPI and TIN. Thus, a single clinician may be measured two or more times if they file Medicare claims under two or more TINs. Each attribution rule includes an algorithm for identifying a unique TIN/NPI combination.

These unique TIN/NPI combinations, and the patients attributed to them, are then directly aggregated into groups of clinicians with the same TIN. We refer to these as eligible clinician groups or simply 'clinician groups.' It should be noted that these approximately align with practice groups (but not perfectly). Note also that patients can only be assigned to groups by way of an eligible clinician (a TIN/NPI combination), and thus these are by default groups with at least one eligible clinician. Within MIPS, an eligible clinician 'group' must include two or more eligible clinicians, at least one of which participates in MIPS. Because we could not identify non-attributed eligible clinicians at each TIN during development, we report all TINs regardless of the number of attributed eligible clinicians.

### 2.5.2   Eligible Clinicians Included within Multiple Clinician Group Attribution

The following three types of individual eligible clinicians are included in the multiple eligible clinician group attribution approach. Therefore, a qualifying inpatient admission is attributed to up to three separate eligible clinician groups using the individual Discharge Clinician, Primary Inpatient Care Provider, and Outpatient PCP assigned to that admission.

Discharge Clinician
The Discharge Clinician is intended to capture the clinician responsible for discharging the patient and thus a key individual responsible for readmission outcomes. The TEP agreed that the Discharge Clinician is both a key individual facilitating the transition from inpatient to outpatient care and is the main point of contact for post-discharge providers, such as home health providers and visiting nurses. They also prioritized this attribution approach over the Attending of Record, as the Attending is designated by the hospital, while the Discharge Clinician is identified through clinician claims and thus is more under the control of the clinician.

The Discharge Clinician is determined by identifying a claim for a discharge procedure code which occurred within the last three days of the hospital stay. Attribution to the Discharge Clinician reinforces the notion that readmission is a signal of quality during a care transition. Practically, the Discharge Clinician is often, but not always, also the attending of record on the inpatient claim. The Discharge Clinician is determined using the outpatient (Carrier) claims, as for most patients discharged from acute care there should be a corresponding claim for a discharge procedure (Current Procedural Terminology [CPT®] code 99238 or 99239). In the case of multiple claims with a discharge procedure code within the same episode of care, the last claim was used. If no discharge procedure code was found, the last day of the stay was searched for a subsequent care code (CPTs 99231, 99232, and 99233), and, if found, the eligible clinician on this claim was assigned the admission. If no eligible clinician is identified at this step, no Discharge Clinician was assigned. The complete algorithm is documented in Figure D.2 in Appendix D.

Primary Inpatient Care Provider
The Primary Inpatient Provider is the eligible clinician who billed the most charges for the patient during their hospital stay. Only patient-facing claims are counted. Conceptually, it may be reasonable that the provider who charged the most for the patient's care during the admission is most responsible for that patient's outcomes. Practically, charges are readily available from the Carrier claims file. This attribution approach was added based upon TEP input. As with the Discharge Clinician, it is identified using clinician claims and thus is more under the control of the individual clinician.

We explored using both the number of claims billed by each clinician as well as the total cost of charges per clinician to identify this provider. Using the greatest charges billed provides greater clinical sensibility and better reflects the different ways surgeons and non-surgical providers bill for inpatient care. While non-surgical providers frequently bill for each individual (often daily) patient encounter, surgeons often bill for the procedure but not for each daily patient encounter. Therefore, using the greatest number of claims produced clinician assignments that lacked face validity for surgical patients. Using the greatest charges billed identified similar non-surgical providers as the greatest number of claims approach, while more accurately identifying surgical providers for patients in the surgery/gynecology specialty cohort.

All patient-facing claims for the patient filed during the stay are identified and totaled over eligible clinician values on each claim; the admission is attributed to the eligible clinician with the greatest charges billed. This may often be the same as the eligible clinician identified as the Discharge Clinician, but in cases where the Discharge Clinician provided care for only a small part of the stay, the Primary Inpatient Care Provider attribution captures an alternate eligible clinician who provided most of the care. The complete algorithm is documented in Figure D.1 in Appendix D.

Outpatient PCP
The Outpatient PCP is the eligible clinician who provides the greatest number of claims for primary care services during the 12 months prior to the hospital admission date. Conceptually, if a patient has a primary care provider, this clinician could plausibly be aware of any admission and provide post-discharge follow-up care that would reduce the need for a readmission. The TEP strongly supported attributing the measure outcome to multiple providers, including outpatient providers, to incentivize shared accountability for readmissions.

In keeping with our principle to align the identified PCP with the way this is done in other measures, this rule is a modification of the attribution used by the MIPS ACR measure currently reported within MIPS.

That measure uses an algorithm to assign inpatient admissions to primary care providers by identifying a clinician using the greatest number of claims of primary care codes during the calendar year of admission. The MIPS ACR algorithm is documented here.[42] Our only modification was to use a different window for each admission, rather than a fixed calendar year.[43] The revised approach uses the 12 months of clinician claims prior to the index admission included in the measure to identify the Outpatient PCP. This ensures the clinician has seen the patient prior to admission and is therefore more likely to be able to meaningfully contribute to the patient's post-discharge care.

Multiplicity, Overlap, and Reporting
Though an admission may be attributed to three distinct eligible clinician groups, it will often be the case that two or even all three of the above-listed roles for a given patient are filled by clinicians assigned to the same clinician group. In the case of multiple assignments of an admission to the same eligible clinician group, each admission is included only once when measuring the eligible clinician group.

Importantly, this implies that while there are three different rules for attribution, these are not distinguished when measuring clinician group performance. While a clinician group can have admissions attributed to them in multiple capacities — for instance, clinicians from the same group may be both a Discharge Clinician for some patients and a Primary Inpatient Care Provider for others – all attributed admissions are used to construct a single score for that eligible clinician group. Thus, while we report some results by attribution role, we report measure scores only for "unique eligible clinician groups."

### 2.5.3    Volume Requirements

It is impractical to measure outcomes for clinician groups which are assigned a small number of patients; though technically it is feasible to construct estimates based on as few as one patient, practically we would want to measure only those entities with adequate volume to construct moderately reliable estimates. For the purposes of measure development and this report, we include only eligible clinician groups with at least 25 attributed patients for reporting results since we considered this the absolute minimum volume for face validity and it is aligned with the threshold for public reporting of the hospital-level HWR measure. However, within the reliability section (Section 4.4), we present reliability results for a range of volume thresholds, both for transparency and to inform CMS's proposal to maintain consistency with the current MIPS ACR measure and apply a minimum case count of 200 admissions.

### 2.6   Risk Adjustment

### 2.6.1    Overview

The goal of risk adjustment is to account for differences across clinician groups in patient demographic and clinical characteristics that might be related to the outcome but are unrelated to quality of care. Risk adjustment for this measure is complicated by the fact that it includes many different principal discharge diagnosis condition categories. We must therefore adjust both for case mix differences (clinical status of the patient, accounted for by adjusting for comorbidities) and service mix differences (the types of conditions/procedures, accounted for by adjusting for the principal discharge diagnosis condition category). In keeping with our key principle regarding alignment with the IQR HWR measure, and because the hospital-level risk model was developed and validated at the patient level using the same cohort adopted for MIPS HWR measure, we used the same risk factors as used by the IQR HWR model. We then tested the model performance.

Consistent with the original IQR HWR measure, we do not adjust for socioeconomic status (SES) because the association between SES and health outcomes can be due, in part, to differences in the quality of health care that groups of patients with varying SES receive. The intent is for the measure to adjust for age and clinical characteristics while illuminating important quality differences and disparities. The IQR HWR measure was re-endorsed by NQF without adjustment for patient-level SES factors. For more information, please refer to the NQF website.

Because the MIPS HWR measure assigns each admission to multiple eligible clinician groups, we could not adapt the hierarchical logistic regression methods of the IQR HWR measure to adjust for differences in eligible clinician group case mix and to account for the clustering of patients within a provider. Instead, we used a method which uses the results of each specialty cohort model to construct a standardized readmission rate for each clinician group which is corrected for clustering and between provider variance after estimation. Each cohort model adjusts for case mix differences among providers by risk adjusting for patients' comorbid conditions identified in inpatient episodes of care for the 12 months prior to the index admission as well as those present at admission. We did not risk adjust for diagnoses that may have been a complication of care during the index admission. We used CMS-CCs, the grouper used in previous CMS risk-standardized outcome measures, to define the comorbid risk adjusters and used a fixed set of comorbid risk variables across models. We risk adjusted for service mix differences among eligible clinician groups within each specialty cohort by including indicator variables for principal discharge diagnosis condition categories (as defined by AHRQ CCS) in each model.

Finally, we used each of the five specialty cohort models to calculate the ratio of observed to expected numbers of unplanned readmissions (as defined below in Section 2.6.2) for each clinician group in each specialty cohort. These SRRs are then used to estimate the between provider variance, and this parameter is then used to adjust each SRR, creating a 'smoothed rate' (SR). We then derived a single summary score from the results of the five specialty cohort models by calculating the volume-weighted log average (that is, the geometric mean) of the SRRs from each model and multiplying the resulting ratio by the average national observed readmission rate. This approach allowed us to take into account the variation in specialty cohort mix across eligible clinician groups.

Service-mix Adjustment
For all CCSs with sufficient volume (defined as those with more than 1,000 admissions nationally each year), we included a condition-specific indicator in the model. Condition categories differ in their baseline readmission risks and eligible clinician groups will differ in their relative distribution of these condition categories (service mix) within each specialty cohort. Therefore, adjusting for condition categories levels the playing field across eligible clinician groups with different service mixes. This was to align with the IQR HWR measure. These are listed in the tables of Appendix F.

Complications of Admission
Complications occurring during admission are not comorbid illnesses, may reflect clinician quality of care, and therefore should not be used for risk adjustment. Although adverse events during admission may increase the risk of readmission, including them as covariates in a risk-adjusted model could attenuate the measure's ability to characterize the quality of care delivered by eligible clinician groups. We used the previously vetted approach from the IQR HWR measure to classify CMS-CCs that are plausibly complications of care; we augmented these with Present on Admission (POA) codes and omitted any potential complications of care lacking a POA flag as risk adjusters. See Appendix E.

Case-mix Adjustment: Comorbid Risk Variables

We used CMS-CCs to group ICD-9-Clinical Modification (CM)/ICD-10-CM codes into comorbid risk adjustment variables. To enhance the CCs for use within measurement, CORE slightly modifies the CCs based on thorough clinical review. Multiple CMS condition-specific claims-based readmission models that use this grouper method to define variables for risk adjustment have been validated against models that use medical record-abstracted data for risk adjustment.[23-25]

## 2.6.2  Statistical Approach to Calculating Risk-Adjusted Readmission Rates

Because the same admission may be attributed to more than one unique eligible clinician group, we could not apply the method used by the IQR HWR measure to construct risk-standardized readmission rates. Instead, we adopted a method that, while requiring an assumption of independence across entities, allowed us to account for correlation within entity.

Let

- $Y_i$ be the observed (0, 1) outcome for patient i

- $\bar{Y}$ be the observed rate for all discharges in the reference population

- $H$ be the total number of providers (clinician groups)

- $\hat{E}_i$ be the expected (<u>predicted</u>) patient-level probability;

- $n_h$ be the number of discharges at provider $h$

We define the observed rate at provider $h$ as

$$O_h = \frac{1}{n_h} \sum_{i=1}^{n_h} Y_i$$

The <u>expected</u> rate at provider h as

$$\hat{E}_h = \frac{1}{n_h} \sum_{i=1}^{n_h} \hat{E}_i$$

The Standardized Readmission Ratio (SRR) as

$$SRR_h = \frac{O_h}{\hat{E}_h}$$

Then the formula for the smoothed rate (SR) is:

$$SR_k = (SRR_k \times Shrinkage\ Weight) + (1 - Shrinkage\ Weight) \qquad (1)$$

Where

$$Shrinkage\ Weight = \frac{Signal\ Variance}{Signal\ Variance + Noise\ Variance}$$

$$Noise\ Variance\ \hat{\sigma}_h^2 = \left(\frac{1}{n_h \hat{E}_h}\right)^2 \sum_{i \in A_h} \hat{E}_i(1 - \hat{E}_i)$$

$$Signal\ Variance\ \hat{\tau}^2 = \frac{\sum_{h=1}^{H} \frac{1}{(\hat{\tau}^2 + \hat{\sigma}_h^2)^2} \max(0, \{(SRR_h - \overline{SRR})^2 - \hat{\sigma}_h^2\})}{\sum_{h=1}^{H} \frac{1}{(\hat{\tau}^2 + \hat{\sigma}_h^2)^2}} \qquad (2)$$

Note that $\hat{\tau}^2$ appears on both sides of the signal variance equation.

For calculating the clinician group RARR using SR scores from five specialty cohorts, we combined the SRs using volume-weighted logarithmic mean as following:

$$SR_j = \exp(\ (\textstyle\sum m_{cj} \log(SR_{cj}))\ /\ \textstyle\sum m_{cj}\ ) \qquad (3)$$
$$RARR_j = SR_j * \overline{Y}$$

where $\overline{Y}$ = overall national observed readmission rate for all index admissions in all cohort, $m_{cj}$ = the number of discharges for provider j in cohort c, $SR_{cj}$ = the calculated smoothed rate score for provider j in cohort c.

Creating Credible Interval Estimates
For purposes of estimating confidence intervals, we used bootstrapping. Because of overlapping attribution of patients, bootstrapping was at the specialty cohort level. Specifically, we select m=1,…,M random samples of discharges with replacement from each specialty cohort. Using the existing attribution, we calculated (1), (2), and (3) above for each eligible clinician group. The 95% credible interval estimate of the $RARR_j$ for each eligible clinician group was used as the estimated 95% confidence interval.

Performance Categories
After bootstrapping the RARRs, we used the estimated 95% confidence intervals to identify eligible clinician groups which have RARRs that are statistically significantly different than the national rate. Those significantly above (worse than) the national rate had 95% confidence intervals above and wholly exclusive of the national rate; those significantly below (better than) the national rate had 95% confidence intervals below and wholly exclusive of the national rate.

# 3. MEASURE TESTING

### 3.1 Evaluation

We used a full year of admission data from 2015–2016, with 12 months history data, to create the specialty cohorts and select risk variables. To assess reliability of the models' performance, we also created a full-year cohort for 2016–2017 and then combined 2015–2016 and 2016–2017 data, randomly split this dataset, and ran the models on each split sample. For the purposes of measure development and this report, we report results using a minimum case volume of 25 admissions per eligible clinician group, as we considered this the absolute minimum volume for face validity and it is aligned with the threshold for public reporting of the IQR HWR measure. However, for measure result reliability, we report results for a range of volume thresholds, both for transparency and to inform CMS's proposal to maintain consistency with the current MIPS ACR measure and apply a minimum case count of 200 admissions.

#### 3.1.1 Cohorts and Outcomes

For each specialty cohort we report the number of admissions, number of readmissions, rate of planned and unplanned readmissions, and proportion of all readmissions that are planned.

#### 3.1.2 Attributed Eligible Clinician Groups

For each attribution rule, we report the distribution of admissions assigned across eligible clinician groups. We also report the percent of admissions that could not be assigned and the total number of distinct eligible clinician groups in that role. Then, for unique eligible clinician groups, we report the number of specialty cohorts assigned and the distribution of unadjusted outcome rates across specialty cohorts.

#### 3.1.3 Unadjusted Outcome Rates

We report distribution of unadjusted readmission rates for eligible clinician groups with at least 25 admissions assigned, both by attribution rule and overall.

#### 3.1.4 Risk-Adjustment Variables

We report the frequency of each risk variable for all datasets. This provides a description of the admissions included in the different samples, informing both face validity and reliability considerations.

#### 3.1.5 Models for Each Specialty Cohort

For each of the five specialty cohorts, we estimated a patient-level logistic regression model. These models included the risk factors listed in Appendix F, with the dependent variable being the outcome, readmission within 30 days after discharge. We report the coefficient and variance estimates for the models. The direction and magnitude of these estimates provide face validity for the risk adjustment.

### 3.1.6 Risk-Adjusted Readmission Rates

We report the distribution of SRs for each specialty cohort and the RARRs across eligible clinician groups with at least 25 admissions. We also report the distribution of high and low outliers for the same eligible clinician groups.

### 3.2 Model Performance

We assessed the reliability of the patient-level models by comparing coefficients from logistic regression models in the Development Sample to both the Validation and Temporal Validation Samples (Section 2.2). For each logistic regression model, we computed five summary statistics to assess model performance: calibration (a measure of over-fitting), discrimination in terms of predictive ability, discrimination in terms of area under the receiver operating curve (ROC), distribution of residuals, and model chi-square.

Over-fitting refers to the phenomenon in which a model describes the relationship between predictive variables and outcome well in the development dataset but fails to provide valid predictions in new patients. If the $\gamma_0$ in the validation sample is close to zero and the $\gamma_1$ is close to 1 in each of the models, there is little evidence of over-fitting.

Discrimination in predictive ability measures the ability to distinguish high-risk subjects from low-risk subjects. Therefore, we would hope to see a wide range between the lowest decile and highest decile, which these models show.

The C-statistic is a measure of how accurately a statistical model is able to distinguish between a patient with and without an outcome. A C-statistic of 0.50 indicates random prediction, implying all patient risk factors are useless; a value of 1 indicates perfect prediction, implying patients' outcomes can be predicted completely by their risk factors, and clinicians play no role in patients' outcomes. While higher C-statistic is desirable, we do not want to maximize C-statistic by adjusting for factors that should not be adjusted for; for example, we do not want to include complications of care as risk factors, even if it produces a higher C-statistic.

The model residuals are the difference between what the model predicts for each patient and the observed outcome. If they are not distributed symmetrically around zero, or if most values are not near zero, this indicates that the model assumptions are not met.

The model chi-square is a statistic which represents the degree to which the model explains the observed data.

### 3.3 Internal Consistency

Because this measure is comprised of five component specialty cohort models, we assessed whether the component scores — the SRs for each specialty cohort — were consistent with each other across providers. To assess the overall internal consistency of the specialty cohort SRs, we report the correlations for unique eligible clinician groups, as well as Cronbach's coefficient α. We do this among those specialty cohorts for which the eligible clinician group has at least 25 admissions attributed.

Cronbach's $\alpha$ reflects the proportion of total variance in the summated scale composite score that is accounted for by a common source among the condition measures. Theoretically, Cronbach's α varies from 0 to 1; α generally increases as the intercorrelations among components increase, although it is also affected by factors such as the number of contributing items. Though internal consistency provides some measure of overall validity, we take a formative perspective in combining the SRs across providers — that the overall RARR serves as an average of perhaps distinct metrics rather than as a measure of a latent trait underlying them.

## 3.4 Reliability

### 3.4.1 Data Element Reliability

In constructing this measure, we utilized only those data elements from claims that have both face validity and reliability. We also assessed the reliability of the data elements by comparing risk factor frequencies and <u>Odds Ratios</u> (ORs) in the Split Sample Datasets.

### 3.4.2 Measure Score Reliability

To test the reliability of this measure, we considered the notion of 'signal-to-noise' reliability (SNR) for each of the specialty cohorts. This is the degree to which the variation between clinician groups ('signal') comprises the total variation ('noise' + 'signal') in the outcome. Because signal-to-noise reliability is based on model parameters, it is only meaningful to calculate it at the level of the specialty cohort; however, according to Rudner[44] the reliability of an aggregated scale is bounded below by the reliability of the least reliable component, and will generally be greater than the most reliable component if the component scales are positively correlated. To estimate the overall signal and noise, we used the bootstrap estimates of RARR variance (<u>Section 2.6.2</u> above) as the within-entity variance $\sigma_j^2$ for the eligible clinician group j. For cohorts, we used equation (2) above to estimate the signal $\tau^2$; for the overall measure, we used the variance in RARRs across groups. Then for each entity calculate

$$SNR_j = \tau^2/(\tau^2 + \sigma^2)$$

To calculate the reliability of each entity measurement; we report the mean and distribution of $SNR_j$ over all entities for different minimum volumes $n_j$.[45]

## 3.5 Validity

### 3.5.1 Data Element Validity

For validity of the data elements, CORE has already demonstrated for a number of prior measures the validity of claims-only measures for profiling hospitals by comparing either the measure results or individual data elements against medical records, as discussed further in the results (<u>Section 4</u>).

### 3.5.2 Measure Score Validity

<u>Validity of Attribution Rules</u>
Prior to developing a list of attribution rules, we conducted literature review and environmental scans to evaluate the attribution used by existing outcome measures under MIPS, as well as those that have

been implemented and evaluated. We reviewed the methodology from the CMS VM program measures, the report on attribution rules proposed for use in or implemented in healthcare delivery models published by the NQF in December 2016, and medical literature published after the NQF compiled its report. After we compiled this comprehensive list of attribution rules, we held two TEP meetings to review the rules with clinical experts and patients and established an approach to identifying and testing candidate attribution rules.

Face Validity of Measure Scores
Following presentation and review of the final measure specification, results, and testing, CORE surveyed the 19 members of the TEP regarding validity and usability of the MIPS HWR measure. We asked them to consider two statements (via an online survey):

*The risk-adjusted readmission rates obtained from the MIPS HWR measure as specified:*

1. *Are valid and useful measures of MIPS eligible clinician group quality of care.*

2. *Will provide MIPS eligible clinician groups with information that can be used to improve their quality of care.*

TEP members were asked to report their agreement with each statement on a 6-point scale, representing a range from "strongly disagree" to "strongly agree."

# 4. RESULTS

## 4.1 Evaluation

### 4.1.1 Cohort and Outcomes

Figure 1 illustrates the cohort selection and exclusions.

**Figure 1. HWR cohort exclusions (dataset: Medicare full sample [July 2015–June 2016])**
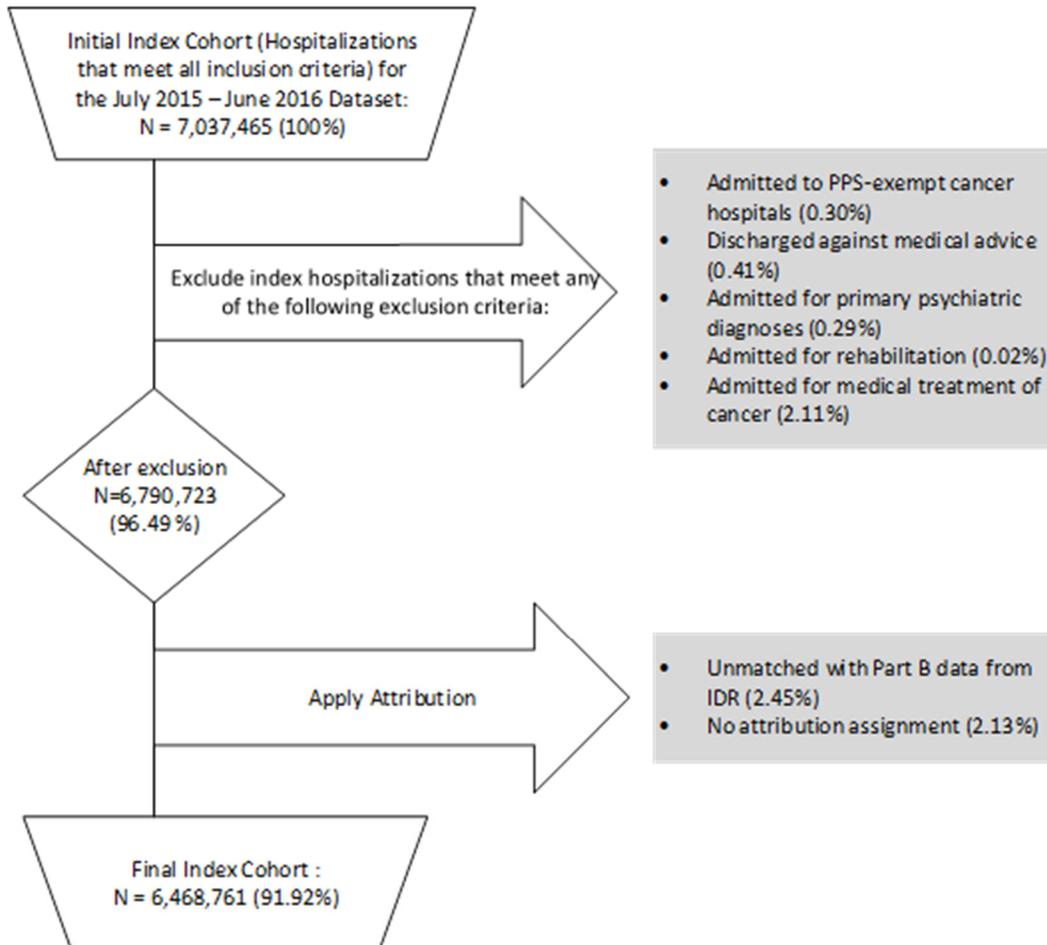
Table 1 reports the number of admissions, number of readmissions, rate of planned and unplanned readmissions, and proportion of all readmissions that are planned.

**Table 1. Admissions, readmissions for the five specialty cohorts (dataset: Medicare Full Sample)**

| Specialty cohort | # of admissions | # of unplanned readmissions | 30-day unplanned readmission rates | # of planned readmissions | 30-day planned readmission rates | Planned to unplanned readmission ratio |
|---|---|---|---|---|---|---|
| Cardiorespiratory | 1,041,507 | 203,182 | 19.5% | 6,307 | 0.6% | 3.1% |
| Cardiovascular | 640,081 | 92,567 | 14.5% | 10,919 | 1.7% | 11.8% |
| Medicine | 2,719,822 | 459,304 | 16.9% | 23,799 | 0.9% | 5.2% |
| Neurology | 402,319 | 52,692 | 13.1% | 3,503 | 0.9% | 6.6% |
| Surgical | 1,665,032 | 189,667 | 11.4% | 11,470 | 0.7% | 6.0% |
| Total | 6,468,761 | 997,412 | 15.4% | 55,998 | 0.9% | 5.6% |

### 4.1.2 Attributed Eligible Clinician Groups

Table 2 reports the distribution of admissions across eligible clinician groups.

**Table 2. Distribution of admissions assigned to eligible clinician groups (dataset: Medicare Full Sample)**

| Statistic | Discharge Clinician | Primary Inpatient Care Provider | Outpatient PCP | All eligible clinician groups (unique TINs) |
|---|---|---|---|---|
| # of admissions in each attribution | 6,417,534 | 6,417,534 | 6,290,391 | 6,468,761 |
| % of admissions in each attribution | 99.2% | 99.2% | 97.2% | 100.0% |
| Minimum | 1 | 1 | 1 | 1 |
| 10$^{th}$ percentile | 1 | 1 | 1 | 1 |
| 25$^{th}$ percentile | 3 | 3 | 2 | 3 |
| 50$^{th}$ percentile | 12 | 16 | 10 | 16 |
| 75$^{th}$ percentile | 48 | 57 | 40 | 59 |
| 90$^{th}$ percentile | 151 | 161 | 103 | 158 |
| Maximum | 31,136 | 16,988 | 12,133 | 35,528 |
| Mean (standard deviation [SD]) | 114.7 (620.6) | 100.1 (466.5) | 57.5 (272.0) | 99.6 (535.6) |
| Number of eligible clinician groups | 55,957 | 64,081 | 109,312 | 130,671 |

Table 3 reports, for unique eligible clinician groups, the number of specialty cohorts assigned and the distribution of unadjusted outcome rates across specialty cohorts.

Accordingly, the final measure score for over 80% of eligible clinician groups with at least 25 admissions is based on all five specialty cohorts. Fewer than 10% of eligible clinician groups with at least 25 admissions have measure results based upon three or fewer specialty cohorts.

**Table 3. Number of eligible clinician groups (unique TINs) by number of specialty cohorts attributed (dataset: Medicare Full Sample)**

| Number of specialty cohorts | All entities | Entities with 25+ admissions attributed |
|---|---|---|
| | # (%) eligible clinician groups | # (%) eligible clinician groups |
| 1 | 26,180 (20.0%) | 334 (0.6%) |
| 2 | 19,225 (14.7%) | 1,645 (3.0%) |
| 3 | 15,613 (11.9%) | 2,471 (4.4%) |
| 4 | 18,050 (13.8%) | 6,433 (11.6%) |
| 5 | 51,603 (39.5%) | 44,710 (80.4%) |

### 4.1.3   Unadjusted Outcome Rates

Below we report the unadjusted unplanned readmission rates for eligible clinician groups, Table 4).

**Table 4. Unadjusted rates for eligible clinician groups (unique TINs) with at least 25 admissions (dataset: Medicare Full Sample)**

| Statistic | Cardio-respiratory | Cardio-vascular | Medicine | Neurology | Surgical | Overall HWR cohort |
|---|---|---|---|---|---|---|
| # of admissions in each attribution with 25 admission cutoff | 1,038,422 | 638,171 | 2,709,870 | 400,984 | 1,657,704 | 6,445,151 |
| % of admissions in each attribution with 25 admission cutoff | 99.7% | 99.7% | 99.6% | 99.7% | 99.6% | 99.6% |
| Minimum | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% |
| 10th percentile | 0.0% | 0.0% | 5.6% | 0.0% | 0.0% | 7.7% |
| 25th percentile | 8.3% | 0.0% | 11.1% | 0.0% | 5.7% | 11.5% |
| 50th percentile | 18.2% | 12.5% | 16.2% | 6.3% | 11.5% | 15.3% |
| 75th percentile | 26.4% | 22.2% | 21.4% | 20.0% | 18.2% | 19.3% |
| 90th percentile | 37.5% | 33.3% | 27.3% | 33.3% | 27.3% | 23.8% |

| Statistic | Cardio-respiratory | Cardio-vascular | Medicine | Neurology | Surgical | Overall HWR cohort |
|---|---|---|---|---|---|---|
| Maximum | 100% | 100% | 100% | 100% | 100% | 64.3% |
| Mean (SD) | 19.3% (16.2%) | 15.0% (17.7%) | 16.6% (9.4%) | 13.3% (19.3%) | 13.4% (12.2%) | 15.6% (6.4%) |
| # of eligible clinician groups with 25 admissions | 81,177 | 77,068 | 110,396 | 68,689 | 104,354 | 130,671 |

### 4.1.4    Risk-Adjustment Variables

The prevalence of the risk factors for each specialty cohort are in Appendix F

### 4.1.5    Models for Each Specialty Cohort

The results of the model estimation for the development and validation cohorts are reported in detail in Appendix F.

### 4.1.6    Risk-Adjusted Readmission Rates

After estimating the models reported in Appendix F, we used the results to construct SRs for each specialty cohort and risk-adjusted readmission rates for eligible clinician groups. In the following table, Table 5, and figure, Figure 2, we report the distributions of SRs and RARRs for each clinician group. These data provide supportive evidence of performance variation.

**Table 5. Distribution of SRs by specialty cohort and overall, for eligible clinician groups with at least 25 admissions (dataset: Medicare Full Sample)**

| Statistic | Cardio-respiratory | Cardio-vascular | Medicine | Neurology | Surgical | Overall HWR SR | RARR |
|---|---|---|---|---|---|---|---|
| Signal variance | 0.0812 | 0.1206 | 0.0612 | 0.2077 | 0.0901 | - | - |
| Minimum | 0.52 | 0.45 | 0.57 | 0.38 | 0.43 | 0.45 | 7.0% |
| 10th percentile | 0.87 | 0.87 | 0.87 | 0.83 | 0.86 | 0.90 | 13.8% |
| 25th percentile | 0.93 | 0.93 | 0.93 | 0.90 | 0.92 | 0.94 | 14.6% |
| 50th percentile | 0.99 | 0.98 | 0.99 | 0.97 | 0.99 | 0.99 | 15.3% |
| 75th percentile | 1.07 | 1.07 | 1.07 | 1.10 | 1.08 | 1.05 | 16.2% |
| 90th percentile | 1.16 | 1.17 | 1.15 | 1.21 | 1.17 | 1.11 | 17.1% |
| Maximum | 1.81 | 1.98 | 1.73 | 2.17 | 1.75 | 1.63 | 25.1% |
| Mean (SD) | 1.00 (0.12) | 1.00 (0.13) | 1.00 (0.11) | 1.00 (0.16) | 1.01 (0.12) | 1.00 (0.09) | 15.4% (1.4%) |

| Statistic | Cardio-respiratory | Cardio-vascular | Medicine | Neurology | Surgical | Overall HWR SR | RARR |
|---|---|---|---|---|---|---|---|
| Number of eligible clinician groups | 51,372 | 50,909 | 55,127 | 48,132 | 54,779 | 55,593 | 55,593 |

**Figure 2. Distribution of RARRs for eligible clinician groups with at least 25 cases (dataset: Medicare Full Sample)**
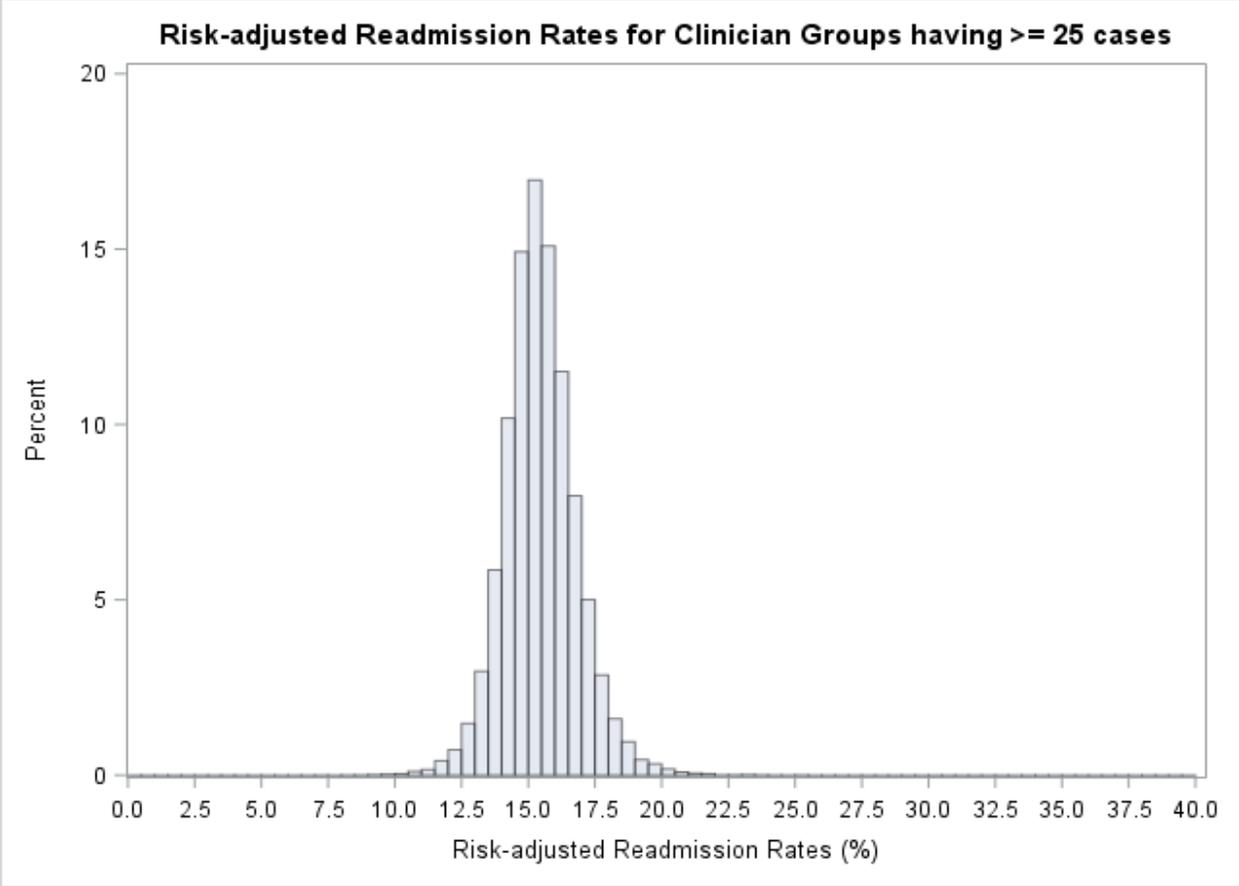


From Table 5 and Figure 2 we can see that the distributions of SRs and RARRs for eligible clinician groups with at least 25 admissions are meaningfully dispersed.

After bootstrapping the RARRs we used the 95% confidence intervals (CIs) to identify eligible clinician groups that have RARRs that are statistically better and worse than the national rate, Table 6.

**Table 6. MIPS HWR outliers, at least 25 admissions (dataset: Medicare Full Sample)**

| Performance category | Eligible clinician groups (unique TINs) | |
|---|---|---|
| | **Number** | **Percent** |
| Better than the national rate (estimated 95% CI wholly below national rate) | 4,318 | 7.8% |
| No different than the national rate (estimated 95% CI includes national rate) | 49,146 | 88.4% |
| Worse than the national rate (estimated 95% CI wholly above national rate) | 2,129 | 3.8% |
| Number of cases too small (<25 admissions) | 75,078 | - |

## 4.2 Model Performance

For each dataset and specialty cohort we report the volume of admissions, eligible clinician groups, overall readmission rate, calibration statistics (relative to the 2015–2016 Development Sample), discrimination, distribution of residuals, and Wald test of residuals; results for each specialty cohort are in a separate table.

**Table 7. Testing and calibration results for cardiorespiratory cohort model**

| Cardiorespiratory | 2015–2016 Development Sample | 2015–2016 Validation Sample | 2016–2017 Temporal Validation Sample |
|---|---|---|---|
| Number of admissions | 520,629 | 520,878 | 840,343 |
| Number of eligible clinician groups | 69,062 | 69,077 | 77,102 |
| Unadjusted readmission rate | 19.6% | 19.4% | 18.8% |
| Calibration (r0, r1) | $0 - 1$ | $-0.023 - 0.988$ | $-0.023 - 1.002$ |
| Discrimination -predictive ability§ (lowest decile %, highest decile %) | 9.76% – 35.94% | 9.78% – 35.68% | 9.43% – 35.3% |
| Discrimination — area under ROC or C-statistic | 0.64 | 0.64 | 0.64 |
| Distribution of residuals | - | - | - |
| %: < -2 | 0% | 0% | 0% |
| %: [-2, 0) | 80.4% | 80.6% | 81.2% |
| %: [0, 2) | 11.2% | 11.0% | 10.0% |
| %: [2 +) | 8.4% | 8.5% | 8.7% |
| Model Wald X2 (Degrees of Freedom [DF]) | 19,851 (39) | 19,491 (39) | 32,279 (39) |

**Table 8. Testing and calibration results for cardiovascular cohort model**

| Cardiovascular | 2015–2016 Development Sample | 2015–2016 Validation Sample | 2016–2017 Temporal Validation Sample |
|---|---|---|---|
| Number of admissions | 320,256 | 319,825 | 611,740 |
| Number of eligible clinician groups | 63,201 | 63,007 | 74,776 |
| Unadjusted readmission rate | 14.5% | 14.4% | 14.4% |
| Calibration (r0, r1) | 0 – 1 | -0.015 – 0.997 | -0.018 – 1.001 |
| Discrimination — predictive ability§ (lowest decile %, highest decile %) | 6.86% – 31.81% | 6.8% – 31.72% | 6.74% – 31.79% |
| Discrimination — area under ROC | 0.66 | 0.66 | 0.66 |
| Distribution of residuals | - | - | - |
| %: < -2 | 0% | 0% | 0% |
| %: [-2, 0) | 85.5% | 85.6% | 85.6% |
| %: [0, 2) | 4.9% | 4.9% | 4.9% |
| %: [2 +) | 9.6% | 9.5% | 9.5% |
| Model Wald X2 (DF) | 12,883 (45) | 12,929 (45) | 24,890 (45) |

**Table 9. Testing and calibration results for medicine cohort model**

| Medicine | 2015–2016 Development Sample | 2015–2016 Validation Sample | 2016–2017 Temporal Validation Sample |
|---|---|---|---|
| Number of admissions | 1,360,000 | 1,359,822 | 2,917,076 |
| Number of eligible clinician groups | 97,210 | 97,258 | 108,989 |
| Unadjusted readmission rate | 16.9% | 16.9% | 17.4% |
| Calibration (r0, r1) | 0 – 1 | 0 – 1.003 | -0.006 – 0.994 |
| Discrimination — predictive ability§ (lowest decile %, highest decile %) | 8.48% – 33.69% | 8.44% – 33.73% | 8.66% – 34.13% |
| Discrimination — area under ROC | 0.65 | 0.65 | 0.65 |
| Distribution of residuals | - | - | - |
| %: < -2 | 0% | 0 | 0 |
| %: [-2, 0) | 83.1% | 83.1% | 82.6% |
| %: [0, 2) | 7.4% | 7.4% | 8.1% |
| %: [2 +) | 9.5% | 9.5% | 9.3% |
| Model Wald X2 (DF) | 51,325 (144) | 51,689 (144) | 111,196 (143) |

**Table 10. Testing and calibration results for neurology cohort model**

| Neurology | 2015–2016 Development Sample | 2015–2016 Validation Sample | 2016–2017 Temporal Validation Sample |
|---|---|---|---|
| Number of admissions | 201,286 | 201,033 | 390,971 |
| Number of eligible clinician groups | 54,113 | 54,189 | 66,570 |
| Unadjusted readmission rate | 13.1% | 13.1% | 13.1% |
| Calibration (r0, r1) | 0 – 1 | -0.085 – 0.951 | -0.047 – 0.978 |
| Discrimination — predictive ability§ (lowest decile %, highest decile %) | 7.31% – 26.67% | 7.53% – 26.16% | 7.46% – 26.55% |
| Discrimination – area under ROC | 0.63 | 0.63 | 0.63 |
| Distribution of residuals | - | - | - |
| %: < -2 | 0% | 0% | 0% |
| %: [-2, 0) | 86.9% | 86.9% | 86.9% |
| %: [0, 2) | 2.9% | 2.8% | 2.8% |
| %: [2 +) | 10.2% | 10.4% | 10.3% |
| Model Wald X2 (DF) | 5,426 (45) | 5,014 (45) | 10,279 (44) |

**Table 11. Testing and calibration results for surgery/gynecology cohort model**

| Surgical | 2015–2016 Development Sample | 2015–2016 Validation Sample | 2016–2017 Temporal Validation Sample |
|---|---|---|---|
| Number of admissions | 832,665 | 832,367 | 1,662,884 |
| Number of eligible clinician groups | 90,349 | 90,253 | 101,738 |
| Unadjusted readmission rate | 11.4% | 11.4% | 11.2% |
| Calibration (r0, r1) | 0 – 1 | 0.007 – 1.002 | 0.004 – 1.012 |
| Discrimination — predictive ability§ (lowest decile %, highest decile %) | 3.18% – 28.21% | 3.21% – 28.3% | 3.03% – 28.34% |
| Discrimination — area under ROC | 0.70 | 0.70 | 0.71 |
| Distribution of residuals | - | - | - |
| %: < -2 | 0% | 0% | 0% |
| %: [-2, 0) | 88.6% | 88.6% | 88.8% |
| %: [0, 2) | 3.2% | 3.2% | 3.2% |
| %: [2 +) | 8.2% | 8.2% | 8.0% |
| Model Wald X2 (DF) | 38,737 (140) | 38,952 (140) | 80,052 (137) |

## 4.3 Internal Consistency

We calculated the weighted correlation among the specialty cohort SRs. As case volume influences the stability of performance estimates, we performed these analyses using a minimum eligible clinician group-level volume of 25 admissions per specialty cohort. This enabled us to assess internal consistency without having to correct for variation due to small volumes. We also calculated the Cronbach's alpha for groups, excluding specialty cohorts with fewer than 25 admissions.

As noted in Section 3.3, we take the perspective that the overall RARR is a formative rather than reflective scale – that is, it is meaningful to combine the specialty cohorts SRs because they capture the same outcome, even if they do so along different directions.

These results (Tables 12 and 13) indicate modest internal consistency among the five specialty cohort SRs. This is consistent with the expectation that eligible clinician groups may have greater influence over specific conditions and procedures, compared to hospitals that are able to influence a greater diversity of care.

**Table 12. Correlations of Smooth Rates (SRs) across specialty cohorts for eligible clinician groups (unique TINs; dataset: Medicare Full Sample); with at least 25 admissions only**

| Pearson correlation | Cardiorespiratory | Cardiovascular | Medicine | Neurology | Surgery |
|---|---|---|---|---|---|
| **Cardiorespiratory** | 1.00 | - | - | - | - |
| | - | - | - | - | - |
| **Cardiovascular** | 0.27 | 1.00 | - | - | - |
| | <0.0001 | - | - | - | - |
| **Medicine** | 0.36 | 0.29 | 1.00 | - | - |
| | <0.0001 | <0.0001 | - | - | - |
| **Neurology** | 0.26 | <0.0001 | 0.32 | 1.00 | - |
| | <.0001 | 0.18 | <0.0001 | - | - |
| **Surgery** | 0.27 | 0.23 | 0.31 | 0.28 | 1.00 |
| | <0.0001 | <0.0001 | <0.0001 | <0.0001 | - |

**Table 13. Cronbach's alpha for 5 specialty cohorts, eligible clinician groups with at least 25 admissions; cohorts with at least 25 admissions only**

| Cohort | Correlation with overall composite score | Cronbach's alpha of overall composite score without this cohort |
|---|---|---|
| Cardiorespiratory | 0.56 | 0.42 |
| Cardiovascular | 0.47 | 0.46 |
| Medicine | 0.79 | 0.40 |
| Neurology | 0.47 | 0.44 |
| Surgery | 0.71 | 0.48 |
| Total | Not applicable | 0.50 |

### 4.4 Reliability

#### 4.4.1 Data Element Reliability

In constructing MIPS HWR measure we utilized only those data elements from the claims that have both face validity and reliability. To ensure that we use data elements that are reliable, we avoid the use of fields that are thought to be coded inconsistently across hospitals or providers. Additionally, CMS has in place several hospital auditing programs used to assess overall claims code accuracy, to ensure appropriate billing, and for overpayment recoupment. CMS routinely conducts data analysis to identify potential problem areas and detect fraud, and audits important data fields used in our measures.

We assessed the reliability of the data elements by comparing risk factor frequencies and ORs in the Split Sample Dataset, with results in Appendix F.

#### 4.4.2 Measure Score Reliability

We assessed measure result reliability using the SNR method for each specialty cohort. This approach produces a measure of reliability for each eligible clinician group. All case volume cut-offs produce high reliability using this approach.

**Table 14. Signal-to-noise ratio results for eligible clinician groups (dataset: Medicare Full Sample)**

| Clinician group case volume | Cardio-respiratory mean (range) | Cardiovascular mean (range) | Medicine mean (range) | Neurology mean (range) | Surgical mean (range) | Number of clinician groups |
|---|---|---|---|---|---|---|
| 25+ | 0.56 (0.22 – 0.99) | 0.57 (0.25 – 0.99) | 0.47 (0.15 – 0.99) | 0.65 (0.36 – 0.99) | 0.45 (0.08 – 0.99) | 77,953 |
| [25,100) | 0.41 (0.22 – 0.63) | 0.42 (0.25 – 0.66) | 0.31 (0.15 – 0.61) | 0.52 (0.36 – 0.73) | 0.31 (0.08 – 0.59) | 37,419 |
| [50, 100) | 0.58 (0.39 – 0.75) | 0.59 (0.43 – 0.79) | 0.47 (0.25 – 0.71) | 0.68 (0.54 – 0.83) | 0.45 (0.15 – 0.77) | 20,093 |
| [100,150) | 0.71 (0.59 – 0.81) | 0.72 (0.62 – 0.85) | 0.62 (0.44 – 0.76) | 0.79 (0.72 – 0.88) | 0.58 (0.28 – 0.81) | 6,849 |
| [150,200) | 0.78 (0.68 – 0.84) | 0.78 (0.70 – 0.88) | 0.69 (0.55 – 0.81) | 0.84 (0.81 – 0.91) | 0.66 (0.38 – 0.85) | 3,377 |
| 200 + | 0.89 (0.77 – 0.99) | 0.88 (0.74 – 0.99) | 0.85 (0.64 – 0.99) | 0.92 (0.85 – 0.99) | 0.82 (0.43 – 0.99) | 10,215 |

### 4.5 Validity

#### 4.5.1 Data Elements

For validity of the data elements, CORE has already demonstrated for a number of prior measures the validity of claims-based measures for profiling hospitals by comparing either the measure results or individual data elements against medical records. CMS validated six NQF-endorsed claims-based

measures currently in public reporting (AMI, heart failure, and pneumonia mortality and readmission) with models that used medical record-abstracted data for risk-adjustment. Specifically, claims model validation was conducted by building comparable models using abstracted medical record data for risk-adjustment for heart failure patients (National Heart Failure data), AMI patients (Cooperative Cardiovascular Project data), and pneumonia patients (National Pneumonia Project dataset). When both models were applied to the same patient population, the hospital risk-standardized rates estimated using the claims-based risk-adjustment models had a high level of agreement with the results based on the medical record model, thus supporting the use of the claims-based models for public reporting.

We have also completed two national, multi-site validation efforts for two procedure-based complications measures (for primary elective hip/knee arthroplasty and implantable cardioverter defibrillator). Both projects demonstrated strong agreement between complications coded in claims and abstracted medical record data.

Comparison of hospital-level measure results obtained using a claims-based measure of mortality after isolated coronary artery bypass graft surgery compared to a registry-based measure also demonstrated high correlation.

These validation efforts suggest that such claims data variables are valid across a variety of conditions, procedures, and outcomes.

### 4.5.2   Measure Score

Face Validity of Final Attribution Rules
The TEP strongly supported attribution to multiple providers, including at least one inpatient and one outpatient provider.

Face Validity of MIPS Eligible Clinician Group Measure Scores
Of 19 TEP members asked to complete a survey regarding validity and usability of the measure, 17 responded. The majority of the respondents, 12/17 or 70%, agreed that the MIPS HWR measure scores were valid and useful, and the same proportion agreed that the measure would provide information that could be used to improve the quality of care.

Among those who disagreed, the primary concern was that factors which led to increased risk of readmission were beyond the control of any clinician group. This concern drove the adoption of 'multiple' attribution, in which no single eligible clinician group is solely responsible for a readmission outcome; this attribution approach also has the potential to incentivize collaboration within the hospital and across the care system, further aligning the measure with the attribution.

Overall, the survey indicates support of the validity and usability of the measure.

# 5. SUMMARY

In this report, we describe an approach to re-specifying the IQR HWR measure for use in measuring eligible clinician groups on the outcome of unplanned readmission within 30 days of discharge. Developed with input from a nationally convened TEP, the re-specified measure attributes admissions to up to three eligible clinician groups. To compare readmission performance across eligible clinician groups, the measure accounts for differences in patient characteristics (i.e., patient case mix) as well as differences in mixes of services and procedures offered by clinicians (i.e., service mix). Using our development data for the purpose of measure testing, we found 55,593 eligible clinician groups had at least 25 admissions attributed by one or more attribution rules. The RARRs for these sets of providers had a mean [range] of 15.4% [7.0%–25.1%]; 11.6% of eligible clinician groups were statistically significant performance outliers, with RARR 95% confidence intervals excluding the national average. These results indicate meaningful variation in performance across eligible clinician groups. Testing demonstrated acceptable measure result reliability for higher volumes and acceptable face validity.

In summary, this report demonstrates the feasibility of measuring eligible clinician groups on the outcome of readmission within 30 days and finds meaningful variation in risk-adjusted readmission rates. Measure development has benefited from close stakeholder engagement, including an engaged TEP that represents clinicians and patients, and a public comment period. This measure fills an important gap by creating a mechanism for shared accountability across healthcare providers for readmitted patients. It will provide clinicians and patients with greater information and transparency to continue to improve patient care quality and outcomes. The MIPS HWR measure has the potential to illuminate differences in quality, inform patient choice, drive quality improvement, and enhance care coordination.

# 6. GLOSSARY

**Acute care hospital**: A hospital that provides inpatient medical care for surgery and acute medical conditions or injuries. Short-term acute care hospitals provide care for short-term illnesses and conditions.

**Bootstrapping:** The bootstrap is a computer-based method for estimating the standard error of an estimate when the estimate is based on a sample with an unknown probability distribution. Bootstrap methods depend on the bootstrap sample, which is a random sample of size $n$ drawn with replacement from the population of $n$ objects. The bootstrap algorithm works by drawing many independent bootstrap samples, evaluating the corresponding bootstrap replications, and estimating the standard error of the statistic by the empirical standard deviation of the replications.

**C-statistic:** An indicator of the model's discriminant ability or ability to correctly classify those who have and have not been readmitted within 30 days of discharge. Potential values range from 0.5, meaning no better than chance, to 1.0, an indication of perfect prediction. Perfect prediction implies that patients' outcomes can be predicted completely by their risk factors, and physicians and hospitals play no role in their patients' outcomes.

**Case mix:** The illness severity, age, and, for some measures, gender characteristics of patients with index admissions at a given hospital.

**Clinical Classification Software (CCS):** Software maintained by the AHRQ that groups thousands of individual procedure and diagnosis codes into clinically coherent, mutually exclusive procedure and diagnosis categories. AHRQ CCS procedure and diagnosis categories are used to define specialty cohorts and risk adjust. Additionally, AHRQ CCS categories are used to determine if a readmission is planned. AHRQ CCS procedure categories are used to define planned and potentially planned procedures. AHRQ CCS diagnosis categories are used to define acute diagnoses and complications of care that are considered unplanned, as well as a few specific types of care that are always considered planned (for example, maintenance chemotherapy). Mappings which show the assignment of ICD-10 codes to the AHRQ CCS diagnosis and procedure categories are available on the AHRQ website.

**Cohort:** The index admissions used to calculate the measure after inclusion and exclusion criteria have been applied.

**Comorbidities**: Medical conditions that the patient had in addition to his/her primary reason for admission to the hospital.

**Complications:** Medical conditions that may have occurred as a consequence of care rendered during admission.

**Condition Categories (CCs):** Groupings of ICD-9-CM/ICD-10-CM diagnosis codes in clinically relevant categories, from the HCCs system.[46,47] CMS uses the grouping but not the hierarchical logic of the system to create risk factor variables. Mappings which show the assignment of ICD-9 and ICD-10 codes to the CCs are available on the *QualityNet* website.

**Confidence interval (CI):** A CI is a range of values that describes the uncertainty surrounding an estimate. It is indicated by its endpoints; for example, a 95% CI for the odds ratio (OR) associated with protein-calorie malnutrition noted as "1.09 – 1.15" would indicate that there is 95% confidence that the OR lies between 1.09 and 1.15.

**Discharge clinician:** The eligible clinician that bills for 1 of the discharge procedure codes or, if a patient does not have such a code during the last 3 days of their stay, a subsequent care code.

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

**Hierarchical regression model:** A widely accepted statistical method that enables evaluation of relative hospital performance by accounting for patient risk factors. This statistical model accounts for the hierarchical structure of the data (patients clustered within hospitals are assumed to be correlated) and accommodates modeling of the association between outcomes and patient characteristics. Based on the hierarchical model, we can evaluate (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-specific effect:** A measure of the hospital quality of care that is calculated through hierarchical logistic regression, taking into consideration how many patients were eligible for the cohort, these patients' risk factors, and how many were readmitted. The hospital-specific effect is the calculated random effect for each hospital. 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 and evaluated for the outcome.

**Interval estimate:** Similar to a CI. The interval estimate is a range of probable values for the estimate that characterizes the amount of associated uncertainty. For example, a 95% CI estimate for a readmission rate indicates there is 95% confidence that the true value of the rate lies between the lower and the upper limit of the interval.

**Medicare fee-for-service (FFS):** Original Medicare plan in which providers receive a fee or payment for each individual service provided directly from Medicare. Only beneficiaries in Medicare FFS, not in managed care (Medicare Advantage), are included in the measure.

**National observed readmission rate:** All included admission s with the outcome divided by all included admissions.

**Odds ratio (OR):** The ORs express the relative odds of the outcome for each of the predictor variables. For example, the OR for Protein-calorie malnutrition (CC 21) represents the odds of the outcome for patients with that risk variable present relative to those without the risk variable present. The model coefficient for each risk variable is the log (odds) for that variable.

**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.

**Outpatient PCP:** The eligible clinician that files the most outpatient primary care claims for a hospitalized patient during the 12 months prior to their admission date.

**Planned readmissions:** A readmission within 30 days of discharge from a short-term acute care hospital that is a scheduled part of the patient's plan of care. Planned readmissions are not captured in the outcome of this measure.

**Predicted readmissions:** The number of readmissions within 30 days predicted based on the hospital's observed case mix and service mix.

**Predictive ability:** An indicator of the model's discriminant ability or ability to distinguish high-risk subjects from low-risk subjects. A wide range between the lowest decile and highest decile suggests better discrimination.

**Primary inpatient care provider**: The eligible clinician that files the most patient-facing charges during the patient inpatient stay.

**Risk-adjustment variables:** Patient demographics and comorbidities used to standardize rates for differences in case mix and service mix across hospitals.

**Service mix:** The conditions and procedures of patients with index admissions at a given hospital.

**Specialty cohort:** A group of index admissions for patients with related AHRQ CCS diagnosis or procedure categories (or related ICD-10-PCS codes, in the case of the surgery/gynecology cohort) that are likely treated by similar care teams. This measure includes 5 cohorts, each with its own risk model.

**Unplanned readmissions:** Acute clinical events a patient experiences that require urgent readmission. Unplanned readmissions are the outcomes of the measure.

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# 8. APPENDICES

## Appendix A. External Stakeholder Engagement

**Table A1. Technical Expert Panel members**

| Name, credentials, and professional role | Organizational affiliation | Location |
|---|---|---|
| **Kathleen Blake**, **MD, MPH**; Vice President, Healthcare Quality (cardiology) | American Medical Association | Washington, DC |
| **John Birkmeyer**, **MD**; Chief Clinical Officer (general surgery) | Sound Physicians | Tacoma, WA |
| **Dale Bratzler**, **DO, MPH**; Chief Quality Officer (internal medicine) | University of Oklahoma Physicians: Chickasaw Nation Department of Public Health | Oklahoma City, OK; Ada, OK |
| **Daniel Brotman**, **MD, SFM, FACP**; Professor of Medicine, Johns Hopkins University Director of Hospitalist Program, (internal medicine) | Johns Hopkins University School of Medicine; Johns Hopkins Hospital | Baltimore, MD |
| **Tracy Cardin**, **ACNP-BC, SFHM**; Director of Nurse Practitioner/Physician Assistant Services (nursing - inpatient) | University of Chicago Hospital Medicine | Chicago, IL |
| **Cathy Castillo, BA** | Patient or caregiver representative | Redwood City, CA |
| **Bruce Chernof, MD**; President and Chief Executive Officer (internal medicine) | The SCAN Foundation | Long Beach, CA |
| **Donna Cryer**, **JD**; President and Chief Executive Officer | Global Liver Institute | Washington, DC |
| **Sherrie H. Kaplan**, **PhD, MPH**; Assistant Vice Chancellor, Healthcare Measurement and Evaluation School of Medicine, Professor of Medicine and Anesthesiology & Perioperative Care | University of California, Irvine | Irvine, CA |
| **Timothy Kresowik**, **MD, MS**; Professor of Surgery - Vascular Surgery (vascular surgery) | University of Iowa Hospitals & Clinics | Iowa City, IA |

| Name, credentials, and professional role | Organizational affiliation | Location |
|---|---|---|
| **Joshua Lapps, MA**; Government Relations Manager | Society of Hospital Medicine | Philadelphia, PA |
| **Frederick Masoudi**, **MD, MSPH**; Professor of Medicine and Staff Cardiologist (cardiology) | University of Colorado Denver | Aurora, CO |
| **Brian McCardel**, **MD**; Orthopedic Surgeon/Board Member (orthopedics) | Sparrow Health System | Lansing, MI |
| **James Moore, MD**; Clinical Professor of Anesthesiology and Perioperative Medicine (anesthesiology) | University of California Los Angeles Health | Los Angeles, CA |
| **Michelle Mourad, MD**; Vice Chair for Clinical Affairs and Value, Medicine (internal medicine - hospital medicine) | University of California, San Francisco Health | San Francisco, CA |
| **Juan Quintana, DNP, MHS, CRNA**; Certified Registered Nurse Anesthetist (nursing - anesthesia) | American Association of Nurse Anesthetists | Winnsboro, TX |
| **Carol Raphael, MA, MPH;** Senior Advisor | Manatt Health Solutions | New York, NY |
| **Charlene Setlow** | Patient representative | Salinas, CA |
| **Heidi L. Wald, MD, MSPH;** Vice President for Clinical Performance (internal medicine-geriatrics) | SCL Health | Aurora, CO |

**Disclaimer**: The views, thoughts, and opinions expressed in this report belong solely to the author, and not necessarily to any contributors or consultants, including Technical Expert Panel members and their affiliated organizations. Acknowledgment of input does not imply endorsement of the methodology and policy decisions.

## Appendix B. Exclusions

**Table B1. Cancer discharge condition categories excluded from the measure**

| AHRQ CCS | Description of AHRQ CCS | Admits* (Total = 182,213) |
|---|---|---|
| 42 | Secondary malignancies | 45,319 |
| 19 | Cancer of bronchus; lung | 30,292 |
| 45 | Maintenance chemotherapy; radiotherapy | 21,522 |
| 44 | Neoplasms of unspecified nature or uncertain behavior | 10,160 |
| 17 | Cancer of pancreas | 8,462 |
| 38 | Non-Hodgkin's lymphoma | 7,977 |
| 39 | Leukemias | 7,809 |
| 14 | Cancer of colon | 6,121 |
| 40 | Multiple myeloma | 4,624 |
| 35 | Cancer of brain and nervous system | 3,561 |
| 16 | Cancer of liver and intrahepatic bile duct | 3,491 |
| 13 | Cancer of stomach | 3,467 |
| 29 | Cancer of prostate | 3,100 |
| 15 | Cancer of rectum and anus | 3,030 |
| 18 | Cancer of other GI organs; peritoneum | 2,974 |
| 12 | Cancer of esophagus | 2,533 |
| 11 | Cancer of head and neck | 2,515 |
| 27 | Cancer of ovary | 2,081 |
| 33 | Cancer of kidney and renal pelvis | 1,863 |
| 32 | Cancer of bladder | 1,807 |
| 24 | Cancer of breast | 1,682 |
| 43 | Malignant neoplasm without specification of site | 1,451 |
| 25 | Cancer of uterus | 1,132 |
| 36 | Cancer of thyroid | 879 |
| 21 | Cancer of bone and connective tissue | 763 |
| 41 | Cancer; other and unspecified primary | 674 |
| 20 | Cancer; other respiratory and intrathoracic | 632 |
| 23 | Other non-epithelial cancer of skin | 593 |
| 26 | Cancer of cervix | 586 |
| 28 | Cancer of other female genital organs | 326 |
| 34 | Cancer of other urinary organs | 301 |
| 37 | Hodgkin`s disease | 236 |

| AHRQ CCS | Description of AHRQ CCS | Admits*<br>(Total = 182,213) |
|---|---|---|
| 22 | Melanomas of skin | 212 |
| 31 | Cancer of other male genital organs | 34 |
| 30 | Cancer of testis | 4 |

*After all other exclusions applied

**Table B2. Psychiatric discharge condition categories excluded from the measure**

| AHRQ CCS | Description of AHRQ CCS | Admits*<br>(Total=21,483) |
|---|---|---|
| 657 | Mood disorders | 7,874 |
| 659 | Schizophrenia and other psychotic disorders | 7,849 |
| 651 | Anxiety disorders | 3,153 |
| 670 | Miscellaneous disorders | 1,315 |
| 654 | Developmental disorders | 594 |
| 650 | Adjustment disorders | 399 |
| 658 | Personality disorders | 127 |
| 652 | Attention-deficit, conduct, and disruptive behavior disorders | 119 |
| 656 | Impulse control disorders, NEC | 27 |
| 655 | Disorders usually diagnosed in infancy, childhood, or adolescence | 16 |
| 662 | Suicide and intentional self-inflicted injury | 10 |

*After all other exclusions applied

# Appendix C. Specialty Cohort Definitions

**Table C1. Procedure categories defining the surgical/gynecology cohort**

| AHRQ CCS | Description of AHRQ CCS | Number of procedures* | Number of readmissions with this procedure* | Readmission rate |
|---|---|---|---|---|
| 1 | Incision and excision of CNS | 28,261 | 5,753 | 20.4% |
| 2 | Insertion; replacement; or removal of extracranial ventricular shunt | 7,270 | 1,304 | 17.9% |
| 3 | Laminectomy; excision intervertebral disc | 79,631 | 6,619 | 8.3% |
| 9 | Other OR therapeutic nervous system procedures | 16,275 | 2,817 | 17.3% |
| 10 | Thyroidectomy; partial or complete | 12,989 | 862 | 6.6% |
| 12 | Other therapeutic endocrine procedures | 10,415 | 1,340 | 12.9% |
| 13 | Corneal transplant | 157 | 16 | 10.2% |
| 14 | Glaucoma procedures | 130 | 18 | 13.8% |
| 15 | Lens and cataract procedures | 633 | 97 | 15.3% |
| 16 | Repair of retinal tear; detachment | 292 | 33 | 11.3% |
| 17 | Destruction of lesion of retina and choroid | 127 | 9 | 7.1% |
| 20 | Other intraocular therapeutic procedures | 1,107 | 138 | 12.5% |
| 21 | Other extraocular muscle and orbit therapeutic procedures | 1,163 | 150 | 12.9% |
| 22 | Tympanoplasty | 140 | 14 | 10.0% |
| 23 | Myringotomy | 450 | 99 | 22.0% |
| 24 | Mastoidectomy | 273 | 29 | 10.6% |
| 26 | Other therapeutic ear procedures | 2,002 | 263 | 13.1% |
| 28 | Plastic procedures on nose | 1,790 | 213 | 11.9% |
| 30 | Tonsillectomy and/or adenoidectomy | 333 | 43 | 12.9% |
| 33 | Other OR therapeutic procedures on nose; mouth and pharynx | 8,040 | 913 | 11.4% |
| 36 | Lobectomy or pneumonectomy | 32,065 | 4,350 | 13.6% |
| 42 | Other OR Rx procedures on respiratory system and mediastinum | 16,452 | 3,453 | 21.0% |
| 43 | Heart valve procedures | 45,477 | 10,398 | 22.9% |
| 44 | Coronary artery bypass graft (CABG) | 82,527 | 14,548 | 17.6% |
| 49 | Other OR heart procedures | 41,585 | 8,125 | 19.5% |

| AHRQ CCS | Description of AHRQ CCS | Number of procedures* | Number of readmissions with this procedure* | Readmission rate |
|---|---|---|---|---|
| 51 | Endarterectomy; vessel of head and neck | 63,024 | 6,288 | 10.0% |
| 52 | Aortic resection; replacement or anastomosis | 27,967 | 3,765 | 13.5% |
| 53 | 'Varicose vein stripping; lower limb | 245 | 33 | 13.5% |
| 55 | Peripheral vascular bypass | 28,972 | 6,163 | 21.3% |
| 56 | Other vascular bypass and shunt; not heart | 2,387 | 763 | 32.0% |
| 59 | Other OR procedures on vessels of head and neck | 14,335 | 1,771 | 12.4% |
| 60 | Embolectomy and endarterectomy of lower limbs | 9,770 | 2,292 | 23.5% |
| 61 | Other OR procedures on vessels other than head and neck | 178,209 | 37,411 | 21.0% |
| 66 | Procedures on spleen | 2,903 | 548 | 18.9% |
| 67 | Other therapeutic procedures; hemic and lymphatic system | 42,288 | 5,557 | 13.1% |
| 72 | Colostomy; temporary and permanent | 10,365 | 1,970 | 19.0% |
| 73 | Ileostomy and other enterostomy | 5,592 | 1,805 | 32.3% |
| 74 | Gastrectomy; partial and total | 6,507 | 1,305 | 20.1% |
| 75 | Small bowel resection | 21,833 | 4,255 | 19.5% |
| 78 | Colorectal resection | 105,467 | 16,702 | 15.8% |
| 79 | Local excision of large intestine lesion (not endoscopic) | 368 | 50 | 13.6% |
| 80 | Appendectomy | 19,326 | 1,851 | 9.6% |
| 84 | Cholecystectomy and common duct exploration | 102,698 | 13,143 | 12.8% |
| 85 | Inguinal and femoral hernia repair | 14,656 | 1,683 | 11.5% |
| 86 | Other hernia repair | 33,253 | 3,887 | 11.7% |
| 89 | Exploratory laparotomy | 2,981 | 611 | 20.5% |
| 90 | Excision; lysis peritoneal adhesions | 36,415 | 6,278 | 17.2% |
| 94 | Other OR upper GI therapeutic procedures | 31,731 | 4,334 | 13.7% |
| 96 | Other OR lower GI therapeutic procedures | 33,387 | 5,846 | 17.5% |
| 99 | Other OR gastrointestinal therapeutic procedures | 29,873 | 6,478 | 21.7% |
| 101 | Transurethral excision; drainage; or removal urinary obstruction | 33,225 | 6,075 | 18.3% |

| AHRQ CCS | Description of AHRQ CCS | Number of procedures* | Number of readmissions with this procedure* | Readmission rate |
|---|---|---|---|---|
| 103 | Nephrotomy and nephrostomy | 13,530 | 3,649 | 27.0% |
| 104 | Nephrectomy; partial or complete | 19,504 | 2,338 | 12.0% |
| 105 | Kidney transplant | 10,873 | 3,175 | 29.2% |
| 106 | Genitourinary incontinence procedures | 8,819 | 351 | 4.0% |
| 112 | Other OR therapeutic procedures of urinary tract | 17,650 | 3,688 | 20.9% |
| 113 | Transurethral resection of prostate (TURP) | 42,523 | 4,259 | 10.0% |
| 114 | Open prostatectomy | 23,965 | 1,158 | 4.8% |
| 118 | Other OR therapeutic procedures; male genital | 6,005 | 835 | 13.9% |
| 142 | Partial excision bone | 37,930 | 5,070 | 13.4% |
| 143 | Bunionectomy or repair of toe deformities | 931 | 84 | 9.0% |
| 144 | Treatment; facial fracture or dislocation | 1,968 | 204 | 10.4% |
| 145 | Treatment; fracture or dislocation of radius and ulna | 14,471 | 1,466 | 10.1% |
| 146 | Treatment; fracture or dislocation of hip and femur | 149,336 | 22,795 | 15.3% |
| 147 | Treatment; fracture or dislocation of lower extremity (other than hip or femur) | 39,901 | 5,000 | 12.5% |
| 148 | Other fracture and dislocation procedure | 23,019 | 2,900 | 12.6% |
| 150 | Division of joint capsule; ligament or cartilage | 3,002 | 230 | 7.7% |
| 151 | Excision of semilunar cartilage of knee | 1,381 | 181 | 13.1% |
| 152 | Arthroplasty knee | 292,149 | 17,995 | 6.2% |
| 153 | Hip replacement; total and partial | 207,011 | 23,096 | 11.2% |
| 154 | Arthroplasty other than hip or knee | 32,597 | 1,772 | 5.4% |
| 157 | Amputation of lower extremity | 51,213 | 13,548 | 26.5% |
| 158 | Spinal fusion | 106,703 | 10,307 | 9.7% |
| 160 | Other therapeutic procedures on muscles and tendons | 32,254 | 4,998 | 15.5% |
| 161 | Other OR therapeutic procedures on bone | 29,314 | 5,611 | 19.1% |
| 162 | Other OR therapeutic procedures on joints | 25,661 | 4,125 | 16.1% |
| 164 | Other OR therapeutic procedures on musculoskeletal system | 5,963 | 1,346 | 22.6% |

| AHRQ CCS | Description of AHRQ CCS | Number of procedures* | Number of readmissions with this procedure* | Readmission rate |
|---|---|---|---|---|
| 166 | Lumpectomy; quadrantectomy of breast | 2,994 | 311 | 10.4% |
| 167 | Mastectomy | 16,333 | 1,102 | 6.7% |
| 172 | Skin graft | 13,987 | 2,508 | 17.9% |
| 175 | Other OR therapeutic procedures on skin and breast | 6,626 | 879 | 13.3% |
| 176 | Other organ transplantation | 2,483 | 855 | 34.4% |
| 119 | Oophorectomy; unilateral and bilateral | 33,667 | 2,856 | 8.5% |
| 120 | Other operations on ovary | 906 | 111 | 12.3% |
| 121 | Ligation or occlusion of fallopian tubes | 228 | 13 | 5.7% |
| 122 | Removal of ectopic pregnancy | 143 | 6 | 4.2% |
| 123 | Other operations on fallopian tubes | 937 | 82 | 8.8% |
| 124 | Hysterectomy; abdominal and vaginal | 48,236 | 3,515 | 7.3% |
| 125 | Other excision of cervix and uterus | 1,062 | 131 | 12.3% |
| 126 | Abortion (termination of pregnancy) | 39 | 10 | 25.6% |
| 127 | Dilatation and curettage (D&C); aspiration after delivery or abortion | 298 | 26 | 8.7% |
| 129 | Repair of cystocele and rectocele; obliteration of vaginal vault | 14,446 | 476 | 3.3% |
| 131 | Other non-OR therapeutic procedures; female organs | 509 | 115 | 22.6% |
| 132 | Other OR therapeutic procedures; female organs | 13,796 | 996 | 7.2% |
| 133 | Episiotomy | 372 | 7 | 1.9% |
| 134 | Cesarean section | 6,226 | 280 | 4.5% |
| 135 | Forceps; vacuum; and breech delivery | 535 | 15 | 2.8% |
| 136 | Artificial rupture of membranes to assist delivery | 1,510 | 37 | 2.5% |
| 137 | Other procedures to assist delivery | 5,131 | 162 | 3.2% |
| 139 | Fetal monitoring | 1,488 | 179 | 12.0% |
| 140 | Repair of current obstetric laceration | 1,387 | 38 | 2.7% |
| 141 | Other therapeutic obstetrical procedures | 166 | 10 | 6.0% |

**Table C2. Condition codes assigned to medicine cohort**

| AHRQ CCS | Description of AHRQ CCS | Admissions | 30-day unplanned readmissions | 30-day unplanned readmission rate |
|---|---|---|---|---|
| 2 | Septicemia (except in labor) | 236,993 | 50,554 | 21.3% |
| 159 | Urinary tract infections | 232,590 | 41,421 | 17.8% |
| 55 | Fluid and electrolyte disorders | 178,808 | 32,670 | 18.3% |
| 157 | Acute and unspecified renal failure | 163,356 | 36,226 | 22.2% |
| 153 | Gastrointestinal hemorrhage | 135,891 | 22,873 | 16.8% |
| 197 | Skin and subcutaneous tissue infections | 111,669 | 17,020 | 15.2% |
| 245 | Syncope | 107,933 | 10,924 | 10.1% |
| 129 | Aspiration pneumonitis; food/vomitus | 88,296 | 19,311 | 21.9% |
| 145 | Intestinal obstruction without hernia | 88,193 | 14,712 | 16.7% |
| 146 | Diverticulosis and diverticulitis | 85,920 | 11,864 | 13.8% |
| 237 | Complication of device; implant or graft | 81,549 | 18,771 | 23.0% |
| 238 | Complications of surgical procedures or medical care | 81,398 | 14,856 | 18.3% |
| 59 | Deficiency and other anemia | 79,516 | 17,683 | 22.2% |
| 50 | Diabetes mellitus with complications | 74,976 | 14,274 | 19.0% |
| 135 | Intestinal infection | 70,077 | 16,192 | 23.1% |
| 231 | Other fractures | 69,105 | 10,186 | 14.7% |
| 99 | Hypertension with complications and secondary hypertension | 67,337 | 14,808 | 22.0% |
| 118 | Phlebitis; thrombophlebitis and thromboembolism | 48,254 | 7,038 | 14.6% |
| 205 | Spondylosis; intervertebral disc disorders; other back problems | 46,916 | 7,395 | 15.8% |
| 653 | Delirium, dementia, and amnestic and other cognitive disorders | 44,266 | 6,489 | 14.7% |
| 155 | Other gastrointestinal disorders | 44,151 | 8,915 | 20.2% |
| 133 | Other lower respiratory disease | 36,203 | 6,414 | 17.7% |
| 152 | Pancreatic disorders (not diabetes) | 34,779 | 5,378 | 15.5% |
| 149 | Biliary tract disease | 33,718 | 5,443 | 16.1% |

| AHRQ CCS | Description of AHRQ CCS | Admissions | 30-day unplanned readmissions | 30-day unplanned readmission rate |
|---|---|---|---|---|
| 138 | Esophageal disorders | 33,354 | 4,733 | 14.2% |
| 154 | Noninfectious gastroenteritis | 33,236 | 4,721 | 14.2% |
| 259 | Residual codes; unclassified | 32,960 | 5,853 | 17.8% |
| 93 | Conditions associated with dizziness or vertigo | 30,934 | 2,296 | 7.4% |
| 130 | Pleurisy; pneumothorax; pulmonary collapse | 29,482 | 7,463 | 25.3% |
| 140 | Gastritis and duodenitis | 29,329 | 4,953 | 16.9% |
| 211 | Other connective tissue disease | 28,565 | 4,106 | 14.4% |
| 251 | Abdominal pain | 27,091 | 4,425 | 16.3% |
| 151 | Other liver diseases | 20,612 | 6,282 | 30.5% |
| 244 | Other injuries and conditions due to external causes | 20,470 | 3,071 | 15.0% |
| 98 | Essential hypertension | 18,409 | 2,104 | 11.4% |
| 207 | Pathological fracture | 18,040 | 3,800 | 21.1% |
| 239 | Superficial injury; contusion | 17,651 | 2,670 | 15.1% |
| 141 | Other disorders of stomach and duodenum | 17,168 | 3,586 | 20.9% |
| 58 | Other nutritional; endocrine; and metabolic disorders | 16,379 | 3,394 | 20.7% |
| 199 | Chronic ulcer of skin | 16,350 | 3,408 | 20.8% |
| 51 | Other endocrine disorders | 16,343 | 3,160 | 19.3% |
| 229 | Fracture of upper limb | 15,309 | 2,477 | 16.2% |
| 252 | Malaise and fatigue | 14,677 | 2,414 | 16.4% |
| 63 | Diseases of white blood cells | 14,138 | 3,387 | 24.0% |
| 123 | Influenza | 14,096 | 1,672 | 11.9% |
| 7 | Viral infection | 13,805 | 2,178 | 15.8% |
| 230 | Fracture of lower limb | 13,448 | 2,039 | 15.2% |
| 246 | Fever of unknown origin | 13,079 | 2,304 | 17.6% |
| 242 | Poisoning by other medications and drugs | 12,394 | 1,915 | 15.5% |
| 160 | Calculus of urinary tract | 12,195 | 1,562 | 12.8% |
| 163 | Genitourinary symptoms and ill-defined conditions | 11,122 | 1,933 | 17.4% |
| 661 | Substance-related disorders | 11,050 | 1,924 | 17.4% |

| AHRQ CCS | Description of AHRQ CCS | Admissions | 30-day unplanned readmissions | 30-day unplanned readmission rate |
|---|---|---|---|---|
| 204 | Other non-traumatic joint disorders | 10,891 | 1,556 | 14.3% |
| 250 | Nausea and vomiting | 10,795 | 2,148 | 19.9% |
| 120 | Hemorrhoids | 10,365 | 1,616 | 15.6% |
| 62 | Coagulation and hemorrhagic disorders | 9,534 | 2,477 | 26.0% |
| 134 | Other upper respiratory disease | 9,068 | 1,569 | 17.3% |
| 226 | Fracture of neck of femur (hip) | 8,585 | 1,303 | 15.2% |
| 660 | Alcohol-related disorders | 8,578 | 1,257 | 14.7% |
| 234 | Crushing injury or internal injury | 8,329 | 1,216 | 14.6% |
| 201 | Infective arthritis and osteomyelitis (except that caused by tuberculosis or sexually transmitted disease) | 8,105 | 1,683 | 20.8% |
| 203 | Osteoarthritis | 7,984 | 1,049 | 13.1% |
| 144 | Regional enteritis and ulcerative colitis | 7,954 | 1,586 | 19.9% |
| 60 | Acute posthemorrhagic anemia | 7,768 | 1,577 | 20.3% |
| 4 | Mycoses | 7,739 | 2,135 | 27.6% |
| 126 | Other upper respiratory infections | 7,663 | 961 | 12.5% |
| 143 | Abdominal hernia | 7,410 | 1,397 | 18.9% |
| 139 | Gastroduodenal ulcer (except hemorrhage) | 7,378 | 1,105 | 15.0% |
| 47 | Other and unspecified benign neoplasm | 7,123 | 1,104 | 15.5% |
| 161 | Other diseases of kidney and ureters | 7,057 | 1,299 | 18.4% |
| 121 | Other diseases of veins and lymphatics | 6,969 | 1,249 | 17.9% |
| 232 | Sprains and strains | 6,531 | 885 | 13.6% |
| 54 | Gout and other crystal arthropathies | 6,150 | 995 | 16.2% |
| 84 | Headache; including migraine | 5,839 | 677 | 11.6% |
| 147 | Anal and rectal conditions | 5,116 | 1,002 | 19.6% |

| AHRQ CCS | Description of AHRQ CCS | Admissions | 30-day unplanned readmissions | 30-day unplanned readmission rate |
|---|---|---|---|---|
| 212 | Other bone disease and musculoskeletal deformities | 4,926 | 744 | 15.1% |
| 158 | Chronic renal failure | 4,886 | 1,186 | 24.3% |
| 228 | Skull and face fractures | 4,632 | 587 | 12.7% |
| 663 | Screening and history of mental health and substance abuse codes | 4,482 | 1,134 | 25.3% |
| 165 | Inflammatory conditions of male genital organs | 4,222 | 465 | 11.0% |
| 52 | Nutritional deficiencies | 4,003 | 972 | 24.3% |
| 253 | Allergic reactions | 3,885 | 565 | 14.5% |
| 162 | Other diseases of bladder and urethra | 3,850 | 698 | 18.1% |
| 137 | Diseases of mouth; excluding dental | 3,821 | 609 | 15.9% |
| 164 | Hyperplasia of prostate | 3,734 | 675 | 18.1% |
| 148 | Peritonitis and intestinal abscess | 3,663 | 896 | 24.5% |
| 48 | Thyroid disorders | 3,634 | 663 | 18.2% |
| 235 | Open wounds of head; neck; and trunk | 3,631 | 453 | 12.5% |
| 241 | Poisoning by psychotropic agents | 3,191 | 406 | 12.7% |
| 6 | Hepatitis | 3,042 | 827 | 27.2% |
| 202 | Rheumatoid arthritis and related disease | 2,806 | 480 | 17.1% |
| 8 | Other infections; including parasitic | 2,381 | 293 | 12.3% |
| 236 | Open wounds of extremities | 2,253 | 353 | 15.7% |
| 49 | Diabetes mellitus without complication | 2,198 | 308 | 14.0% |
| 198 | Other inflammatory condition of skin | 2,028 | 418 | 20.6% |
| 76 | Meningitis (except that caused by tuberculosis or sexually transmitted disease) | 2,003 | 332 | 16.6% |
| 248 | Gangrene | 1,996 | 435 | 21.8% |

| AHRQ CCS | Description of AHRQ CCS | Admissions | 30-day unplanned readmissions | 30-day unplanned readmission rate |
|---|---|---|---|---|
| 90 | Inflammation; infection of eye (except that caused by tuberculosis or sexually transmitted disease) | 1,994 | 272 | 13.6% |
| 132 | Lung disease due to external agents | 1,866 | 376 | 20.2% |
| 136 | Disorders of teeth and jaw | 1,602 | 192 | 12.0% |
| 89 | Blindness and vision defects | 1,550 | 163 | 10.5% |
| 210 | Systemic lupus erythematosus and connective tissue disorders | 1,466 | 351 | 23.9% |
| 243 | Poisoning by nonmedicinal substances | 1,424 | 112 | 7.9% |
| 3 | Bacterial infection; unspecified site | 1,386 | 260 | 18.8% |
| 240 | Burns | 1,373 | 222 | 16.2% |
| 77 | Encephalitis (except that caused by tuberculosis or sexually transmitted disease) | 1,361 | 242 | 17.8% |
| 91 | Other eye disorders | 1,344 | 144 | 10.7% |
| 175 | Other female genital disorders | 1,119 | 203 | 18.1% |
| 225 | Joint disorders and dislocations; trauma-related | 1,104 | 129 | 11.7% |
| 94 | Other ear and sense organ disorders | 1,005 | 117 | 11.6% |
| 119 | Varicose veins of lower extremity | 991 | 138 | 13.9% |
| 200 | Other skin disorders | 985 | 148 | 15.0% |
| 167 | Nonmalignant breast conditions | 977 | 123 | 12.6% |
| 257 | Other aftercare | 894 | 141 | 15.8% |
| 168 | Inflammatory diseases of female pelvic organs | 852 | 137 | 16.1% |
| 87 | Retinal detachments; defects; vascular occlusion; and retinopathy | 852 | 83 | 9.7% |
| 142 | Appendicitis and other appendiceal conditions | 803 | 98 | 12.2% |
| 209 | Other acquired deformities | 760 | 108 | 14.2% |
| 156 | Nephritis; nephrosis; renal sclerosis | 756 | 200 | 26.5% |

| AHRQ CCS | Description of AHRQ CCS | Admissions | 30-day unplanned readmissions | 30-day unplanned readmission rate |
|---|---|---|---|---|
| 173 | Menopausal disorders | 748 | 116 | 15.5% |
| 1 | Tuberculosis | 735 | 135 | 18.4% |
| 64 | Other hematologic conditions | 730 | 146 | 20.0% |
| 92 | Otitis media and related conditions | 724 | 104 | 14.4% |
| 166 | Other male genital disorders | 714 | 149 | 20.9% |
| 5 | HIV infection | 611 | 175 | 28.6% |
| 247 | Lymphadenitis | 456 | 87 | 19.1% |
| 249 | Shock | 451 | 109 | 24.2% |
| 9 | Sexually transmitted infections (not HIV or hepatitis) | 366 | 55 | 15.0% |
| 258 | Other screening for suspected conditions (not mental disorders or infectious disease) | 328 | 41 | 12.5% |
| 217 | Other congenital anomalies | 312 | 58 | 18.6% |
| 214 | Digestive congenital anomalies | 305 | 49 | 16.1% |
| 170 | Prolapse of female genital organs | 257 | 52 | 20.2% |
| 215 | Genitourinary congenital anomalies | 239 | 42 | 17.6% |
| 124 | Acute and chronic tonsillitis | 221 | 10 | 4.5% |
| 61 | Sickle cell anemia | 203 | 49 | 24.1% |
| 57 | Immunity disorders | 158 | 54 | 34.2% |
| 206 | Osteoporosis | 148 | 22 | 14.9% |
| 10 | Immunizations and screening for infectious disease | 127 | 16 | 12.6% |
| 88 | Glaucoma | 124 | 20 | 16.1% |
| 172 | Ovarian cyst | 114 | 14 | 12.3% |
| 208 | Acquired foot deformities | 103 | 17 | 16.5% |
| 46 | Benign neoplasm of uterus | 102 | 15 | 14.7% |
| 53 | Disorders of lipid metabolism | 98 | 16 | 16.3% |
| 171 | Menstrual disorders | 68 | 11 | 16.2% |
| 86 | Cataract | 37 | 6 | 16.2% |
| 256 | Medical examination/evaluation | 30 | 5 | 0.0% |
| 255 | Administrative/social admission | 14 | 2 | 0.0% |
| 56 | Cystic fibrosis | 14 | 3 | 0.0% |
| 169 | Endometriosis | 13 | 2 | 0.0% |

| AHRQ CCS | Description of AHRQ CCS | Admissions | 30-day unplanned readmissions | 30-day unplanned readmission rate |
|---|---|---|---|---|
| -- | Total | 3,086,792 | 556,131 | 18.0% |

**Table C3. Condition codes assigned to cardio-respiratory cohort**

| AHRQ CCS | Description of AHRQ CCS | Admissions | 30-day unplanned readmissions | 30-day unplanned readmission rate |
|---|---|---|---|---|
| 108 | Congestive heart failure; nonhypertensive | 453,340 | 111,720 | 24.6% |
| 122 | Pneumonia (except that caused by tuberculosis or sexually transmitted disease) | 403,972 | 71,538 | 17.7% |
| 127 | Chronic obstructive pulmonary disease and bronchiectasis | 297,735 | 64,132 | 21.5% |
| 131 | Respiratory failure; insufficiency; arrest (adult) | 117,569 | 28,597 | 24.3% |
| 128 | Asthma | 61,696 | 11,066 | 17.9% |
| 103 | Pulmonary heart disease | 45,122 | 7,432 | 16.5% |
| 125 | Acute bronchitis | 25,833 | 3,264 | 12.6% |
| -- | Total | 1,405,267 | 297,749 | 21.2% |

**Table C4. Condition codes assigned to cardiovascular cohort**

| AHRQ CCS | Description of AHRQ CCS | Admissions | 30-day unplanned readmissions | 30-day unplanned readmission rate |
|---|---|---|---|---|
| 106 | Cardiac dysrhythmias | 315,298 | 49,471 | 15.7% |
| 102 | Nonspecific chest pain | 142,883 | 15,241 | 10.7% |
| 100 | Acute myocardial infarction | 116,810 | 25,035 | 21.4% |
| 101 | Coronary atherosclerosis and other heart disease | 116,147 | 15,040 | 12.9% |
| 117 | Other circulatory disease | 56,016 | 8,998 | 16.1% |
| 105 | Conduction disorders | 33,899 | 3,704 | 10.9% |
| 114 | Peripheral and visceral atherosclerosis | 27,169 | 4,262 | 15.7% |
| 97 | Peri-; endo-; and myocarditis; cardiomyopathy (except that caused by tuberculosis or sexually transmitted disease) | 13,241 | 2,735 | 20.7% |
| 96 | Heart valve disorders | 9,920 | 1,803 | 18.2% |

| AHRQ CCS | Description of AHRQ CCS | Admissions | 30-day unplanned readmissions | 30-day unplanned readmission rate |
|---|---|---|---|---|
| 115 | Aortic; peripheral; and visceral artery aneurysms | 5,010 | 767 | 15.3% |
| 116 | Aortic and peripheral arterial embolism or thrombosis | 2,570 | 444 | 17.3% |
| 107 | Cardiac arrest and ventricular fibrillation | 2,009 | 360 | 17.9% |
| 104 | Other and ill-defined heart disease | 1,749 | 247 | 14.1% |
| 213 | Cardiac and circulatory congenital anomalies | 652 | 117 | 17.9% |
| -- | Total | 843,373 | 128,224 | 15.2% |

**Table C5. Condition codes assigned to neurology cohort**

| AHRQ CCS | Description of AHRQ CCS | Admissions | 30-day unplanned readmissions | 30-day unplanned readmission rate |
|---|---|---|---|---|
| 109 | Acute cerebrovascular disease | 197,598 | 28,620 | 14.5% |
| 112 | Transient cerebral ischemia | 82,499 | 9,073 | 11.0% |
| 95 | Other nervous system disorders | 58,486 | 10,172 | 17.4% |
| 83 | Epilepsy; convulsions | 38,034 | 6,013 | 15.8% |
| 233 | Intracranial injury | 35,366 | 5,890 | 16.7% |
| 81 | Other hereditary and degenerative nervous system conditions | 10,075 | 1,760 | 17.5% |
| 110 | Occlusion or stenosis of precerebral arteries | 9,091 | 1,273 | 14.0% |
| 79 | Parkinson`s disease | 6,651 | 907 | 13.6% |
| 113 | Late effects of cerebrovascular disease | 6,396 | 1,044 | 16.3% |
| 85 | Coma; stupor; and brain damage | 6,092 | 975 | 16.0% |
| 111 | Other and ill-defined cerebrovascular disease | 5,316 | 621 | 11.7% |
| 80 | Multiple sclerosis | 1,036 | 147 | 14.2% |
| 82 | Paralysis | 883 | 131 | 14.8% |
| 227 | Spinal cord injury | 832 | 144 | 17.3% |
| 78 | Other CNS infection and poliomyelitis | 786 | 135 | 17.2% |
| 216 | Nervous system congenital anomalies | 48 | 12 | 25.0% |
| -- | Total | 459,189 | 66,917 | 14.6% |

**Table C6. Condition codes assigned across all cohorts**

| Description of AHRQ CCS | Admissions | 30-day unplanned readmissions | 30-day unplanned readmission rate |
|---|---|---|---|
| Grand Total | 7,957,901 | 1,321,851 | 16.6% |

# Appendix D. Additional Details on Identification and Evaluation of Candidate Attribution Rules

### D1. Identification of Candidate Attribution Rules

Our approach to identifying attribution rules was guided by historical, analytic, policy, and clinical considerations. This includes prior work by the NQF, existing CMS programs, the Environmental Scan/Literature Review, described below, input from the TEP, and descriptive analyses of claims patterns. This appendix describes the attribution rules evaluated for use in MIPS HWR measure: how they were identified and why they were or were not adopted.

NQF Recommendations
Consistent with the NQF Attribution Committee's recommendations, we considered multiple approaches determined by measure cohort and outcome. We also were attentive to the minimum standards for any attribution rule proposed by the NQF Attribution Committee:

- *Use transparent, clearly articulated methods that produce consistent and reproducible results.* Consistent with this standard, we developed attribution rules that were reproducible and straightforward to implement.

- *Ensure that accountable units can meaningfully influence measured outcomes.* We met this standard by obtaining clinical input on all candidate attribution rules.

Existing CMS Programs
We considered attribution approaches that had been used or were currently in use for attributed hospital outcomes to individual clinicians or their practice groups. These included:

- Value-based Payment Modifier: two-step attribution methodology based on plurality of primary care service delivery, first assigning to primary care provider and secondly to a specialist who provides primary care service.[48]

- Medicare Accountable Care Organizations (ACOs) (Medicare Shared Savings Program, Pioneer ACO Model, Next Generation ACOs): two-step attribution method for beneficiaries who receive at least one primary care service from physician within an ACO, first assigning them to the primary care physician who provides the plurality of services and secondly to an ACO professional who provides primary care services.[49]

- Comprehensive Primary Care Plus (CPC+): attribution primarily based on billings for complex care management services and secondarily based on plurality of primary care visits, if not assigned in first step.[50]

- Medicare Multi-Payer Advanced Primary Care Practice (MAPCP) Demonstration: attribution to provider with most primary care visits and break tie with most recent visit.[51]

Environmental Scan/Literature Review
We performed an environmental scan and literature review to identify approaches to attribution. First, we reviewed work completed by the NQF under contract to the Department of Health and Human Services in 2016.[28] As part of its work, the NQF convened a researcher and clinician-based team to conduct a comprehensive literature review and environmental scan to identify attribution rules proposed for use in or implemented in healthcare delivery models. The NQF also convened a multi-stakeholder committee that reviewed the research team's findings, developed principles of fair attribution models, and developed a guide to assist measure developers and those designing payment models in selecting attribution rules.[28]

Second, we updated the findings of the NQF Attribution Committee's literature review, which evaluated medical literature through October 2016. We searched PubMed (January 1, 2016 through January 4, 2017) and EMBASE (January 1, 2016 through January 4, 2017) to identify any new attribution methods not captured in the NQF's 2016 report. We adopted the NQF's search strategy and supplemented the search by consulting content experts to include additional studies focused on assigning beneficiaries to clinicians.[52]

Our literature search identified several attribution approaches that were used in high-impact or multiple studies; we considered these as candidates for the current assessment. These included:

- Plurality of charges or claims during a fixed time frame.

- Most recent charges/claims/visits prior to an event.

- Procedure claim for patients undergoing a procedure.

Claims Patterns
To better understand patterns of care that could help identify or exclude from consideration different attribution rules, we examined for each measure cohort, the patterns of claims around each inpatient stay, focusing specifically and separately on the 365 days prior to admission and during the inpatient stay. This included both institutional and outpatient claims. For example, by examining the claims distributions during and before an inpatient stay for AMI, we could identify for a given cohort the proportion of patients who saw a cardiologist during or prior to a hospitalization, which would, in turn, indicate the feasibility of attributing an outcome to a cardiologist. We also examined the distribution in numbers and types of clinicians seen by patients during their hospitalization, and the completeness of institutional claims with respect to clinician NPIs. These kinds of data, while not used for evaluation of the attribution approaches, provided a profile of the kinds of clinician contact patients in a given measure cohort had prior to and during their hospitalization to help identify feasible attribution rules.

Clinical Input
For initial clinical input, we organized a group of clinician researchers at CORE. We gave them background information on the objectives of the project, the candidate measures, and our initial list of candidate attribution approaches. We then solicited their thoughts or concerns about the candidate attribution rules, and their input on any additional attribution rules we should consider.

Stakeholder Input
In the context of measure re-specification, we solicited input from a national TEP. This panel, listed in Appendix A provided iterative feedback, through three meetings, including one in-person meeting, and

through written commentary. At each meeting, CORE presented proposals for attribution along with relevant results and obtained suggestions for additional analyses or additional attributions to be considered. The TEP also considered and endorsed the importance of attributing the readmission outcome to multiple eligible clinician groups.

### D2. Candidate Attribution Rules Considered

The following attribution rules were considered and evaluated during this process.

- *Attending:* Assigns the patient/outcome to the attending physician. Conceptually, the attending physician guides the patient's overall care, and thus it is reasonable to hold them responsible for the care transition at discharge. To apply this concept, we use the attending physician on the inpatient claim for the inpatient stay, entered as an NPI. Practically, this is an unambiguous assignment available for nearly all patients in an inpatient cohort.

- *Discharge Clinician:* Assigns the patient to the clinician who billed for discharging the patient. Consistent with the concept of the attending, it is aligned with the conceptual basis of readmission as a signal of quality during a care transition to assign to the Discharge Clinician. Practically, this will often, but not always, be the attending of record on the inpatient claim. The Discharge Clinician can be determined using the outpatient claims, as for any patient discharged from acute care there should be a corresponding claim for a discharge procedure (CPT® code 99238 or 99239).

- *Primary Inpatient Care Provider (charges):* Assigns the patient to the clinician with the plurality of charges billed during the dates of the index hospitalization. Conceptually, it may be reasonable that the provider who charged the most for the patient's care during the hospitalization is most responsible for that patient's outcomes. Practically, charges are readily available from the Carrier claims file.

- *Primary Inpatient Care Provider (claims)*: Assigns the patient to the clinician with the plurality of claims billed during the dates of the index hospitalization. Conceptually, this is analogous to the 'most charges' assignment (3), using the same set of claims and clinicians but counting the number of claims rather than charges on those claims, but may be less biased towards certain specialties. Practically, claim counts are readily available from the Carrier claims file.

- *Value Modifier (VM) Approach:* Used in CMS's VM program to assign inpatient admissions to providers. Assigns the patient to the clinician who provides the most primary care services during the 12 calendar months of the measurement period. Conceptually, if a patient has a primary care provider, this clinician could plausibly be aware of any hospitalization and provide post-discharge care that would reduce the need for a rehospitalization. The existing algorithm identifies a PCP if possible, a specialist if not, using plurality of charges for primary care codes during the reporting calendar year.

- *Outpatient PCP:* We wanted to rule out the possibility that a patient would be attributed to a clinician they cared for only after discharge, so we modified the VM approach to count only those codes during the 365 days prior to admission.

- *Outpatient PCP+:* In a variation on the previous rule, we dropped the precedence given to primary care physicians.

Our empirical evaluation of the selected attribution methods for each test measure was comprised of analyses that would allow us to understand the implications of each approach with regards to feasibility, validity, reliability, and sample size. Our analytic evaluation was attentive to the minimum standards for any attribution rule proposed by the NQF Attribution Committee:

- Use adequate sample sizes, outlier exclusion, and/or risk adjustment to fairly compare the performance of attributed units. We examined sample size distribution and outlier patterns and used original hospital risk-adjustment models.

- *Conduct sufficient testing with scientific rigor at the level of accountability being measured.* Though additional testing would be necessary before adoption, we undertook implementation consistent with the hospital-level measures, which have been rigorously tested.

The analytic evaluation of each attribution method focused on the following aspects of each:

- *Face validity*: For each approach, we assessed face validity by summarizing the number and percent of unattributed patients as well as rates of missing clinician or TIN information. The distribution also provides face validity in that an attribution rule which leads to unexpected or senseless results is unlikely to be accepted by stakeholders. Implementation also provided a measure of feasibility; if an approach led to a high proportion of unattributed patients, then it was considered less valid. Thus, we examined the patterns of volume for eligible clinician groups overall and by specialty.

- *Differentiation among providers*: The greater the variation in entity performance, the more evidence that the attribution is aligned with some underlying true quality signal. Therefore, for each attribution method, we examined: the distribution of unadjusted outcome rates across physicians and eligible clinician groups; the between-clinician and between-TIN variance estimated from a hierarchical generalized linear model (HGLM) for different volume cut-offs; distribution of RARR; and the impact of risk adjustment on these variances.

- *Reliability and sample size*: Reliability relates the accuracy of measurement to the sample size of the measured entities. For each approach, we calculated the estimated average unit (clinician [NPI] or group [TIN]) reliability for a volume cut-off of 25 as well as a range of volume thresholds.

- *Overlap with other attribution rules*: As recommended by the NQF report, we examined the overlap between the different candidate attribution rules. If several different attribution rules are consistent (have high overlap), then it suggests there is little practical difference in choosing among them. For all attribution rules assigned to a single entity, we summarized how much pairwise overlap there was in their assignments.

For all attribution rules, we evaluated implementation of the rule at the individual eligible clinician level and at the eligible clinician group level.

**Table D1. Attribution rules evaluated**

| Attribution rule | Definition | Justification for inclusion as candidate attribution rule | Reason for exclusion |
|---|---|---|---|
| Attending | Identified as the "attending provider" on the inpatient claim | Logically responsible for patient care and discharge transition. | Concern that eligible clinicians had little control over whether they were listed on an inpatient claim as the Attending. |
| Discharge clinician | Identified by claim with 'discharge procedure' codes | Logically responsible for discharge transition. | Not applicable; rule not excluded |
| Primary inpatient care provider (greatest number of claims) | Identified by plurality of Part B patient-facing claim lines during inpatient stay | Logically responsible for patient care during inpatient stay. | Analyses found that the eligible clinicians identified by charges had specialties that were more aligned with clinical expectations. |
| Primary Inpatient Care Provider (greatest total charges) | Identified by plurality of Part B patient-facing claim charges during inpatient stay | Logically responsible for patient care during inpatient stay. | Not applicable; rule not excluded |
| Outpatient PCP | identified by plurality of outpatient primary care during 12 months prior to admissions, precedence given to primary care specialties | Logically responsible for patient care in the outpatient setting. | Not applicable; rule not excluded |
| Outpatient PCP+ | identified by plurality of outpatient primary care during 12 months prior to admissions, no precedence given to primary care specialties | Logically responsible for patient care in the outpatient setting. | Compared with Outpatient PCP, more often identified specialties that were unlikely to be responsible for admission decisions. |

### D3. Final Attributions

CORE sought consensus from a national TEP around which of the rules should be used for MIPS HWR measure. The TEP strongly supported attributing readmissions to more than one eligible clinician and identified combinations of preferences for the Discharge Clinician, Outpatient PCP, and some version of the Primary Inpatient care clinician.

**Figure D1. Hospital-wide readmission: Primary inpatient care clinician attribution (eligible clinician level)**



Total HWR measure cohort

Have Patient facing encounter HCPCS codes (v2018) and eligible specialty codes (v2017)?

**Plurality rule:**

Assign to physician with
→ Most total charges
→ Most recent billing date (if tie)
→ Random selection (if tie)

Yes

Have any Part-B carrier lines remaining?

Yes

No

Select the Eligible Clinician combination who billed total sum of highest charges; break ties by plurality rule.

**Assign to Primary Inpatient Care Clinician Eligible Clinician**

**Unassigned: No Carrier Claim from Eligible Clinician**

**Figure D2. Hospital-wide readmission: Greatest Total Charges Attribution (eligible clinician level)**
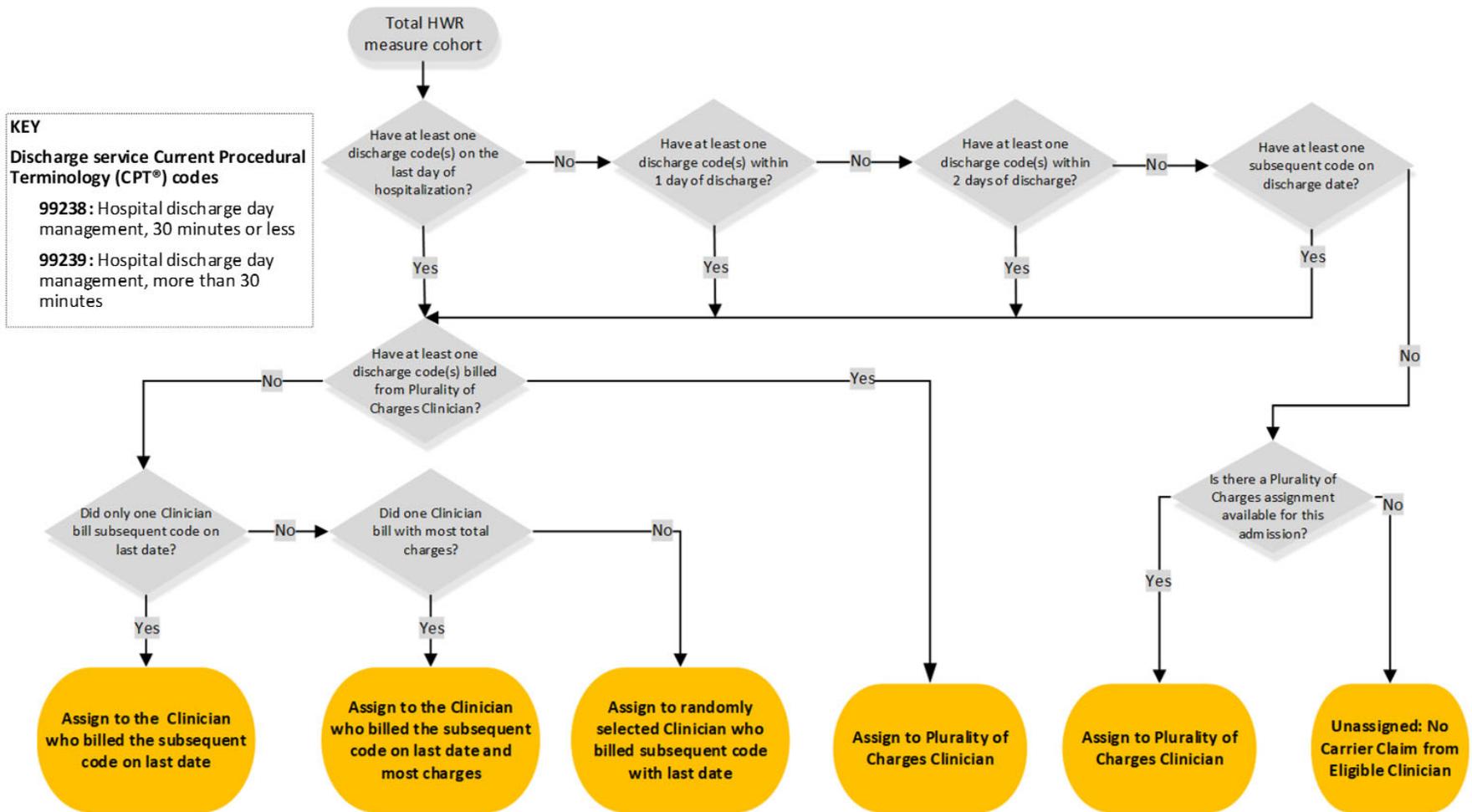
### D4. Excluded Attribution Rules

CORE sought consensus from the TEP around which of these rules should be used for MIPS HWR measure. These rules were excluded for the following reasons:

*Attending*: The TEP and other stakeholders were concerned that eligible clinicians had little control over whether they were listed on an inpatient claim as the Attending. This would dilute responsibility and raise concerns about validity.

*Primary Inpatient Care Provider (claims):* While closely related to the adopted attribution rule, "Primary Inpatient Care Provider (Charges)," analyses found the eligible clinicians identified by charges had specialties more closely aligned with clinical expectations. Specifically, for the surgery/gynecology cohort, using charges typically identified a surgeon, while the number of claims typically identified other specialties. For non-surgical cohorts, the same eligible clinician was often identified using both methods. Thus, attribution based on number of claims was dropped in favor of an approach that could be more accurately applied across all specialty cohorts.

*Outpatient PCP+*: While very similar to the Outpatient PCP that was ultimately adopted, the modification to ignore specialty unsurprisingly identified specialties that were unlikely to be responsible for admission decisions. Feedback from the TEP also indicated greater face validity for the Outpatient PCP approach finally adopted.

# Appendix E. Potential Complications of Care Excluded from Risk Adjustment

**Table E1. Conditions that are treated as potential complications of care if occurring during index admission**

| CMS-CC[53] | Label | Potential complication |
|---|---|---|
| 2 | Septicemia/Shock | Yes |
| 6 | Other Infectious Diseases | Yes |
| 17 | Diabetes with Acute Complications | Yes |
| 23 | Disorders of Fluid/Electrolyte/Acid-Base | Yes |
| 24 | Other Endocrine/Metabolic/ Nutritional Disorders | No |
| 28 | Acute Liver Failure/Disease | Yes |
| 31 | Intestinal Obstruction/Perforation | Yes |
| 34 | Peptic Ulcer, Hemorrhage, Other Specified Gastrointestinal Disorders | Yes |
| 36 | Other Gastrointestinal Disorders | No |
| 37 | Bone/Joint/Muscle Infections/Necrosis | No |
| 43 | Other Musculoskeletal and Connective Tissue Disorders | No |
| 46 | Coagulation Defects and Other Specified Hematological Disorders | Yes |
| 47 | Iron Deficiency and Other/ Unspecified Anemias and Blood Disease | No |
| 48 | Delirium and Encephalopathy | Yes |
| 51 | Drug/Alcohol Psychosis | No |
| 75 | Coma, Brain Compression/Anoxic Damage | Yes |
| 76 | Mononeuropathy, Other Neurological Conditions/Injuries | No |
| 77 | Respirator Dependence/Tracheostomy Status | Yes |
| 78 | Respiratory Arrest | Yes |
| 79 | Cardio-Respiratory Failure and Shock | Yes |
| 80 | Congestive Heart Failure | Yes |
| 81 | Acute Myocardial Infarction | Yes |
| 82 | Unstable Angina and Other Acute Ischemic Heart Disease | Yes |
| 85 | Heart Infection/Inflammation, Except Rheumatic | No |
| 92 | Specified Heart Arrhythmias | Yes |

| CMS-CC[53] | Label | Potential complication |
|---|---|---|
| 93 | Other Heart Rhythm and Conduction Disorders | Yes |
| 95 | Cerebral Hemorrhage | Yes |
| 96 | Ischemic or Unspecified Stroke | Yes |
| 97 | Precerebral Arterial Occlusion and Transient Cerebral Ischemia | Yes |
| 100 | Hemiplegia/Hemiparesis | Yes |
| 101 | Diplegia (Upper), Monoplegia, and Other Paralytic Syndromes | Yes |
| 102 | Speech, Language, Cognitive, Perceptual | Yes |
| 104 | Vascular Disease with Complications | Yes |
| 105 | Vascular Disease | Yes |
| 106 | Other Circulatory Disease | Yes |
| 111 | Aspiration and Specified Bacterial Pneumonias | Yes |
| 112 | Pneumococcal Pneumonia, Emphysema, Lung Abscess | Yes |
| 114 | Pleural Effusion/Pneumothorax | Yes |
| 124 | Other Eye Disorders | No |
| 129 | End Stage Renal Disease | Yes |
| 130 | Dialysis Status | Yes |
| 131 | Renal Failure | Yes |
| 132 | Nephritis | Yes |
| 133 | Urinary Obstruction and Retention | Yes |
| 135 | Urinary Tract Infection | Yes |
| 148 | Decubitus Ulcer of Skin | Yes |
| 152 | Cellulitis, Local Skin Infection | Yes |
| 154 | Severe Head Injury | Yes |
| 155 | Major Head Injury | Yes |
| 156 | Concussion or Unspecified Head Injury | Yes |
| 157 | Vertebral Fractures | No |
| 158 | Hip Fracture/Dislocation | Yes |
| 159 | Major Fracture, Except of Skull, Vertebrae, or Hip | Yes |
| 160 | Internal Injuries | No |
| 161 | Traumatic Amputation | No |
| 162 | Other Injuries | No |
| 163 | Poisonings and Allergic Reactions | Yes |
| 164 | Major Complications of Medical Care and Trauma | Yes |

| CMS-CC[53] | Label | Potential complication |
|---|---|---|
| 165 | Other Complications of Medical Care | Yes |
| 166 | Major Symptoms, Abnormalities | No |
| 174 | Major Organ Transplant Status | Yes |
| 175 | Other Organ Transplant/Replacement | Yes |
| 176 | Artificial Openings for Feeding or Elimination | Yes |
| 177 | Amputation Status, Lower Limb/Amputation | Yes |
| 178 | Amputation Status, Upper Limb | Yes |
| 179 | Post-Surgical States/Aftercare/Elective | Yes |

**Table E2. Discharge condition categories considered acute and/or complications of care**

| AHRQ CCS | Description of AHRQ CCS | 30-day readmissions with this condition and one of the planned procedures (Total=64,181) |
|---|---|---|
| 237 | Complication of device; implant or graft | 11,689 |
| 106 | Cardiac dysrhythmias | 10,267 |
| 207, 225, 226, 227, 229, 230, 231, 232 | Fracture | 6,307 |
| 100 | Acute myocardial infarction | 5,643 |
| 238 | Complications of surgical procedures or medical care | 5,438 |
| 108 | Congestive heart failure; nonhypertensive | 5,119 |
| 2 | Septicemia (except in labor) | 3,372 |
| 146 | Diverticulosis and diverticulitis | 2,434 |
| 105 | Conduction disorders | 2,130 |
| 109 | Acute cerebrovascular disease | 1,886 |
| 145 | Intestinal obstruction without hernia | 1,341 |
| 233 | Intracranial injury | 1,271 |
| 116 | Aortic and peripheral arterial embolism or thrombosis | 1,115 |
| 122 | Pneumonia (except that caused by TB or sexually transmitted disease) | 710 |
| 131 | Respiratory failure; insufficiency; arrest (adult) | 678 |
| 157 | Acute and unspecified renal failure | 645 |
| 201 | Infective arthritis and osteomyelitis (except that caused by TB or sexually transmitted disease) | 608 |
| 153 | Gastrointestinal hemorrhage | 566 |
| 130 | Pleurisy; pneumothorax; pulmonary collapse | 510 |
| 97 | Peri-; endo-; and myocarditis; cardiomyopathy | 484 |
| 127 | Chronic obstructive pulmonary disease and bronchiectasis | 462 |
| 55 | Fluid and electrolyte disorders | 424 |
| 159 | Urinary tract infections | 410 |
| 245 | Syncope | 353 |

| AHRQ CCS | Description of AHRQ CCS | 30-day readmissions with this condition and one of the planned procedures (Total=64,181) |
|---|---|---|
| 139 | Gastroduodenal ulcer (except hemorrhage) | 133 |
| 160 | Calculus of urinary tract | 98 |
| 112 | Transient cerebral ischemia | 88 |

# Appendix F. Model Results

**Table F1. Cardiorespiratory cohort prevalence and model coefficient, development, and validation cohorts**

| Variable | Dataset: MIPS HWR 2015–2016 | | Dataset: MIPS HWR 2016–2017 | |
|---|---|---|---|---|
| | % | Coefficient (95% CI) | % | Coefficient (95% CI) |
| Age (years over 65) | 14.0% | 0.00 (0.00, 0.00) | 13.7% | 0.00 (0.00, 0.00) |
| Alcohol | 3.5% | 0.16 (0.13, 0.18) | 3.7% | 0.18 (0.15, 0.21) |
| Arrhythmias | 33.3% | 0.09 (0.08, 0.10) | 29.0% | 0.10 (0.09, 0.12) |
| Arthritis | 5.8% | 0.07 (0.05, 0.09) | 6.1% | 0.05 (0.03, 0.07) |
| CAD/CVD | 58.9% | 0.12 (0.11, 0.13) | 54.5% | 0.11 (0.10, 0.13) |
| Congestive Heart Failure | 37.7% | 0.18 (0.17, 0.20) | 32.8% | 0.19 (0.17, 0.20) |
| Low frequency Conditions | 0.0% | -0.03 (-0.61, 0.56) | 0.0% | 0.04 (-0.64, 0.71) |
| Pulmonary heart disease (CCS 103) | 4.8% | -0.09 (-0.18, -0.01) | 6.0% | -0.10 (-0.20, 0.00) |
| Congestive heart failure; nonhypertensive (CCS 108) | 34.8% | 0.15 (0.07, 0.24) | 19.9% | 0.17 (0.07, 0.27) |
| Pneumonia (except that caused by tuberculosis or sexually transmitted disease) (CCS 122) | 26.3% | -0.02 (-0.11, 0.06) | 25.6% | -0.01 (-0.11, 0.08) |
| Acute bronchitis (CCS 125) | 1.6% | -0.22 (-0.31, -0.13) | 2.0% | -0.18 (-0.29, -0.08) |
| Chronic obstructive pulmonary disease and bronchiectasis (CCS 127) | 19.8% | 0.15 (0.06, 0.23) | 30.0% | 0.12 (0.02, 0.22) |
| Asthma (CCS 128) | 1.7% | -0.04 (-0.14, 0.05) | 1.4% | -0.14 (-0.25, -0.03) |
| Respiratory failure; insufficiency; arrest (adult) (CCS 131) | 10.9% | Ref | 15.0% | ref |
| COPD | 51.6% | 0.20 (0.18, 0.21) | 53.4% | 0.19 (0.18, 0.20) |
| Cardiorespiratory | 28.4% | 0.16 (0.14, 0.17) | 29.6% | 0.19 (0.17, 0.20) |
| Coagulopathy | 7.0% | 0.03 (0.02, 0.05) | 6.7% | 0.04 (0.02, 0.06) |
| Diabetes | 40.7% | 0.09 (0.08, 0.10) | 36.0% | 0.09 (0.08, 0.10) |
| Hematological | 1.1% | 0.25 (0.20, 0.29) | 1.1% | 0.22 (0.17, 0.27) |

| Variable | Dataset: MIPS HWR 2015–2016 | | Dataset: MIPS HWR 2016–2017 | |
|---|---|---|---|---|
| | % | Coefficient (95% CI) | % | Coefficient (95% CI) |
| Hip fracture | 2.3% | -0.10 (-0.14, -0.07) | 2.3% | -0.10 (-0.14, -0.07) |
| History of infection | 1.6% | 0.14 (0.10, 0.18) | 1.7% | 0.09 (0.05, 0.13) |
| Iron deficiency | 47.2% | 0.18 (0.17, 0.19) | 44.5% | 0.18 (0.17, 0.19) |
| Liver disease | 1.9% | 0.15 (0.12, 0.18) | 1.8% | 0.14 (0.11, 0.18) |
| Lung disorder | 7.6% | 0.09 (0.07, 0.11) | 7.6% | 0.08 (0.06, 0.10) |
| Malnutrition | 11.1% | 0.08 (0.06, 0.09) | 12.1% | 0.10 (0.09, 0.12) |
| Metastatic cancer | 2.8% | 0.20 (0.17, 0.23) | 3.2% | 0.23 (0.20, 0.26) |
| Metabolic disorder | 35.0% | 0.13 (0.12, 0.14) | 33.2% | 0.13 (0.12, 0.15) |
| Motor dysfunction | 4.3% | 0.08 (0.05, 0.10) | 4.8% | 0.08 (0.05, 0.10) |
| On dialysis | 2.4% | 0.22 (0.19, 0.25) | 2.35% | 0.22 (0.19, 0.25) |
| Other cancer | 6.0% | 0.07 (0.05, 0.09) | 5.8% | 0.06 (0.04, 0.08) |
| Other infectious | 38.0% | 0.09 (0.08, 0.10) | 40.9% | 0.06 (0.05, 0.07) |
| Pancreatic disease | 8.7% | 0.07 (0.05, 0.08) | 8.0% | 0.09 (0.07, 0.11) |
| Psychological | 33.9% | 0.08 (0.07, 0.09) | 34.9% | 0.09 (0.08, 0.11) |
| Renal failure | 43.2% | 0.18 (0.17, 0.20) | 38.8% | 0.17 (0.15, 0.18) |
| Respirator dependence | 0.6% | 0.18 (0.13, 0.23) | 0.6% | 0.09 (0.03, 0.15) |
| Seizure | 3.8% | 0.08 (0.05, 0.10) | 3.9% | 0.06 (0.04, 0.09) |
| Septicemia | 9.9% | 0.02 (0.00, 0.03) | 10.3% | 0.02 (0.00, 0.03) |
| Severe cancer | 6.3% | 0.20 (0.18, 0.22) | 6.9% | 0.21 (0.19, 0.24) |
| Transplants | 0.7% | 0.07 (0.02, 0.13) | 0.7% | 0.14 (0.07, 0.20) |
| Ulcers | 5.4% | 0.12 (0.10, 0.14) | 4.8% | 0.10 (0.08, 0.13) |

**Table F2. Cardiovascular cohort: prevalence and model coefficients, development, and validation cohorts**

| Variable | Dataset: MIPS HWR 2015–2016 | | Dataset: MIPS HWR 2016–2017 | |
|---|---|---|---|---|
| | % | Coefficients (95% CI) | % | Coefficients (95% CI) |
| Age (years over 65) | 13.4% | 0.01 (0.01, 0.01) | 13.3% | 0.01 (0.01, 0.01) |
| Alcohol | 2.5% | 0.20 (0.16, 0.24) | 2.5% | 0.22 (0.18, 0.27) |
| Arrhythmias | 27.3% | 0.08 (0.06, 0.10) | 27.2% | 0.06 (0.04, 0.08) |
| Arthritis | 5.0% | 0.13 (0.10, 0.16) | 5.1% | 0.11 (0.08, 0.15) |
| CAD/CVD | 63.4% | 0.10 (0.08, 0.12) | 63.3% | 0.09 (0.07, 0.11) |
| Congestive Heart Failure | 21.9% | 0.23 (0.21, 0.25) | 21.9% | 0.21 (0.19, 0.24) |
| Acute myocardial infarction (CCS 100) | 23.1% | 0.13 (0.11, 0.16) | 24.9% | 0.13 (0.11, 0.15) |
| Coronary atherosclerosis and other heart disease (CCS 101) | 11.2% | -0.11 (-0.13, -0.08) | 10.6% | -0.14 (-0.17, -0.11) |
| Nonspecific chest pain (CCS 102) | 7.9% | -0.24 (-0.28, -0.21) | 6.4% | -0.21 (-0.25, -0.18) |
| Other and ill-defined heart disease (CCS 104) | 0.5% | -0.05 (-0.16, 0.05) | 0.5% | 0.00 (-0.11, 0.10) |
| Conduction disorders (CCS 105) | 3.8% | -0.26 (-0.30, -0.22) | 4.1% | -0.30 (-0.35, -0.26) |
| Cardiac dysrhythmias (CCS 106) | 37.4% | 0.11 (0.09 ,0.13) | 37.2% | 0.11 (0.09, 0.13) |
| Cardiac arrest and ventricular fibrillation (CCS 107) | 0.4% | 0.01 (-0.09, 0.11) | 0.4% | -0.03 (-0.13, 0.07) |
| Peripheral and visceral atherosclerosis (CCS 114) | 3.8% | 0.00 (-0.04, 0.04) | 3.3% | 0.01 (-0.03, 0.06) |
| Aortic; peripheral; and visceral artery aneurysms (CCS 115) | 2.9% | -0.02 (-0.07, 0.02) | 3.6% | -0.07 (-0.11, -0.02) |
| Aortic and peripheral arterial embolism or thrombosis (CCS 116) | 0.5% | 0.17 (0.08, 0.25) | 0.5% | 0.12 (0.02, 0.22) |
| Other circulatory disease (CCS 117) | 5.3% | -0.04 (-0.07, 0.00) | 5.2% | -0.01 (-0.04, 0.03) |

| Variable | Dataset: MIPS HWR 2015–2016 | | Dataset: MIPS HWR 2016–2017 | |
|---|---|---|---|---|
| | % | Coefficients (95% CI) | % | Coefficients (95% CI) |
| Cardiac and circulatory congenital anomalies (CCS 213) | 0.3% | 0.08 (-0.03, 0.20) | 0.3% | 0.14 (0.03, 0.24) |
| Heart valve disorders (CCS 96) | 1.5% | -0.06 (-0.11, 0.00) | 1.4% | -0.04 (-0.09, 0.02) |
| Peri-; endo-; and myocarditis; cardiomyopathy (except that caused by tuberculosis or sexually transmitted disease) (CCS 97) | 1.5% | Ref | 1.5% | ref |
| COPD | 25.2% | 0.27 (0.25, 0.29) | 25.5% | 0.28 (0.27, 0.30) |
| Cardiorespiratory | 10.2% | 0.07 (0.05, 0.10) | 10.9% | 0.06 (0.04, 0.08) |
| Coagulopathy | 4.5% | 0.02 (-0.01, 0.05) | 4.8% | 0.02 (-0.01, 0.05) |
| Diabetes | 37.1% | 0.14 (0.13, 0.16) | 34.3% | 0.13 (0.12, 0.15) |
| Hematological | 0.8% | 0.29 (0.22, 0.36) | 0.7% | 0.23 (0.16, 0.30) |
| Hip fracture | 1.4% | -0.08 (-0.14, -0.03) | 1.4% | -0.10 (-0.16, -0.05) |
| History infection | 0.8% | 0.15 (0.08, 0.22) | 0.8% | 0.15 (0.08, 0.22) |
| Iron deficiency | 34.2% | 0.25 (0.24, 0.27) | 34.3% | 0.27 (0.25, 0.29) |
| Liver disease | 1.3% | 0.29 (0.24, 0.34) | 1.4% | 0.23 (0.18, 0.28) |
| Lung disorder | 2.8% | 0.09 (0.05, 0.13) | 2.6% | 0.13 (0.09, 0.17) |
| Malnutrition | 5.7% | 0.15 (0.13, 0.18) | 6.4% | 0.14 (0.12, 0.17) |
| Metastatic cancer | 1.7% | 0.37 (0.32, 0.43) | 1.8% | 0.31 (0.26, 0.36) |
| Metabolic disorder | 22.0% | 0.12 (0.10, 0.14) | 22.1% | 0.13 (0.11, 0.15) |
| Motor dysfunction | 3.2% | 0.09 (0.05, 0.12) | 3.9% | 0.13 (0.10, 0.17) |
| On dialysis | 2.4% | 0.32 (0.28, 0.36) | 2.5% | 0.37 (0.33, 0.40) |
| Other cancer | 5.1% | 0.04 (0.01, 0.08) | 5.1% | 0.05 (0.02, 0.08) |
| Other infectious | 17.1% | 0.14 (0.12, 0.16) | 17.1% | 0.14 (0.12, 0.17) |
| Pancreatic disease | 6.1% | 0.06 (0.04, 0.09) | 6.2% | 0.08 (0.05, 0.11) |
| Psychological | 24.7% | 0.14 (0.12, 0.15) | 25.1% | 0.12 (0.11, 0.14) |
| Renal failure | 34.0% | 0.25 (0.24, 0.27) | 34.8% | 0.27 (0.25, 0.28) |
| Respirator dependence | 0.2% | 0.08 (-0.06, 0.21) | 0.2% | 0.00 (-0.14, 0.14) |
| Seizure | 3.0% | 0.12 (0.08, 0.16) | 3.1% | 0.13 (0.09, 0.16) |

| Variable | Dataset: MIPS HWR 2015–2016 | | Dataset: MIPS HWR 2016–2017 | |
|---|---|---|---|---|
| | % | Coefficients (95% CI) | % | Coefficients (95% CI) |
| Septicemia | 4.9% | -0.01 (-0.04, 0.02) | 5.2% | -0.02 (-0.05, 0.01) |
| Severe cancer | 3.6% | 0.22 (0.18, 0.25) | 3.7% | 0.25 (0.22, 0.29) |
| Transplants | 0.6% | 0.17 (0.09, 0.25) | 0.6% | 0.11 (0.03, 0.19) |
| Ulcers | 3.4% | 0.21 (0.17, 0.24) | 3.2% | 0.18 (0.14, 0.21) |

**Table F3. Medicine cohort: prevalence and model coefficients, development and validation cohorts**

| Variable | Dataset: MIPS HWR 2015–2016 | | Dataset: MIPS HWR 2016–2017 | |
|---|---|---|---|---|
| | % | Coefficient (95% CI) | % | Coefficient (95% CI) |
| Age (years over 65) | 14.1% | 0.00 (0.00, 0.00) | 14.3% | 0.00 (0.00, 0.00) |
| Alcohol | 4.3% | 0.07 (0.06, 0.09) | 4.0% | 0.10 (0.08, 0.11) |
| Arrhythmias | 24.9% | 0.08 (0.07, 0.09) | 26.2% | 0.08 (0.07, 0.09) |
| Arthritis | 6.2% | 0.10 (0.08, 0.11) | 6.3% | 0.10 (0.09, 0.11) |
| CAD/CVD | 50.6% | 0.11 (0.10, 0.11) | 52.0% | 0.11 (0.11, 0.12) |
| Congestive Heart Failure | 22.4% | 0.16 (0.15, 0.17) | 25.0% | 0.16 (0.15, 0.17) |
| Low Frequency Conditions | 0.5% | -0.04 (-0.09, 0.01) | 0.5% | 0.01 (-0.04, 0.05) |
| Phlebitis; thrombophlebitis and thromboembolism (CCS 118) | 1.2% | -0.02 (-0.05, 0.02) | 1.0% | -0.04 (-0.07, -0.01) |
| Hemorrhoids (CCS 120) | 0.3% | -0.05 (-0.11, 0.02) | 0.2% | 0.01 (-0.05, 0.08) |
| Other diseases of veins and lymphatics (CCS 121) | 0.1% | 0.01 (-0.07, 0.10) | 0.1% | 0.08 (-0.01, 0.16) |
| Influenza (CCS 123) | 0.5% | -0.27 (-0.32, -0.21) | 1.3% | -0.28 (-0.31, -0.24) |
| Other upper respiratory infections (CCS 126) | 0.2% | -0.17 (-0.25, -0.09) | 0.2% | -0.21 (-0.29, -0.13) |
| Aspiration pneumonitis; food/vomitus (CCS 129) | 2.3% | 0.05 (0.03, 0.07) | 2.0% | 0.06 (0.03, 0.08) |

| Variable | Dataset: MIPS HWR 2015–2016 | | Dataset: MIPS HWR 2016–2017 | |
|---|---|---|---|---|
| | % | Coefficient (95% CI) | % | Coefficient (95% CI) |
| Pleurisy; pneumothorax; pulmonary collapse (CCS 130) | 0.9% | 0.32 (0.29, 0.36) | 0.8% | 0.36 (0.32, 0.39) |
| Lung disease due to external agents (CCS 132) | 0.1% | 0.17 (0.06, 0.29) | 0.1% | 0.19 (0.08, 0.30) |
| Other lower respiratory disease (CCS 133) | 0.8% | 0.05 (0.02, 0.09) | 0.8% | 0.08 (0.04, 0.11) |
| Other upper respiratory disease (CCS 134) | 0.2% | 0.01 (-0.07, 0.08) | 0.2% | -0.01 (-0.09, 0.07) |
| Intestinal infection (CCS 135) | 2.0% | 0.17 (0.15, 0.20) | 1.9% | 0.15 (0.12, 0.17) |
| Disorders of teeth and jaw (CCS 136) | 0.0% | -0.34 (-0.52, -0.16) | 0.0% | -0.19 (-0.36, -0.01) |
| Diseases of mouth; excluding dental (CCS 137) | 0.1% | -0.19 (-0.29, -0.08) | 0.1% | -0.29 (-0.40, -0.17) |
| Esophageal disorders (CCS 138) | 0.8% | -0.02 (-0.06, 0.02) | 0.7% | 0.00 (-0.04, 0.04) |
| Gastroduodenal ulcer (except hemorrhage) (CCS 139) | 0.2% | -0.07 (-0.15, 0.01) | 0.2% | -0.01 (-0.09, 0.06) |
| Gastritis and duodenitis (CCS 140) | 0.6% | 0.04 (0.00, 0.09) | 0.5% | 0.07 (0.03, 0.12) |
| Other disorders of stomach and duodenum (CCS 141) | 0.4% | 0.20 (0.16, 0.25) | 0.4% | 0.23 (0.18, 0.27) |
| Appendicitis and other appendiceal conditions (CCS 142) | 0.1% | -0.06 (-0.22, 0.10) | 0.1% | 0.04 (-0.10, 0.18) |
| Abdominal hernia (CCS 143) | 0.6% | -0.18 (-0.23, -0.13) | 0.3% | -0.12 (-0.19, -0.06) |
| Regional enteritis and ulcerative colitis (CCS 144) | 0.3% | 0.28 (0.22, 0.34) | 0.2% | 0.32 (0.26, 0.38) |

| Variable | Dataset: MIPS HWR 2015–2016 | | Dataset: MIPS HWR 2016–2017 | |
|---|---|---|---|---|
| | % | Coefficient (95% CI) | % | Coefficient (95% CI) |
| Intestinal obstruction without hernia (CCS 145) | 2.8% | 0.03 (0.01, 0.05) | 2.5% | 0.00 (-0.02, 0.03) |
| Diverticulosis and diverticulitis (CCS 146) | 2.6% | -0.03 (-0.05, -0.01) | 2.3% | 0.00 (-0.03, 0.02) |
| Anal and rectal conditions (CCS 147) | 0.2% | 0.09 (0.01, 0.17) | 0.2% | 0.09 (0.01, 0.17) |
| Peritonitis and intestinal abscess (CCS 148) | 0.1% | 0.21 (0.13, 0.29) | 0.1% | 0.26 (0.17, 0.34) |
| Biliary tract disease (CCS 149) | 0.9% | 0.13 (0.09, 0.16) | 1.0% | 0.17 (0.13, 0.20) |
| Other liver diseases (CCS 151) | 0.8% | 0.39 (0.35, 0.42) | 0.8% | 0.40 (0.37, 0.44) |
| Pancreatic disorders (not diabetes) (CCS 152) | 1.1% | 0.02 (-0.01, 0.06) | 1.0% | 0.02 (-0.01, 0.06) |
| Gastrointestinal hemorrhage (CCS 153) | 4.3% | -0.05 (-0.07, -0.04) | 3.9% | -0.02 (-0.04, 0.00) |
| Noninfectious gastroenteritis (CCS 154) | 1.0% | -0.03 (-0.06, 0.01) | 0.9% | -0.03 (-0.06, 0.01) |
| Other gastrointestinal disorders (CCS 155) | 1.3% | 0.16 (0.14, 0.19) | 1.2% | 0.14 (0.12, 0.17) |
| Nephritis; nephrosis; renal sclerosis (CCS 156) | 0.0% | 0.51 (0.38, 0.64) | 0.0% | 0.39 (0.25, 0.53) |
| Acute and unspecified renal failure (CCS 157) | 6.6% | 0.13 (0.12, 0.15) | 6.1% | 0.12 (0.10, 0.13) |
| Chronic kidney disease (CCS 158) | 0.1% | 0.10 (0.01, 0.20) | 0.0% | 0.06 (-0.07, 0.19) |
| Urinary tract infections (CCS 159) | 7.2% | 0.03 (0.02, 0.05) | 6.6% | 0.02 (0.00, 0.03) |
| Calculus of urinary tract (CCS 160) | 0.2% | -0.17 (-0.25, -0.08) | 0.1% | -0.15 (-0.26, -0.03) |
| Other diseases of kidney and ureters (CCS 161) | 0.3% | -0.07 (-0.13, -0.01) | 0.4% | -0.01 (-0.06, 0.05) |

| Variable | Dataset: MIPS HWR 2015–2016 | | Dataset: MIPS HWR 2016–2017 | |
|---|---|---|---|---|
| | % | Coefficient (95% CI) | % | Coefficient (95% CI) |
| Other diseases of bladder and urethra (CCS 162) | 0.1% | 0.14 (0.03, 0.25) | 0.1% | 0.13 (0.01, 0.24) |
| Genitourinary symptoms and ill-defined conditions (CCS 163) | 0.3% | 0.10 (0.04, 0.16) | 0.3% | 0.09 (0.03, 0.15) |
| Hyperplasia of prostate (CCS 164) | 0.1% | 0.16 (0.06, 0.26) | 0.1% | 0.21 (0.11, 0.31) |
| Inflammatory conditions of male genital organs (CCS 165) | 0.1% | -0.21 (-0.31, -0.11) | 0.1% | -0.35 (-0.46, -0.25) |
| Skin and subcutaneous tissue infections (CCS 197) | 3.8% | -0.07 (-0.09, -0.06) | 3.3% | -0.10 (-0.12, -0.08) |
| Other inflammatory condition of skin (CCS 198) | 0.1% | 0.35 (0.23, 0.47) | 0.1% | 0.30 (0.18, 0.42) |
| Chronic ulcer of skin (CCS 199) | 0.3% | -0.04 (-0.10, 0.02) | 0.2% | -0.05 (-0.12, 0.01) |
| Septicemia (except in labor) (CCS 2) | 16.6% | 0.00 (-0.01, 0.02) | 16.6% | 0.00 (-0.01, 0.01) |
| Other skin disorders (CCS 200) | 0.0% | 0.02 (-0.15, 0.19) | 0.0% | - |
| Infective arthritis and osteomyelitis (except that caused by tuberculosis or sexually transmitted disease) (CCS 201) | 0.3% | -0.05 (-0.12, 0.01) | 0.2% | 0.04 (-0.03, 0.10) |
| Rheumatoid arthritis and related disease (CCS 202) | 0.1% | 0.01 (-0.12, 0.15) | 0.1% | -0.04 (-0.18, 0.10) |
| Osteoarthritis (CCS 203) | 0.2% | -0.24 (-0.33, -0.15) | 0.2% | -0.20 (-0.29, -0.11) |
| Other non-traumatic joint disorders (CCS 204) | 0.3% | -0.10 (-0.17, -0.03) | 0.2% | -0.11 (-0.18, -0.04) |

| Variable | Dataset: MIPS HWR 2015–2016 | | Dataset: MIPS HWR 2016–2017 | |
|---|---|---|---|---|
| | % | Coefficient (95% CI) | % | Coefficient (95% CI) |
| Spondylosis; intervertebral disc disorders; other back problems (CCS 205) | 1.3% | -0.08 (-0.11, -0.05) | 1.2% | -0.10 (-0.14, -0.07) |
| Pathological fracture (CCS 207) | 0.4% | -0.02 (-0.07, 0.04) | 0.3% | -0.07 (-0.13, -0.01) |
| Systemic lupus erythematosus and connective tissue disorders (CCS 210) | 0.15% | 0.19 (0.08, 0.30) | 0.1% | 0.27 (0.17, 0.37) |
| Other connective tissue disease (CCS 211) | 0.8% | -0.12 (-0.16, -0.08) | 0.7% | -0.15 (-0.19, -0.11) |
| Other bone disease and musculoskeletal deformities (CCS 212) | 0.1% | -0.16 (-0.28, -0.04) | 0.1% | -0.09 (-0.21, 0.02) |
| Fracture of neck of femur (hip) (CCS 226) | 0.3% | -0.28 (-0.34, -0.21) | 0.3% | -0.25 (-0.32, -0.18) |
| Skull and face fractures (CCS 228) | 0.2% | -0.19 (-0.28, -0.09) | 0.1% | -0.09 (-0.19, 0.00) |
| Fracture of upper limb (CCS 229) | 0.5% | 0.01 (-0.04, 0.06) | 0.4% | -0.02 (-0.07, 0.04) |
| Fracture of lower limb (CCS 230) | 0.4% | -0.05 (-0.11, 0.00) | 0.4% | -0.12 (-0.18, -0.06) |
| Other fractures (CCS 231) | 2.6% | -0.16 (-0.18, -0.13) | 2.4% | -0.17 (-0.20, -0.15) |
| Sprains and strains (CCS 232) | 0.1% | -0.12 (-0.23, -0.02) | 0.1% | -0.19 (-0.30, -0.07) |
| Crushing injury or internal injury (CCS 234) | 0.3% | 0.02 (-0.05, 0.08) | 0.3% | -0.12 (-0.19, -0.06) |
| Open wounds of head; neck; and trunk (CCS 235) | 0.1% | -0.17 (-0.28, -0.07) | 0.1% | -0.15 (-0.26, -0.04) |
| Open wounds of extremities (CCS 236) | 0.1% | -0.04 (-0.17, 0.08) | 0.1% | -0.03 (-0.16, 0.10) |
| Complication of device; implant or graft (CCS 237) | 3.3% | 0.13 (0.12, 0.15) | 3.1% | 0.13 (0.11, 0.15) |

| Variable | Dataset: MIPS HWR 2015–2016 | | Dataset: MIPS HWR 2016–2017 | |
|---|---|---|---|---|
| | % | Coefficient (95% CI) | % | Coefficient (95% CI) |
| Complications of surgical procedures or medical care (CCS 238) | 2.5% | 0.03 (0.01, 0.05) | 2.3% | 0.04 (0.01, 0.06) |
| Superficial injury; contusion (CCS 239) | 0.4% | -0.06 (-0.11, 0.00) | 0.4% | -0.13 (-0.19, -0.08) |
| Burns (CCS 240) | 0.0% | 0.14 (-0.03, 0.31) | 0.0% | 0.09 (-0.08, 0.27) |
| Poisoning by psychotropic agents (CCS 241) | 0.1% | -0.06 (-0.17, 0.05) | 0.1% | -0.12 (-0.23, 0.00) |
| Poisoning by other medications and drugs (CCS 242) | 0.5% | -0.04 (-0.09, 0.01) | 0.4% | -0.06 (-0.10, -0.01) |
| Poisoning by nonmedicinal substances (CCS 243) | 0.1% | -0.56 (-0.74, -0.37) | 0.1% | -0.54 (-0.72, -0.36) |
| Other injuries and conditions due to external causes (CCS 244) | 0.5% | -0.10 (-0.15, -0.05) | 0.6% | -0.12 (-0.17, -0.08) |
| Syncope (CCS 245) | 1.5% | -0.30 (-0.33, -0.27) | 1.2% | -0.28 (-0.31, -0.25) |
| Fever of unknown origin (CCS 246) | 0.3% | 0.08 (0.02, 0.14) | 0.2% | 0.03 (-0.04, 0.09) |
| Gangrene (CCS 248) | 0.1% | 0.44 (0.35, 0.53) | 0.1% | 0.47 (0.37, 0.57) |
| Shock (CCS 249) | 0.1% | 0.03 (-0.07, 0.14) | 0.1% | -0.02 (-0.14, 0.09) |
| Nausea and vomiting (CCS 250) | 0.3% | 0.19 (0.13, 0.25) | 0.2% | 0.26 (0.20, 0.32) |
| Abdominal pain (CCS 251) | 0.5% | 0.08 (0.03, 0.13) | 0.4% | 0.03 (-0.02, 0.09) |
| Malaise and fatigue (CCS 252) | 0.4% | -0.01 (-0.06, 0.04) | 0.4% | -0.04 (-0.09, 0.01) |
| Allergic reactions (CCS 253) | 0.1% | -0.05 (-0.16, 0.06) | 0.1% | -0.03 (-0.15, 0.08) |
| Other aftercare (CCS 257) | 0.1% | -0.38 (-0.53, -0.23) | 0.0% | -0.13 (-0.31, 0.04) |
| Other screening for suspected conditions (not mental disorders or infectious disease) (CCS 258) | 0.1% | 0.06 (-0.03, 0.16) | 0.1% | 0.02 (-0.08, 0.13) |

| Variable | Dataset: MIPS HWR 2015–2016 | | Dataset: MIPS HWR 2016–2017 | |
|---|---|---|---|---|
| | % | Coefficient (95% CI) | % | Coefficient (95% CI) |
| Residual codes; unclassified (CCS 259) | 0.7% | 0.00 (-0.04, 0.04) | 0.6% | -0.02 (-0.07, 0.02) |
| Adverse effects of medical drugs (CCS 2617) | 0.1% | -0.03 (-0.12, 0.06) | 0.0% | - |
| Poisoning by psychotropic agents (CCS 241) | 0.0% | - | 0.1% | 0.05 (-0.05, 0.16) |
| Bacterial infection; unspecified site (CCS 3) | 0.2% | 0.03 (-0.05, 0.11) | 0.2% | -0.04 (-0.11, 0.04) |
| Mycoses (CCS 4) | 0.2% | 0.36 (0.29, 0.43) | 0.1% | 0.35 (0.28, 0.42) |
| Other and unspecified benign neoplasm (CCS 47) | 0.2% | -0.05 (-0.13, 0.03) | 0.2% | 0.01 (-0.07, 0.09) |
| Thyroid disorders (CCS 48) | 0.1% | 0.14 (0.03, 0.24) | 0.1% | 0.19 (0.09, 0.29) |
| Diabetes mellitus with complications (CCS 50) | 2.0% | 0.06 (0.04, 0.09) | 2.0% | 0.05 (0.03, 0.08) |
| Other endocrine disorders (CCS 51) | 0.6% | 0.17 (0.13, 0.21) | 0.6% | 0.15 (0.11, 0.19) |
| Nutritional deficiencies (CCS 52) | 0.1% | 0.17 (0.07, 0.27) | 0.1% | 0.13 (0.03, 0.23) |
| Gout and other crystal arthropathies (CCS 54) | 0.2% | -0.21 (-0.28, -0.13) | 0.2% | -0.15 (-0.23, -0.08) |
| Fluid and electrolyte disorders (CCS 55) | 3.8% | 0.10 (0.08, 0.11) | 3.4% | 0.08 (0.06, 0.10) |
| Other nutritional; endocrine; and metabolic disorders (CCS 58) | 0.5% | 0.08 (0.03, 0.12) | 0.5% | 0.12 (0.07, 0.16) |
| Deficiency and other anemia (CCS 59) | 1.7% | 0.17 (0.14, 0.19) | 1.4% | 0.17 (0.14, 0.19) |
| Hepatitis (CCS 6) | 0.1% | 0.34 (0.25, 0.43) | 0.1% | 0.37 (0.27, 0.47) |
| Acute posthemorrhagic anemia (CCS 60) | 0.6% | 0.07 (0.03, 0.11) | 0.5% | 0.09 (0.05, 0.13) |
| Coagulation and hemorrhagic disorders (CCS 62) | 0.2% | 0.37 (0.31, 0.44) | 0.4% | 0.19 (0.15, 0.24) |

| Variable | Dataset: MIPS HWR 2015–2016 | | Dataset: MIPS HWR 2016–2017 | |
|---|---|---|---|---|
| | % | Coefficient (95% CI) | % | Coefficient (95% CI) |
| Diseases of white blood cells (CCS 63) | 0.4% | 0.20 (0.15, 0.25) | 0.3% | 0.25 (0.20, 0.30) |
| Delirium, dementia, and amnestic and other cognitive disorders (CCS 653) | 1.1% | -0.05 (-0.09, -0.02) | 1.0% | -0.06 (-0.10, -0.03) |
| Alcohol-related disorders (CCS 660) | 0.6% | 0.18 (0.14, 0.23) | 0.6% | 0.19 (0.15, 0.24) |
| Substance-related disorders (CCS 661) | 0.2% | 0.02 (-0.06, 0.10) | 0.1% | -0.06 (-0.16, 0.03) |
| Viral infection (CCS 7) | 0.3% | -0.01 (-0.07, 0.05) | 0.3% | -0.04 (-0.10, 0.03) |
| Meningitis (except that caused by tuberculosis or sexually transmitted disease) (CCS 76) | 0.1% | -0.03 (-0.17, 0.11) | 0.1% | -0.05 (-0.19, 0.09) |
| Encephalitis (except that caused by tuberculosis or sexually transmitted disease) (CCS 77) | 0.1% | 0.16 (0.03, 0.29) | 0.1% | 0.20 (0.08, 0.33) |
| Other infections; including parasitic (CCS 8) | 0.1% | -0.27 (-0.43, -0.11) | 0.0% | -0.62 (-0.81, -0.42) |
| Headache; including migraine (CCS 84) | 0.2% | -0.25 (-0.34, -0.16) | 0.2% | -0.31 (-0.41, -0.21) |
| Blindness and vision defects (CCS 89) | 0.0% | -0.30 (-0.47, -0.12) | 0.0% | -0.25 (-0.43, -0.06) |
| Inflammation; infection of eye (except that caused by tuberculosis or sexually transmitted disease) (CCS 90) | 0.1% | -0.08 (-0.24, 0.07) | 0.0% | -0.05 (-0.21, 0.11) |
| Other eye disorders (CCS 91) | 0.0% | -0.32 (-0.51, -0.13) | 0.0% | -0.40 (-0.62, -0.19) |
| Conditions associated with dizziness or vertigo (CCS 93) | 0.6% | -0.74 (-0.80, -0.67) | 0.5% | -0.63 (-0.69, -0.56) |
| Essential hypertension (CCS 98) | 0.6% | -0.31 (-0.37, -0.26) | 0.2% | -0.23 (-0.31, -0.16) |

| Variable | Dataset: MIPS HWR 2015–2016 | | Dataset: MIPS HWR 2016–2017 | |
|---|---|---|---|---|
| | % | Coefficient (95% CI) | % | Coefficient (95% CI) |
| Hypertension with complications and secondary hypertension (CCS 99) | 2.7% | Ref | 9.9% | Ref |
| COPD | 26.9% | 0.16 (0.15, 0.17) | 28.2% | 0.16 (0.16, 0.17) |
| Cardiorespiratory | 14.3% | 0.07 (0.06, 0.08) | 16.2% | 0.08 (0.07, 0.09) |
| Coagulopathy | 7.4% | 0.07 (0.06, 0.08) | 8.1% | 0.07 (0.06, 0.08) |
| Diabetes | 39.3% | 0.10 (0.09, 0.10) | 37.7% | 0.10 (0.09, 0.10) |
| Hematological | 1.4% | 0.30 (0.28, 0.32) | 1.4% | 0.31 (0.29, 0.33) |
| Hip fracture | 2.8% | -0.08 (-0.10, -0.06) | 2.8% | -0.08 (-0.10, -0.06) |
| Hx infection | 1.8% | 0.13 (0.11, 0.15) | 1.7% | 0.12 (0.09, 0.14) |
| Iron deficiency | 50.8% | 0.18 (0.18, 0.19) | 50.8% | 0.17 (0.17, 0.18) |
| Liver disease | 3.6% | 0.27 (0.25, 0.29) | 3.7% | 0.24 (0.23, 0.26) |
| Lung disorder | 3.4% | 0.09 (0.08, 0.11) | 3.3% | 0.09 (0.07, 0.10) |
| Malnutrition | 14.2% | 0.13 (0.12, 0.14) | 15.0% | 0.13 (0.12, 0.14) |
| Metastatic cancer | 4.3% | 0.25 (0.23, 0.26) | 4.2% | 0.24 (0.23, 0.26) |
| Metabolic disorder | 34.5% | 0.15 (0.14, 0.16) | 35.2% | 0.15 (0.15, 0.16) |
| Motor dysfunction | 6.4% | 0.09 (0.08, 0.10) | 7.2% | 0.07 (0.06, 0.08) |
| On dialysis | 3.1% | 0.25 (0.24, 0.27) | 3.3% | 0.25 (0.23, 0.26) |
| Other cancer | 9.7% | 0.07 (0.06, 0.09) | 9.4% | 0.08 (0.07, 0.09) |
| Other infectious | 30.2% | 0.10 (0.09, 0.11) | 31.2% | 0.10 (0.09, 0.11) |
| Pancreatic disease | 11.9% | 0.14 (0.13, 0.15) | 11.9% | 0.11 (0.10, 0.12) |
| Psychological | 31.7% | 0.06 (0.06, 0.07) | 31.9% | 0.06 (0.05, 0.07) |
| Renal failure | 41.2% | 0.19 (0.18, 0.20) | 44.0% | 0.20 (0.19, 0.21) |
| Respirator dependence | 0.6% | 0.17 (0.13, 0.20) | 0.5% | 0.13 (0.10, 0.17) |
| Seizure | 5.3% | 0.10 (0.09, 0.11) | 5.2% | 0.08 (0.06, 0.09) |
| Septicemia | 12.1% | 0.02 (0.01, 0.03) | 12.3% | 0.03 (0.02, 0.04) |
| Severe cancer | 6.6% | 0.23 (0.22, 0.25) | 6.6% | 0.22 (0.21, 0.23) |
| Transplants | 1.1% | 0.19 (0.16, 0.22) | 1.2% | 0.19 (0.16, 0.21) |
| Ulcers | 7.8% | 0.12 (0.11, 0.13) | 7.6% | 0.11 (0.10, 0.13) |

**Table F4. Neurology: prevalence and model coefficients, development and, validation cohorts**

| Variable | Dataset: MIPS HWR 2015–2016 | | Dataset: MIPS HWR 2016–2017 | |
|---|---|---|---|---|
| | % | Coefficient (95% CI) | % | Coefficient (95% CI) |
| Age (years over 65) | 14.4% | 0.00 (0.00, 0.00) | 14.3% | 0.00 (0.00, 0.00) |
| Alcohol | 3.9% | 0.08 (0.03, 0.12) | 3.8% | 0.06 (0.01, 0.10) |
| Arrhythmias | 19.6% | 0.10 (0.08, 0.13) | 19.2% | 0.09 (0.07, 0.12) |
| Arthritis | 4.7% | 0.07 (0.03, 0.11) | 4.7% | 0.10 (0.05, 0.14) |
| CAD/CVD | 56.3% | 0.12 (0.10, 0.14) | 55.9% | 0.13 (0.11, 0.15) |
| Congestive Heart Failure | 14.6% | 0.14 (0.11, 0.17) | 14.6% | 0.12 (0.09, 0.15) |
| Low Frequency Conditions | 0.4% | 0.11 (-0.03, 0.25) | 0.5% | 0.23 (0.12, 0.35) |
| Acute cerebrovascular disease (CCS 109) | 46.1% | -0.03 (-0.06, 0.00) | 46.9% | -0.06 (-0.09, -0.03) |
| Occlusion or stenosis of precerebral arteries (CCS 110) | 0.9% | -0.21 (-0.31, -0.11) | 0.8% | -0.16 (-0.27, -0.06) |
| Other and ill-defined cerebrovascular disease (CCS 111) | 0.6% | -0.16 (-0.29, -0.04) | 0.5% | -0.10 (-0.23, 0.03) |
| Transient cerebral ischemia (CCS 112) | 11.7% | -0.28 (-0.32, -0.24) | 10.6% | -0.28 (-0.32, -0.24) |
| Late effects of cerebrovascular disease (CCS 113) | 1.4% | -0.12 (-0.19, -0.04) | 1.3% | -0.13 (-0.21, -0.05) |
| Intracranial injury (CCS 233) | 10.6% | 0.24 (0.20, 0.27) | 10.9% | 0.22 (0.18, 0.26) |
| Parkinson`s disease (CCS 79) | 1.4% | 0.03 (-0.05, 0.11) | 1.6% | -0.01 (-0.09, 0.06) |
| Multiple sclerosis (CCS 80) | 0.3% | 0.13 (-0.03, 0.29) | 0.3% | 0.27 (0.12, 0.42) |
| Other hereditary and degenerative nervous system conditions (CCS 81) | 1.4% | 0.09 (0.02, 0.17) | 1.2% | 0.00 (-0.09, 0.08) |
| Paralysis (CCS 82) | 0.3% | -0.10 (-0.27, 0.06) | 0.3% | -0.06 (-0.22, 0.10) |
| Epilepsy; convulsions (CCS 83) | 8.2% | -0.04 (-0.08, 0.00) | 8.4% | -0.04 (-0.08, 0.00) |
| Coma; stupor; and brain damage (CCS 85) | 0.35 | 0.24 (0.10, 0.38) | 0.0% | 0.00 (0.00, 0.00) |

| Variable | Dataset: MIPS HWR 2015–2016 | | Dataset: MIPS HWR 2016–2017 | |
|---|---|---|---|---|
| | % | Coefficient (95% CI) | % | Coefficient (95% CI) |
| Other nervous system disorders (CCS 95) | 16.5% | Ref | 16.7% | Ref |
| COPD | 18.2% | 0.16 (0.14, 0.18) | 18.1% | 0.16 (0.13, 0.18) |
| Cardiorespiratory | 8.4% | 0.04 (0.01, 0.07) | 8.8% | 0.08 (0.04, 0.11) |
| Coagulopathy | 4.5% | 0.01 (-0.03, 0.05) | 4.8% | 0.06 (0.02, 0.10) |
| Diabetes | 36.4% | 0.14 (0.12, 0.16) | 34.6% | 0.16 (0.14, 0.18) |
| Hematological | 0.7% | 0.23 (0.13, 0.32) | 0.6% | 0.26 (0.16, 0.36) |
| Hip fracture | 2.2% | -0.14 (-0.20, -0.08) | 2.2% | -0.20 (-0.26, -0.14) |
| History of infection | 1.2% | 0.19 (0.12, 0.26) | 1.2% | 0.11 (0.03, 0.18) |
| Iron deficiency | 31.5% | 0.21 (0.19, 0.23) | 31.4% | 0.19 (0.17, 0.22) |
| Liver disease | 1.4% | 0.22 (0.15, 0.29) | 1.4% | 0.31 (0.25, 0.38) |
| Lung disorder | 1.8% | 0.09 (0.03, 0.15) | 1.7% | 0.07 (0.00, 0.13) |
| Malnutrition | 8.2% | 0.12 (0.09, 0.15) | 9.1% | 0.11 (0.08, 0.14) |
| Metastatic cancer | 3.1% | 0.23 (0.18, 0.28) | 3.3% | 0.29 (0.24, 0.34) |
| Metabolic disorder | 24.0% | 0.12 (0.09, 0.14) | 24.1% | 0.11 (0.08, 0.13) |
| Motor dysfunction | 7.7% | 0.08 (0.05, 0.11) | 9.2% | 0.08 (0.05, 0.11) |
| On dialysis | 1.9% | 0.33 (0.27, 0.38) | 2.0% | 0.36 (0.30, 0.41) |
| Other cancer | 6.3% | 0.10 (0.06, 0.13) | 6.4% | 0.08 (0.05, 0.12) |
| Other infectious | 16.8% | 0.12 (0.09, 0.14) | 16.8% | 0.11 (0.09, 0.14) |
| Pancreatic disease | 5.9% | 0.06 (0.02, 0.09) | 5.8% | 0.04 (0.00, 0.07) |
| Psychological | 29.4% | 0.04 (0.02, 0.06) | 29.7% | 0.01 (-0.02, 0.03) |
| Renal failure | 28.1% | 0.19 (0.17, 0.22) | 29.2% | 0.21 (0.19, 0.23) |
| Respirator dependence | 0.2% | 0.05 (-0.11, 0.21) | 0.2% | -0.04 (-0.21, 0.12) |
| Seizure | 10.5% | 0.15 (0.12, 0.18) | 10.8% | 0.14 (0.11, 0.17) |
| Septicemia | 5.7% | -0.02 (-0.06, 0.02) | 5.9% | 0.00 (-0.04, 0.04) |
| Severe cancer | 4.3% | 0.28 (0.23, 0.32) | 4.4% | 0.23 (0.19, 0.28) |
| Transplants | 0.5% | 0.25 (0.14, 0.35) | 0.6% | 0.16 (0.06, 0.26) |
| Ulcers | 3.2% | 0.13 (0.08, 0.17) | 3.2% | 0.14 (0.09,0.19) |

**Table F5. Surgery/gynecology cohort: prevalence and model coefficients, development, and validation cohorts**

| Variable | Dataset: MIPS HWR 2015–2016 | | Dataset: MIPS HWR 2016–2017 | |
|---|---|---|---|---|
| | % | Coefficient (95% CI) | % | Coefficient (95% CI) |
| Age (years over 65) | 10.9% | 0.01 (0.01, 0.01) | 10.8% | 0.01 (0.01, 0.01) |
| Alcohol | 2.6% | 0.11 (0.08, 0.14) | 2.5% | 0.11 (0.08, 0.13) |
| Arrhythmias | 13.7% | 0.08 (0.07, 0.09) | 13.5% | 0.07 (0.06, 0.09) |
| Arthritis | 5.3% | 0.12 (0.10, 0.14) | 5.5% | 0.13 (0.11, 0.15) |
| CAD/CVD | 37.8% | 0.17 (0.16, 0.18) | 37.5% | 0.19 (0.18, 0.20) |
| Congestive Heart Failure | 10.7% | 0.12 (0.11, 0.14) | 10.9% | 0.13 (0.12, 0.15) |
| Low Frequency Conditions | 1.9% | 0.13 (0.10, 0.16) | 2.0% | 0.12 (0.08, 0.15) |
| Acute myocardial infarction (CCS 100) | 1.4% | 0.19 (0.15, 0.22) | 1.1% | 0.16 (0.12, 0.20) |
| Coronary atherosclerosis and other heart disease (CCS 101) | 2.3% | -0.01 (-0.04, 0.02) | 2.2% | -0.03 (-0.06, 0.01) |
| Cardiac dysrhythmias (CCS 106) | 1.0% | 0.10 (0.06, 0.15) | 1.0% | 0.05 (0.00, 0.09) |
| Congestive heart failure; nonhypertensive (CCS 108) | 0.4% | 0.35 (0.29, 0.40) | 0.2% | 0.30 (0.22, 0.38) |
| Acute cerebrovascular disease (CCS 109) | 1.0% | 0.25 (0.21, 0.29) | 1.1% | 0.19 (0.15, 0.23) |
| Cancer of head and neck (CCS 11) | 0.3% | -0.08 (-0.17, 0.01) | 0.3% | -0.07 (-0.16, 0.02) |
| Occlusion or stenosis of precerebral arteries (CCS 110) | 2.2% | -0.61 (-0.66, -0.57) | 2.2% | -0.61 (-0.65, -0.56) |
| Other and ill-defined cerebrovascular disease (CCS 111) | 0.1% | -0.19 (-0.32, -0.05) | 0.2% | -0.34 (-0.48, -0.20) |
| Peripheral and visceral atherosclerosis (CCS 114) | 1.2% | 0.28 (0.24, 0.31) | 1.1% | 0.20 (0.16, 0.24) |
| Aortic; peripheral; and visceral artery aneurysms (CCS 115) | 0.6% | 0.10 (0.04, 0.16) | 0.4% | 0.29 (0.22, 0.35) |

| Variable | Dataset: MIPS HWR 2015–2016 | | Dataset: MIPS HWR 2016–2017 | |
|---|---|---|---|---|
| | % | Coefficient (95% CI) | % | Coefficient (95% CI) |
| Aortic and peripheral arterial embolism or thrombosis (CCS 116) | 0.3% | 0.40 (0.32, 0.48) | 0.2% | 0.44 (0.36, 0.52) |
| Other circulatory disease (CCS 117) | 0.1% | 0.22 (0.09, 0.34) | 0.1% | 0.33 (0.21, 0.44) |
| Phlebitis; thrombophlebitis and thromboembolism (CCS 118) | 0.1% | 0.23 (0.10, 0.36) | 0.1% | 0.08 (-0.04, 0.21) |
| Cancer of esophagus (CCS 12) | 0.1% | 0.51 (0.36, 0.65) | 0.1% | 0.57 (0.43, 0.70) |
| Pneumonia (except that caused by tuberculosis or sexually transmitted disease) (CCS 122) | 0.2% | 0.23 (0.15, 0.31) | 0.2% | 0.22 (0.14, 0.31) |
| Chronic obstructive pulmonary disease and bronchiectasis (CCS 127) | 0.1% | 0.44 (0.34, 0.54) | 0.2% | 0.33 (0.24, 0.41) |
| Aspiration pneumonitis; food/vomitus (CCS 129) | 0.1% | 0.25 (0.14, 0.36) | 0.1% | 0.30 (0.19, 0.41) |
| Cancer of stomach (CCS 13) | 0.2% | 0.27 (0.17, 0.37) | 0.2% | 0.17 (0.07, 0.28) |
| Pleurisy; pneumothorax; pulmonary collapse (CCS 130) | 0.2% | 0.05 (-0.04, 0.13) | 0.2% | 0.10 (0.01, 0.18) |
| Respiratory failure; insufficiency; arrest (adult) (CCS 131) | 0.2% | 0.26 (0.18, 0.34) | 0.2% | 0.17 (0.10, 0.25) |
| Other lower respiratory disease (CCS 133) | 0.2% | -0.02 (-0.14, 0.10) | 0.2% | -0.03 (-0.14, 0.08) |
| Other upper respiratory disease (CCS 134) | 0.1% | -0.04 (-0.16, 0.09) | 0.1% | 0.12 (0.00, 0.23) |
| Esophageal disorders (CCS 138) | 0.2% | -0.04 (-0.14, 0.06) | 0.2% | -0.02 (-0.13, 0.08) |

| Variable | Dataset: MIPS HWR 2015–2016 | | Dataset: MIPS HWR 2016–2017 | |
|---|---|---|---|---|
| | % | Coefficient (95% CI) | % | Coefficient (95% CI) |
| Gastroduodenal ulcer (except hemorrhage) (CCS 139) | 0.2% | 0.26 (0.16, 0.37) | 0.2% | 0.24 (0.13, 0.35) |
| Cancer of colon (CCS 14) | 1.4% | -0.07 (-0.11, -0.04) | 1.4% | -0.10 (-0.14, -0.06) |
| Other disorders of stomach and duodenum (CCS 141) | 0.2% | 0.27 (0.18, 0.35) | 0.2% | 0.23 (0.13, 0.32) |
| Appendicitis and other appendiceal conditions (CCS 142) | 0.6% | -0.28 (-0.36, -0.21) | 0.5% | -0.22 (-0.29, -0.14) |
| Abdominal hernia (CCS 143) | 1.8% | -0.04 (-0.07, 0.00) | 2.2% | -0.13 (-0.17, -0.10) |
| Regional enteritis and ulcerative colitis (CCS 144) | 0.1% | 0.59 (0.45, 0.73) | 0.1% | 0.53 (0.39, 0.67) |
| Intestinal obstruction without hernia (CCS 145) | 1.3% | 0.15 (0.12, 0.19) | 1.3% | 0.10 (0.06, 0.14) |
| Diverticulosis and diverticulitis (CCS 146) | 0.9% | 0.12 (0.07, 0.17) | 0.9% | 0.05 (0.00, 0.10) |
| Anal and rectal conditions (CCS 147) | 0.3% | -0.08 (-0.16, 0.01) | 0.3% | -0.13 (-0.22, -0.04) |
| Biliary tract disease (CCS 149) | 2.8% | -0.11 (-0.14, -0.07) | 2.4% | -0.17 (-0.20, -0.13) |
| Cancer of rectum and anus (CCS 15) | 0.4% | 0.40 (0.33, 0.46) | 0.4% | 0.42 (0.36, 0.49) |
| Other liver diseases (CCS 151) | 0.1% | 0.44 (0.31, 0.57) | 0.1% | 0.54 (0.43, 0.66) |
| Pancreatic disorders (not diabetes) (CCS 152) | 0.4% | 0.06 (-0.01, 0.13) | 0.4% | 0.03 (-0.05, 0.11) |
| Gastrointestinal hemorrhage (CCS 153) | 0.5% | 0.17 (0.12, 0.23) | 0.4% | 0.13 (0.07, 0.19) |
| Other gastrointestinal disorders (CCS 155) | 0.8% | 0.11 (0.06, 0.15) | 0.8% | 0.02 (-0.03, 0.07) |
| Acute and unspecified renal failure (CCS 157) | 0.4% | 0.35 (0.29, 0.41) | 0.4% | 0.32 (0.27, 0.38) |
| Urinary tract infections (CCS 159) | 0.4% | 0.29 (0.23, 0.35) | 0.4% | 0.30 (0.24, 0.37) |

| Variable | Dataset: MIPS HWR 2015–2016 | | Dataset: MIPS HWR 2016–2017 | |
|---|---|---|---|---|
| | % | Coefficient (95% CI) | % | Coefficient (95% CI) |
| Cancer of liver and intrahepatic bile duct (CCS 16) | 0.1% | 0.34 (0.21, 0.47) | 0.1% | 0.41 (0.28, 0.54) |
| Calculus of urinary tract (CCS 160) | 0.4% | -0.09 (-0.18, -0.01) | 0.2% | -0.16 (-0.26, -0.05) |
| Other diseases of kidney and ureters (CCS 161) | 0.4% | -0.08 (-0.15, -0.01) | 0.5% | -0.11 (-0.18, -0.04) |
| Other diseases of bladder and urethra (CCS 162) | 0.2% | 0.08 (-0.02, 0.18) | 0.2% | 0.15 (0.04, 0.25) |
| Genitourinary symptoms and ill-defined conditions (CCS 163) | 0.2% | 0.11 (0.01, 0.21) | 0.1% | 0.08 (-0.03, 0.20) |
| Hyperplasia of prostate (CCS 164) | 0.5% | -0.26 (-0.33, -0.19) | 0.4% | -0.23 (-0.31, -0.16) |
| Cancer of pancreas (CCS 17) | 0.2% | 0.50 (0.42, 0.58) | 0.2% | 0.49 (0.41, 0.57) |
| Prolapse of female genital organs (CCS 170) | 0.3% | -0.74 (-0.87, -0.62) | 0.2% | -0.80 (-0.95, -0.64) |
| Other female genital disorders (CCS 175) | 0.1% | -0.02 (-0.16, 0.11) | 0.1% | 0.01 (-0.14, 0.15) |
| Cancer of other GI organs; peritoneum (CCS 18) | 0.2% | 0.29 (0.20, 0.38) | 0.2% | 0.24 (0.14, 0.34) |
| Cancer of bronchus; lung (CCS 19) | 1.0% | -0.09 (-0.14, -0.05) | 1.0% | -0.10 (-0.15, -0.06) |
| Skin and subcutaneous tissue infections (CCS 197) | 0.4% | -0.11 (-0.18, -0.04) | 0.5% | -0.09 (-0.15, -0.02) |
| Chronic ulcer of skin (CCS 199) | 0.3% | -0.01 (-0.08, 0.06) | 0.3% | 0.01 (-0.06, 0.08) |
| Septicemia (except in labor) (CCS 2) | 3.0% | 0.26 (0.23, 0.28) | 3.1% | 0.23 (0.20, 0.25) |

| Variable | Dataset: MIPS HWR 2015–2016 | | Dataset: MIPS HWR 2016–2017 | |
|---|---|---|---|---|
| | % | Coefficient (95% CI) | % | Coefficient (95% CI) |
| Infective arthritis and osteomyelitis (except that caused by tuberculosis or sexually transmitted disease) (CCS 201) | 0.6% | -0.08 (-0.14, -0.03) | 0.6% | -0.11 (-0.17, -0.05) |
| Rheumatoid arthritis and related disease (CCS 202) | 0.1% | -0.73 (-0.98, -0.48) | 0.1% | -0.74 (-1.00, -0.48) |
| Osteoarthritis (CCS 203) | 22.5% | -0.95 (-0.97, -0.93) | 23.8% | -0.98 (-1.00, -0.96) |
| Other non-traumatic joint disorders (CCS 204) | 0.3% | -0.87 (-1.00, -0.74) | 0.2% | -0.85 (-1.00, -0.71) |
| Spondylosis; intervertebral disc disorders; other back problems (CCS 205) | 5.6% | -0.38 (-0.40, -0.35) | 5.1% | -0.40 (-0.43, -0.37) |
| Pathological fracture (CCS 207) | 0.9% | -0.04 (-0.09, 0.00) | 1.0% | -0.05 (-0.09, 0.00) |
| Other acquired deformities (CCS 209) | 1.2% | -0.45 (-0.51, -0.40) | 1.3% | -0.44 (-0.50, -0.39) |
| Cancer of bone and connective tissue (CCS 21) | 0.1% | 0.11 (-0.03, 0.25) | 0.1% | 0.18 (0.03, 0.32) |
| Other connective tissue disease (CCS 211) | 0.5% | -0.53 (-0.61, -0.45) | 0.6% | -0.61 (-0.70, -0.53) |
| Other bone disease and musculoskeletal deformities (CCS 212) | 0.3% | -0.38 (-0.48, -0.29) | 0.2% | -0.51 (-0.62, -0.39) |
| Cardiac and circulatory congenital anomalies (CCS 213) | 0.1% | -0.05 (-0.20, 0.09) | 0.1% | -0.07 (-0.21, 0.07) |
| Other congenital anomalies (CCS 217) | 0.1% | -0.41 (-0.64, -0.18) | 0.0% | |
| Joint disorders and dislocations; trauma-related (CCS 225) | 0.2% | -0.15 (-0.27, -0.03) | 0.1% | -0.16 (-0.29, -0.03) |
| Fracture of neck of femur (hip) (CCS 226) | 9.0% | -0.17 (-0.19, -0.15) | 8.9% | -0.20 (-0.22, -0.18) |

| Variable | Dataset: MIPS HWR 2015–2016 | | Dataset: MIPS HWR 2016–2017 | |
|---|---|---|---|---|
| | % | Coefficient (95% CI) | % | Coefficient (95% CI) |
| Skull and face fractures (CCS 228) | 0.1% | -0.23 (-0.41, -0.05) | 0.1% | -0.27 (-0.45, -0.09) |
| Fracture of upper limb (CCS 229) | 1.3% | -0.35 (-0.40, -0.30) | 1.2% | -0.41 (-0.46, -0.36) |
| Other non-epithelial cancer of skin (CCS 23) | 0.1% | -0.31 (-0.48, -0.14) | 0.1% | -0.29 (-0.47, -0.11) |
| Fracture of lower limb (CCS 230) | 2.0% | -0.11 (-0.15, -0.08) | 2.1% | -0.15 (-0.19, -0.12) |
| Other fractures (CCS 231) | 0.9% | 0.04 (-0.01, 0.08) | 1.0% | 0.07 (0.02, 0.11) |
| Sprains and strains (CCS 232) | 0.1% | -0.43 (-0.59, -0.27) | 0.1% | -0.58 (-0.77, -0.39) |
| Intracranial injury (CCS 233) | 0.5% | 0.35 (0.29, 0.41) | 0.5% | 0.25 (0.20, 0.31) |
| Crushing injury or internal injury (CCS 234) | 0.1% | 0.06 (-0.08, 0.20) | 0.1% | 0.23 (0.10, 0.36) |
| Open wounds of head; neck; and trunk (CCS 235) | 0.0% | - | 0.1% | -0.34 (-0.55, -0.13) |
| Open wounds of extremities (CCS 236) | 0.1% | -0.19 (-0.33, -0.05) | 0.1% | -0.06 (-0.19, 0.07) |
| Complication of device; implant or graft (CCS 237) | 4.9% | -0.01 (-0.03, 0.01) | 4.7% | 0.00 (-0.02, 0.02) |
| Complications of surgical procedures or medical care (CCS 238) | 2.0% | 0.14 (0.11, 0.17) | 2.4% | 0.08 (0.05, 0.11) |
| Cancer of breast (CCS 24) | 0.3% | -0.50 (-0.60, -0.40) | 0.3% | -0.44 (-0.55, -0.32) |
| Burns (CCS 240) | 0.1% | 0.24 (0.07, 0.41) | 0.1% | 0.22 (0.05, 0.39) |
| Other injuries and conditions due to external causes (CCS 244) | 0.1% | 0.01 (-0.16, 0.18) | 0.1% | 0.06 (-0.10, 0.23) |
| Gangrene (CCS 248) | 0.5% | 0.44 (0.39, 0.49) | 0.4% | 0.43 (0.37, 0.49) |
| Cancer of uterus (CCS 25) | 0.3% | -0.07 (-0.16, 0.03) | 0.3% | -0.16 (-0.26, -0.06) |

| Variable | Dataset: MIPS HWR 2015–2016 | | Dataset: MIPS HWR 2016–2017 | |
|---|---|---|---|---|
| | % | Coefficient (95% CI) | % | Coefficient (95% CI) |
| Other aftercare (CCS 257) | 0.1% | -0.42 (-0.57, -0.28) | 0.1% | -0.35 (-0.48, -0.23) |
| Cancer of ovary (CCS 27) | 0.2% | 0.03 (-0.08, 0.13) | 0.2% | -0.11 (-0.22,0.00) |
| Cancer of other female genital organs (CCS 28) | 0.1% | -0.11 (-0.28, 0.06) | 0.1% | 0.24 (0.08,0.39) |
| Cancer of prostate (CCS 29) | 0.8% | -0.58 (-0.65, -0.50) | 0.9% | -0.59 (-0.66,-0.52) |
| Cancer of bladder (CCS 32) | 0.5% | 0.51 (0.46, 0.56) | 0.5% | 0.52 (0.46,0.57) |
| Cancer of kidney and renal pelvis (CCS 33) | 0.6% | -0.21 (-0.28, -0.15) | 0.6% | -0.28 (-0.35,-0.21) |
| Cancer of other urinary organs (CCS 34) | 0.1% | 0.00 (-0.15, 0.16) | 0.1% | 0.01 (-0.15,0.16) |
| Cancer of brain and nervous system (CCS 35) | 0.2% | 0.54 (0.44, 0.64) | 0.2% | 0.39 (0.29,0.50) |
| Cancer of thyroid (CCS 36) | 0.1% | -0.35 (-0.56, -0.13) | 0.2% | 0.87 (0.78,0.95) |
| Non-Hodgkin`s lymphoma (CCS 38) | 0.2% | 0.75 (0.66, 0.84) | 0.8% | 0.23 (0.18,0.28) |
| Secondary malignancies (CCS 42) | 0.8% | 0.19 (0.14, 0.24) | 0.1% | 0.30 (0.13,0.47) |
| Neoplasms of unspecified nature or uncertain behavior (CCS 44) | 0.2% | -0.04 (-0.14, 0.07) | 0.2% | -0.01 (-0.12,0.10) |
| Other and unspecified benign neoplasm (CCS 47) | 1.0% | -0.11 (-0.16, -0.06) | 1.0% | -0.10 (-0.15,-0.05) |
| Thyroid disorders (CCS 48) | 0.1% | -0.64 (-0.88, -0.41) | 0.0% | - |
| Diabetes mellitus with complications (CCS 50) | 1.1% | 0.15 (0.11, 0.19) | 1.6% | 0.15 (0.11,0.18) |
| Other endocrine disorders (CCS 51) | 0.1% | 0.14 (-0.03, 0.32) | 0.0% | 0.00 (0.00,0.00) |
| Fluid and electrolyte disorders (CCS 55) | 0.1% | 0.34 (0.22, 0.45) | 0.1% | 0.24 (0.13,0.36) |

| Variable | Dataset: MIPS HWR 2015–2016 | | Dataset: MIPS HWR 2016–2017 | |
|---|---|---|---|---|
| | % | Coefficient (95% CI) | % | Coefficient (95% CI) |
| Other nutritional; endocrine; and metabolic disorders (CCS 58) | 0.3% | -0.39 (-0.49, -0.29) | 0.3% | -0.49 (-0.60,-0.39) |
| Parkinson`s disease (CCS 79) | 0.1% | -0.44 (-0.66, -0.22) | 0.1% | -0.62 (-0.86, -0.38) |
| Other hereditary and degenerative nervous system conditions (CCS 81) | 0.1% | -0.02 (-0.17, 0.12) | 0.0% | - |
| Other nervous system disorders (CCS 95) | 0.4% | 0.05 (-0.02, 0.13) | 0.5% | 0.11 (0.04, 0.17) |
| Heart valve disorders (CCS 96) | 2.9% | 0.00 (-0.03, 0.02) | 3.2% | -0.05 (-0.08, -0.02) |
| Peri-; endo-; and myocarditis; cardiomyopathy (except that caused by tuberculosis or sexually transmitted disease) (CCS 97) | 0.2% | 0.28 (0.19, 0.37) | 0.2% | 0.27 (0.18, 0.36) |
| Hypertension with complications and secondary hypertension (CCS 99) | 0.3% | Ref | 0.6% | Ref |
| COPD | 18.1% | 0.23 (0.22, 0.24) | 17.9% | 0.23 (0.22, 0.24) |
| Cardiorespiratory | 6.6% | 0.02 (0.00, 0.04) | 7.0% | 0.02 (0.00, 0.04) |
| Coagulopathy | 3.5% | 0.03 (0.01, 0.06) | 3.7% | 0.00 (-0.02, 0.03) |
| Diabetes | 30.3% | 0.15 (0.14, 0.16) | 28.9% | 0.16 (0.15, 0.17) |
| Hematological | 0.6% | 0.28 (0.23, 0.33) | 0.5% | 0.32 (0.27, 0.37) |
| Hip fracture | 2.1% | -0.04 (-0.07, -0.01) | 2.1% | -0.06 (-0.09, -0.03) |
| H infection | 1.0% | 0.11 (0.07, 0.15) | 1.0% | 0.18 (0.14, 0.21) |
| Iron deficiency | 44.6% | 0.23 (0.22, 0.24) | 43.9% | 0.24 (0.23, 0.25) |
| Liver disease | 1.4% | 0.29 (0.26, 0.33) | 1.4% | 0.29 (0.25, 0.32) |
| Lung disorder | 1.8% | 0.12 (0.09, 0.16) | 1.6% | 0.12 (0.09, 0.15) |
| Malnutrition | 7.7% | 0.19 (0.17, 0.20) | 8.2% | 0.19 (0.18, 0.21) |
| Metastatic cancer | 3.4% | 0.27 (0.25, 0.30) | 3.2% | 0.26 (0.24, 0.29) |
| Metabolic disorder | 17.3% | 0.08 (0.06, 0.09) | 17.5% | 0.09 (0.08, 0.11) |

| Variable | Dataset: MIPS HWR 2015–2016 | | Dataset: MIPS HWR 2016–2017 | |
|---|---|---|---|---|
| | % | Coefficient (95% CI) | % | Coefficient (95% CI) |
| Motor dysfunction | 3.9% | 0.08 (0.06, 0.10) | 4.5% | 0.08 (0.05, 0.10) |
| On dialysis | 1.4% | 0.31 (0.28, 0.34) | 1.7% | 0.30 (0.27, 0.33) |
| Other cancer | 6.4% | 0.06 (0.04, 0.07) | 6.2% | 0.06 (0.04, 0.08) |
| Other infectious | 13.0% | 0.12 (0.11, 0.14) | 13.0% | 0.10 (0.09, 0.12) |
| Pancreatic disease | 5.8% | 0.05 (0.03, 0.07) | 6.0% | 0.04 (0.02, 0.05) |
| Psychological | 23.6% | 0.10 (0.09, 0.11) | 24.4% | 0.10 (0.09, 0.11) |
| Renal failure | 22.9% | 0.24 (0.22, 0.25) | 23.9% | 0.24 (0.23, 0.25) |
| Respirator dependence | 0.2% | 0.05 (-0.03, 0.12) | 0.2% | 0.00 (-0.07, 0.08) |
| Seizure | 2.7% | 0.13 (0.10, 0.15) | 2.7% | 0.13 (0.10, 0.15) |
| Septicemia | 5.2% | -0.05 (-0.07, -0.03) | 5.3% | -0.06 (-0.08, -0.04) |
| Severe cancer | 3.9% | 0.19 (0.17, 0.22) | 3.8% | 0.18 (0.16, 0.21) |
| Transplants | 0.6% | 0.33 (0.28, 0.38) | 0.6% | 0.30 (0.25 ,0.35) |
| Ulcers | 4.9% | 0.05 (0.02, 0.07) | 5.2% | 0.06 (0.04, 0.08) |