

## **Appendix to NQF Submission**

### **Measure Title:**

Risk-Standardized Acute Admission Rate for Patients with Heart Failure

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Yale New Haven Health Services Corporation – Center for Outcomes Research and Evaluation (CORE)

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# **Risk-Standardized Acute Admission Rates for Older Patients with Diabetes and Heart Failure**

## **Measure Technical Report**

### **Submitted by:**

Yale New Haven Health Services Corporation – Center for Outcomes Research and  
Evaluation (CORE)

### **Prepared for:**

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# 1. Executive Summary

The Yale New Haven Health Services Corporation – Center for Outcomes Research and Evaluation (CORE) developed two measures for the Centers for Medicare & Medicaid Services (CMS) under a contract supporting the development of ambulatory care measures. This report presents the development, testing, and final specifications of these two measures: (1) risk-standardized acute admission rates (RSAARs) for patients with diabetes mellitus and (2) RSAARs for patients with heart failure. These measures assess hospital admission rates for acute illness as an indicator of the quality of ambulatory care delivered jointly by groups of providers who share responsibility for patients' care and outcomes. They were designed for use in Accountable Care Organizations (ACOs), but we expect the measures could be adapted for use in other provider groups, such as health plans or state-based programs, who also jointly manage care for defined patient populations.

## 1.1. Rationale for Developing Measures of Acute Admission Rates

Diabetes and heart failure are complex, high-prevalence chronic diseases that increase the risk for hospital admission. Provision of coordinated care that is focused on improving health for the whole patient, across all stages of disease, and in the context of coexisting comorbidities and life circumstances should lower the risk of hospitalization. In order to: (1) illuminate variation in hospital admission rates and (2) incentivize ACOs to develop efficient and coordinated chronic disease management strategies that anticipate and respond to patients' needs and preferences, we developed two measures assessing RSAARs. These measures use hospitalizations for acute illness as the outcome because acute admissions are often sentinel events associated with high morbidity as well as physical and emotional stress; they also result in high costs for both the patient and the ACO. Research shows that effective health care can lower the risk of admission for these vulnerable groups of patients. These measures are consistent with ACOs' commitment to deliver patient-centered care that fulfills the goals of the United States (U.S.) Department of Health and Human Services National Quality Strategy Triple Aim: (1) improving population health, (2) improving care, and (3) lowering care costs.<sup>1</sup>

## 1.2. Measure Development

To develop these measures, we assembled a multidisciplinary team of clinicians, health services researchers, and biostatisticians. Through a public process, we convened a national technical expert panel (TEP) comprised of patients, health industry representatives, researchers, and healthcare providers with expertise in diabetes, heart failure, and geriatrics. We also held a public comment period soliciting stakeholder input on the measure methodology, and refined the measure in response to comments.

CORE used Medicare claims data from 6.5 million Medicare fee-for-service (FFS) beneficiaries with diabetes and 2.6 million Medicare FFS beneficiaries with heart failure to evaluate the performance of 114 ACOs participating in the Medicare Shared Savings Program (MSSP) in 2012. We compared RSAARs among patients with diabetes and heart failure assigned to MSSP ACOs and benchmarked them against national rates of admissions among patients with these conditions. This report presents the final measure specifications, methodology, and testing results.

### **1.3. Measure Specifications**

In brief, the measures include Medicare FFS beneficiaries aged  $\geq 65$  years who meet criteria for the diagnosis of diabetes and heart failure. The measures require that Medicare FFS beneficiaries have continuous Medicare Part A and B coverage in the year prior to the measurement period, but use up to two years of data to define the diagnosis of diabetes and heart failure.

- The diabetes measure includes all patients with type 1 or type 2 diabetes based on at least one inpatient claim *or* two outpatient claims for diabetes (in any position) within the two years prior to the measurement year.
- The heart failure measure includes patients with at least one inpatient principal diagnosis for heart failure *or* at least two outpatient or inpatient heart failure diagnoses in any position within the two years prior to the measurement year. Patients with left ventricular assist devices are excluded.

The outcome for both measures is the number of acute, unplanned admissions per 100 person-years at risk for hospitalization. Admissions are defined as any inpatient admission to an acute care hospital for any cause during the measurement year, unless an admission is identified as “planned.” Persons are considered at risk for admission if they are alive, enrolled in FFS Medicare, and not currently admitted.

To calculate ACO-specific RSAARs, the measures use hierarchical negative binomial models. The first level of the model adjusts for patients’ clinical risk factors. The second level of the model estimates the random-intercept term that reflects ACOs’ contribution to admission risk. This strategy accounts for within-ACO correlation of the observed outcome and it operates on the assumption that underlying differences in quality across ACOs lead to systematic differences in outcomes. For fairness, the models adjust for clinical comorbidities and disease severity that vary across patient populations, are unrelated to quality, and influence the outcome to help ensure that differences in the measure scores do not reflect differences in case mix across

ACOs. Notably, the models benchmark ACO RSAARs against national admission rates among all ACO and non-ACO patients with diabetes or heart failure.

#### **1.4. Measure Testing and Results**

We tested the measures against the National Quality Forum's (NQF's) criteria for scientific soundness and importance, including testing the risk-adjustment model properties and evaluating the measure score variation across MSSP ACOs. The model showed good fit across groups of patients with varying risk levels. Measure score reliability was excellent.

Among patients with diabetes, the crude U.S. national Medicare FFS rate of acute, unplanned admissions was 41.4 per 100-person years. The mean RSAAR among patients with diabetes assigned to ACOs was 39.6 per 100 person-years (range 23.9 to 68.1 per 100 person-years).

Among patients with heart failure, the crude U.S. national Medicare FFS rate of acute, unplanned admissions was 85.5 per 100-person years. The mean RSAAR among patients with heart failure assigned to ACOs was 81.9 per 100 person-years (range 53.7 to 120.8 per 100 person-years).

#### **1.5. Summary**

In summary, we developed two claims-based, risk-standardized measures of acute, unplanned admission rates to assess ambulatory care quality at the ACO level. Stakeholder and expert input informed measure development throughout. The measures are scientifically sound and reveal important variation across ACOs.

## 2. Introduction

To provide high-quality care for patients with chronic conditions, health systems must effectively prevent and manage the complications of chronic disease as well as other related and unrelated illnesses that frequently arise among patients with chronic disease. In addition, opportunities to engage in healthy behaviors and to access health and health-related services must exist in order for patients to self-manage their disease successfully. Collectively, these clinical and contextual factors influence outcomes for patients with chronic disease.

For more than a decade we have known that admission rates vary across the country, even after adjusting for differences in patient populations.<sup>2-5</sup> To date, however, admission rates have been used as quality and accountability measures to only a limited degree.<sup>6</sup> For example, it is only recently that the Centers for Medicare & Medicaid Services (CMS) has started to use admission scores developed by the Agency for Healthcare Research and Quality (AHRQ), known as Prevention Quality Indicators (PQIs), in several of its programs. These admission scores, however, are narrowly focused and measure only disease-specific admissions (e.g., heart failure admissions). They do not capture the wide spectrum of hospital admissions for which patients with chronic conditions are at increased risk.

As we move toward *patient*-centered systems of care and away from *disease*-centered systems of care, it is important to develop outcome measures that reflect the quality of comprehensive, coordinated care for patients with chronic diseases. Such outcome measures are timely, as new models of care delivery and accountability are testing providers' abilities to improve outcomes for entire patient populations. For example, CMS is supporting Accountable Care Organizations (ACOs), which are designed to provide coordinated care for a given population, and ultimately meet CMS's adaptation of the Triple Aim goals of high-quality care, improved health, and lower cost.<sup>1</sup>

To help evaluate and to improve the quality of care for patients with chronic illness cared for by ACOs, CORE developed two admission measures for CMS: (1) risk-standardized acute admission rates (RSAARs) for patients with diabetes and (2) RSAARs for patients with heart failure. We chose to focus on hospital admissions for acute illness as the outcome and indicator of ambulatory care quality for several reasons: (1) hospital admissions are often sentinel events associated with high morbidity and stress; (2) hospital admissions are associated with high cost for both patients and the ACO; and (3) research shows that effective health care can lower the risk of admission for these vulnerable groups of patients.<sup>7-13</sup> The use of admission measures is also synergistic with the overall goal of ACOs to reduce costs, while maintaining high quality of care. We focused on patients with diabetes and heart failure because they make up a significant proportion of Medicare beneficiaries and experience high morbidity and costs

associated with their disease. They require efficient, coordinated, patient-centered care management as well as community support and infrastructure to facilitate effective chronic disease management, all of which are a part of the mission of ACOs. Examples of potential strategies to lower admission rates are shown in Table 1.

This report presents specifications of two ACO-level admission measures for ambulatory patients with diabetes and ambulatory patients with heart failure. We hope these performance measures will provide valuable feedback to ACOs about their performance in comparison with other ACOs and will incentivize ACOs to provide high-quality, coordinated care that focuses on the whole patient. In order to improve outcomes, we envision that ACOs will facilitate collaboration among participating providers in order to provide the best system of clinical care and will partner with health and health-related organizations in their communities, as appropriate, to improve the health of their patient populations.

## 3. Detailed Measure Specifications and Methods

### 3.1. Measure Overview

The measures compare ACO performance based on the RSAAR among patients with diabetes and among patients with heart failure. The RSAAR for each ACO is calculated as the number of “predicted” to the number of “expected” admissions per person-year, multiplied by the national rate of admissions among all Medicare fee-for-service (FFS) patients with diabetes and all Medicare FFS patients with heart failure. The predicted over expected ratio of admissions is analogous to an observed over expected ratio, but the numerator accounts for clustering, sample-size variation, and ACO-specific performance. The denominator is an expected rate of admission calculated using data from all eligible Medicare FFS patients with diabetes and all eligible Medicare FFS patients with heart failure, whether or not they are assigned to an ACO; as such, the denominator represents the expected rate of admission among a national cohort of patients with the specified condition.

The measures utilize up to two years of data prior to the measurement year to define the cohort of patients with diabetes and the cohort of patients with heart failure. Claims data collected one year prior to the measurement year are used for risk adjustment. The measurement period is one full calendar year. We refer to the beginning of the measurement year (effectively, January 1) as time “zero” (see Figure 1).

### 3.1. Measure Development Process

In developing the measures, we followed CMS’s standardized, transparent process that includes obtaining expert and stakeholder input on the proposed admission measures and holding a public comment period. We convened a technical expert panel (TEP) to provide input on key conceptual and methodological decisions. The TEP is comprised of individuals with diverse perspectives and backgrounds and includes patients, clinicians, purchasers, healthcare administrators, and researchers. Specifically, the TEP brings in expertise in the areas of geriatrics, palliative care, diabetes, heart failure, healthcare disparities, quality measurement, quality improvement, and ACO administration. In addition, on an ad hoc basis, we solicited input from individuals with expertise relevant to chronic conditions and ambulatory quality measurement. Finally, we held a public comment period to seek broader stakeholder input on the measures.



## **3.2. Data Sources**

To develop each measure, we assembled three years of Medicare FFS claims data from 2010-2012 and linked them together using unique patient identifiers. Specifically, we used Medicare Part A and Part B claims from the 100% Chronic Conditions Data Warehouse (CCW) dataset to define the cohorts (2010-2011 data) and to identify each patient's risk factors for the outcome of admission (2011 data). We used the Medicare Provider Analysis and Review (MedPAR) 100% FFS dataset, containing Medicare Part A claims, to assess the outcome of admissions (2012 data). To determine Medicare FFS enrollment, demographic, and death information, we used 2011-2012 Medicare denominator files; this was necessary to determine inclusion/exclusion criteria as well as person-time at risk for admission. CMS informed CORE of the 114 Medicare Shared Savings Program (MSSP) ACOs that participated in 2012 and of the beneficiaries assigned to each ACO using CMS's MSSP ACO assignment algorithm. In addition, to investigate the effects of socioeconomic status (SES) on ACO performance, we adapted a composite SES index developed by AHRQ, using data from the 2008-2012 American Community Survey data from the United States (U.S.) Census Bureau. We assessed the distribution of this score among Medicare beneficiaries using the 2011 CCW Medicare FFS 5% Sample in order to set a threshold for defining low SES.

We refer to data on clinical variables for risk adjustment, measure outcome, and ACO assignment for all patients included in each measure as the 2012 Medicare Full Sample. The 2012 Medicare Full Sample includes data on patients assigned to ACOs as well as patients cared for in traditional FFS Medicare. For measure development and testing, we randomly split the 2012 Medicare Full Sample into the 2012 Development and Validation Samples for each of the two measures. In addition, for measure score reliability testing, we randomly split the 2012 Medicare Full Sample into two equal samples by randomly splitting each ACO's patients in half and then randomly splitting all non-ACO patients in half.

## **3.3. Measure Cohorts**

The target populations for these measures are Medicare FFS patients aged  $\geq 65$  years with diabetes or heart failure. We sought to define cohorts inclusive of patients at all stages of diabetes and heart failure while ensuring the measures can fairly balance differences in patient mix across ACOs.

### **3.3.1. Inclusion Criteria**

- Patient is aged  $\geq 65$  years at the start of the year prior to the measurement period (i.e., year 2011).

*Rationale:* Younger Medicare patients represent a distinct population with dissimilar characteristics and outcomes. Additionally, these patients tend to cluster among certain providers. These factors make risk adjustment difficult.

- Patient is a Medicare FFS beneficiary with continuous enrollment in Medicare Parts A and B during the year prior to the measurement period (i.e., year 2011).

*Rationale:* This information is necessary to provide clinical information for cohort identification and risk adjustment. To clarify, while the measure uses up to two years of data to define the cohort, full enrollment is only required for the first year prior to the measurement period in order to enable adequate and fair risk adjustment.

- Patient has diabetes or patient has heart failure. See below for further explanation.

*Diabetes Cohort:* Patient has at least one inpatient or two outpatient claims for diabetes (in any position on the claim) within the two years prior to the measurement period. Table 2 defines the specific International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes required for diagnosis.

*Rationale:* We require outpatient diagnoses from at least two distinct encounters because defining the cohort from fewer outpatient encounters decreases specificity. We use diagnosis codes in any position on the claim because studies have validated this approach for identifying patients with diabetes using claims data.<sup>14-16</sup> Diabetes is rarely the principal diagnosis for hospitalization, but we also include a single inpatient claim in any position in the algorithm consistent with prior studies.<sup>14-16</sup> Patients identified with diabetes based on hospital admission claims alone comprised a very small proportion of our diabetes cohort (approximately 2%). Our analyses showed that restricting to a one-year timeframe would miss >10% of patients with diabetes compared with using two years of claims data. The diagnostic codes are consistent with the Healthcare Effectiveness Data and Information Set (HEDIS) measure definition of diabetes,<sup>17-19</sup> with the exception that we do not include ICD-9-CM code 648.0 for gestational diabetes.

- *Heart Failure Cohort:* Patient has at least one hospital claim with a principal diagnosis code for heart failure *or* two claims (inpatient or outpatient) with codes for heart failure in any position within the two years prior to the measurement period. Table 3 defines the specific ICD-9-CM codes required for diagnosis.

*Rationale:* Studies have demonstrated good sensitivity and specificity when a single hospital principal diagnosis for heart failure is used to identify patients with true heart failure.<sup>20</sup> However, the positive predictive value is significantly diminished when the heart failure codes appear in other positions on the claim; similarly, requiring only one outpatient heart failure code is associated with a low positive predictive value for true heart failure. Restricting to a one-year timeframe would miss >10% of patients with heart failure compared with using two years of data. The diagnostic codes are consistent with existing heart failure measures,<sup>21-23</sup> with the exception of rheumatic heart failure (i.e., ICD-9-CM code 398.91), which we chose to include for these measures based on the recommendation of the American Heart Association (AHA) Coding Clinic.<sup>24,25</sup>

### 3.3.2. *Exclusion Criteria*

We determined the following exclusion criteria after extensive literature review, examination of existing measures, and discussion with the working group and TEP. The goal was to be as inclusive as possible; therefore, we include patients at all stages of disease (e.g., patients with diabetes and end stage renal disease [ESRD] or patients with metastatic cancer) as well as patients of all ages  $\geq 65$  years.

For both diabetes and heart failure measures we exclude:

- Patients without continuous enrollment in Medicare Part A during the measurement period.

*Rationale:* We exclude these patients to ensure full data availability for outcome assessment (Part A during the measurement year).

For heart failure cohort only, we also exclude:

- Patients with left ventricular assist devices (LVADs).

*Rationale:* We exclude these patients because while they have a high risk of admission, they are low in prevalence and are clustered among a few ACOs.

## 3.4. **Outcome**

The outcome for the diabetes and heart failure measures is the number of acute, unplanned hospital admissions per 100 person-years at risk for hospitalization during the measurement period. The years at risk for hospitalization are calculated by taking the number of days a patient is alive during the measurement period, excluding days spent in the hospital. The risk

period begins on January 1 of the measurement year and extends until the end of the measurement year or until death, whichever occurs first.

The outcome for the diabetes and heart failure measures is hospital admissions for acute illness. The measures do not count admissions for planned or elective procedures in the outcome.

The outcome is measured over one year, consistent with the structure of the ACO program that evaluates quality and expenditures yearly.<sup>26</sup>

### *3.4.1. Outcome Timeframe*

The outcome period begins on January 1 (in this case, of the year 2012) and extends throughout the entire calendar year. This period of 365 days qualifies as the risk period for admission. Days spent in the hospital are subtracted from the risk period. We did not subtract days spent in acute or long-term rehabilitation; these patients are at risk for admissions and we want to encourage ACOs to work with rehabilitation centers to reduce the risk of admission. This decision was supported by the TEP. Patients who die during the measurement year are censored at the time of death. A small proportion of patients begin the year in the hospital and then die; thus, they do not contribute admission-free days to the denominator and will not be counted in the measure.

### *3.4.2. Removal of Planned Admissions from the Outcome*

We only include unplanned admissions in the measure outcome. Planned admissions are those planned by providers for anticipated medical treatment or procedures that must be provided in the inpatient setting. We do not count these in the outcome because most planned admissions are part of ongoing clinical care and do not represent acute events that could have been prevented by high-quality care. Moreover, for ambulatory patients with chronic disease, admissions for certain planned procedures (e.g., placement of a cardiac device designed to prolong life) are consistent with the highest quality of care. For these reasons, planned admissions are not counted in the measure outcome.

To identify planned admissions, we adopted an algorithm we previously developed for CMS's hospital readmission measures, CMS's Planned Readmission Algorithm Version 3.0.<sup>27</sup> In brief, the algorithm uses the procedure codes and principal discharge diagnosis code on each hospital claim to identify admissions that are typically planned. A few specific, limited types of care are always considered planned (e.g., major organ transplant, rehabilitation, or maintenance chemotherapy). Other types of care are sometimes considered planned (e.g., total hip replacement or cholecystectomy), if they are associated with a non-acute discharge diagnosis.

Admissions that include potentially planned procedures that might represent progression of clinical conditions that could have been addressed in the ambulatory setting, such as cardiac catheterization and amputation, are not considered planned. Admissions for an acute illness are never considered planned. The CMS Planned Readmission Algorithm Version 3.0, adapted to identify planned admissions for diabetes and heart failure patients, is presented in Appendix A.<sup>27</sup>

### **3.5. Model Development**

#### **3.5.1. Overview**

The RSAAR for each ACO is calculated as the number of predicted to the number of expected admissions per 100 person-years, multiplied by the national rate of admissions among all Medicare FFS patients with diabetes or among all Medicare FFS patients with heart failure. The measure uses a hierarchical (two-level) statistical model that accounts for the clustering of patients within ACOs and accommodates the varying sizes of different ACOs.

The measure uses a negative binomial model because our outcome is a count of the number of admissions. The first level of the model adjusts for patient factors. The relationship between patient risk factors and the outcome of admission is determined based on all patients with diabetes or all patients with heart failure. Since the effects that risk factors exert on the number of admissions are estimated based on data from all patients in the nation, irrespective of whether they are cared for by an ACO, the expected number of admissions for each ACO is benchmarked against the performance of a national group of providers. The second level of the model estimates a random-intercept term that reflects the ACO's contribution to admission risk based on its actual admission rate, the performance of other providers with similar case mix, and its sample size. The ACO-specific random intercept is used in the numerator calculation to derive ACO-specific number of predicted admissions per person-year.

For a full description of the modeling, please see Appendix B.

#### **3.5.2. Candidate Variables for Patient-Level Risk Adjustment**

We considered variables for risk adjustment based on the existing literature, clinical judgment, and input from our TEP and other experts. We considered factors that may impact the rate of admission, including patient-level factors (e.g., demographics, SES, or clinical risk factors on admission); we also considered the impact of other non-clinical factors such as patient and community resources as well as health behaviors.

To select candidate variables for risk adjustment, we used Medicare Part A and B data from one year prior to the measurement year for 100% of the Medicare FFS patients included in the cohort (2012 Medicare Full Sample). We reviewed 189 diagnostic condition groups included in CMS's Hierarchical Condition Category (HCC) clinical classification system.<sup>28</sup> We defined comorbidities using condition categories (CCs), which are clinically meaningful groupings of more than 15,000 ICD-9-CM diagnosis codes. Two clinicians reviewed all 189 CCs and excluded those that were not relevant to the Medicare FFS population or that were not clinically relevant to the acute admission outcome (e.g., attention deficit disorder or female infertility). The remaining 181 clinically relevant CCs were considered as candidate variables. Among the 181 clinically relevant CCs, we calculated the prevalence of the CC in the year preceding the measurement period (i.e., 2011), the number of hospital admissions per patient-year during the measurement period (i.e., 2012) among patients with and without the CC, and the rate ratio for the number of hospital admissions associated with each CC. We independently reviewed these data for both the diabetes and heart failure cohorts, and reduced the list of CCs to 92 from the initial list of 181 clinically relevant CCs; in this group of 92 CCs, most were prevalent among  $\geq 3\%$  of the cohort and were associated with a rate ratio of  $>1.3$ . Among the 92 CCs, we combined conditions that were clinically coherent and carried a similar rate ratio for the number of hospital admissions, resulting in 22 candidate variables, plus age.

For the diabetes cohort, we also included a diabetes complications severity index in the candidate variables. This variable captures the number of complications associated with diabetes that each patient has: retinopathy, nephropathy, neuropathy, cerebrovascular, cardiovascular, peripheral vascular disease, and metabolic complications. The index takes on values from zero to seven, according to the number of complications present, and has been validated in claims data.<sup>29,30</sup>

For the heart failure cohort, we included an additional candidate variable capturing more advanced heart failure, comprised of a history of implantable cardiac defibrillator (ICD), cardiac resynchronization therapy (CRT), or permanent pacemaker (PPM). While PPM does not necessarily reflect advanced heart failure, we chose to include it in this variable as the unadjusted rates of admission were similar for ICD, CRT, and PPM.

These measures do not adjust for sex or race since differences in risk of admission among these groups should be captured in the risk-adjustment model (which includes age and clinical factors). Any remaining differences in the risk for hospitalization among patients of different sex or race may represent disparities in the delivery and quality of care. However, we did examine the effects of including sex in the models, since the relationship between sex and acute, unplanned admissions has not been tested in this setting (see Section 4.2.6).

These measures also do not adjust for SES because ACOs should and do influence a broad range of patient-level and community-level factors that can mitigate the risk of admission associated with low SES. However, we recognize that the capacity for each ACO to mitigate the potential effect of low SES on a patients' admission risk may be variable; we also recognize that ACOs with different proportions of low SES patients may have varying capacities to mitigate admission risk, for reasons that may be related or unrelated to their case mix. To address these concerns, we performed additional analyses to evaluate the effect of adjustment for low SES on the measure scores and to evaluate performance among ACOs caring for varying proportions of low SES patients (see Section 4.2.6).

Finally, these measures do not adjust for patient resources or health behaviors because ACOs have some ability to influence the effects of these factors on hospital admission. Additionally, these measures do not adjust for community resources such as social service agencies, rehabilitation centers or accessibility to healthy foods and green spaces. As part of their mission, ACOs are encouraged to develop strategic partnerships with community-based organizations and businesses, in order to improve population health and to reduce the risk of admission.

### *3.5.3. Final Variable Selection*

In order to select the final set of variables, we used the 2012 Development Sample to rank the candidate variables in terms of their importance for the model by comparing the Akaike Information Criterion (AIC) values. The AIC is used to select the best-fitting model using the least number of variables; it is commonly used in variable selection for negative binomial models (which use count data, such as a count of the number admissions) to account for overdispersion (whereby data vary more than expected).<sup>31</sup> We selected variables starting with the 24 candidate variables. We removed one variable and determined the best combination of 23 variables that resulted in the smallest AIC compared with other combinations of 23 variables. Based on the best 23 variables, we removed one more variable and determined the best 22 variables. We repeated these steps until we reached one variable. Each of the final 24 models, containing combinations of one to 24 variables, represents the best model (i.e., combination of variables) given the different numbers of variables. We calculated the AIC for these 24 models. Based on the smallest AIC, we selected the final combination of variables.

### *3.5.4. Model Performance and Validation*

To assess performance of the model for each measure, we computed two summary statistics: (1) goodness-of-fit statistic (i.e., deviance R-squared) and (2) overfitting indices. We then compared the model performance in the 2012 Development Sample with its performance in

the 2012 Validation Sample. Because the outcome is a count of admissions – rather than a binary outcome, such as whether or not a patient has been admitted – several routinely used metrics of model performance cannot be applied (e.g., we cannot use a c-statistic).

We calculated deviance R-squared using the model deviance residual defined by Cameron.<sup>32</sup> The deviance R-squared evaluates how successful the fit is in explaining the variation of the data and can take on any value between zero and one, with a value closer to one indicating that a greater proportion of deviance is accounted for by the model. For example, a deviance R-squared value of 0.12 means that the fit explains 12% of the total deviance.

Overfitting refers to the phenomenon in which a model accurately describes the relationship between the predictive variables and the outcome in the development dataset, but fails to provide valid predictions in new patients.

In order to determine whether the model performs well across groups of patients at different risk of admission, the sample was divided into quartiles of predicted admission rate (highest, second highest, lowest, and second lowest). We then assessed the predicted probability of the number of admissions derived from the model compared with the observed probability of the number of admissions. The predicted probability for a group of patients is the average probability of observing 0, 1, 2, ... $n$  hospital admissions, given these patients' risk factors for admission. The observed probability of each count of admissions for a group of patients is the proportion of these patients admitted to the hospital 0, 1, 2, ... $n$  times.

### *3.5.5. Calculation of ACO-Level Measure Score*

The measures use a hierarchical (two-level) statistical model that accounts for the clustering of patients within ACOs and accommodates the varying sizes of different ACOs. The measures use a negative binomial model since our outcome is a count of the number of admissions. The first level of the model adjusts for patient factors. The relationship between patient risk factors and the outcome of admission is determined based on all national patients with diabetes for the diabetes measure and all national patients with heart failure for the heart failure measure. Stated another way, since the effects that risk factors exert on the number of admissions are estimated based on data from all patients in the nation with the specified condition, regardless of whether they are cared for by an ACO, the expected number of admissions for each ACO is based on the performance of a national group of providers.

The second level of the model estimates a random-intercept term that reflects the ACO's contribution to admission risk, based on its actual admission rate, the performance of other providers with similar case mix, and its sample size. The ACO-specific random intercept is used



in the numerator calculation to derive ACO-specific number of predicted admissions per person-year.

The measure score is the ratio of predicted admissions over the expected admissions multiplied by the crude national rate. The predicted to expected ratio of admissions is analogous to an observed over expected ratio, but the numerator accounts for clustering, sample-size variation and ACO-specific performance.

The expected number of admissions is calculated based on the ACO's case mix and national average intercept.

The predicted number of admissions is calculated based on the ACO's case mix and the estimated ACO-specific intercept term. We multiply the ratio for each ACO by a constant, the crude national rate of acute, unplanned admissions, for ease of interpretation.

For each ACO, we calculate an interval estimate (IE) using bootstrapping methodology. Using 95% interval estimates, we assigned ACOs to one of three performance categories: 'better than national rate,' 'no different than national rate,' and 'worse than national rate.' The ACO is 'better than national rate' if the 95% IE is completely below the U.S. national rate among Medicare FFS diabetes or heart failure patients; 'no different than national rate' if the 95% IE is included in the U.S. national rate among Medicare FFS diabetes or heart failure patients; and 'worse than national rate' if the 95% IE is above the U.S. national rate among Medicare FFS diabetes or heart failure patients.

### *3.5.6. Measure Score Reliability*

To calculate measure score reliability, we randomly sampled half of the patients from each ACO and half of the patients who were not in ACOs from the 2012 Medicare Full Sample. We calculated the measure score for all the ACOs using data from ACO and non-ACO patients, and repeated the calculation using the second half of patients. Thus, each ACO was measured twice, but each measurement was made using an entirely distinct set of patients. As a metric of agreement we calculated the intraclass correlation coefficient (ICC) and assessed the values according to conventional standards. The agreement of the two RSAARs was quantified for ACOs in each sample using the ICC (2,1) by Shrout and Fleiss.<sup>33,34</sup>

### *3.5.7. Additional Analyses*

We examined potential disparities in ACO performance that may be related to sex or SES.

### Defining Low Socioeconomic Status

As there are no standardized methods for assessing a Medicare FFS beneficiary's SES status, we used two different indicators of SES: (1) the SES score of the patient's five-digit zip code, adapted from the AHRQ SES Index, which was created for the purpose of characterizing the SES of Medicare beneficiaries and (2) the Medicaid dual-eligibility status of beneficiaries.<sup>35</sup> The AHRQ SES Index is based on seven variables previously shown to contribute to SES. They are: (1) median household income, (2) percentage of persons living below the federal poverty level, (3) percentage of persons who are aged  $\geq 16$  years and in the labor force but not employed, (4) median value of owner-occupied homes, (5) percentage of persons aged  $\geq 25$  years who completed at least a 12<sup>th</sup> grade education, (6) percentage of persons aged  $\geq 25$  years who completed at least four years of college, and (7) percentage of households that average one or more persons per room. The original AHRQ SES Index was derived using data from the 2000 U.S. Census Bureau and was calculated using U.S. Census Block data, which corresponded to Medicare beneficiaries' nine-digit zip code. For this measure, we used data from the U.S. Census Bureau, American Community Survey (2008-2012) and performed a principal component analysis to derive a composite SES index score for each five-digit zip code, which we then assigned to the patient based on their zip code of residence (i.e., the smallest unit by which we could identify Medicare beneficiaries' home address). The AHRQ SES Index is a continuous variable whereby lower scores indicate lower SES zip codes and higher scores indicate higher SES zip codes.

We created a dichotomous variable from the AHRQ SES index, stratifying zip code scores into 'low SES' and 'non-low SES.' Based on the distribution of the AHRQ SES index among the entire FFS Medicare population in the 5% Medicare FFS sample, we selected the lowest quintile to represent low SES. In this lowest quintile, 21.9% of beneficiaries were Medicaid dual-eligible, as compared with 13.7% in the second lowest quintile.

Additionally, we categorized ACOs based on the proportion of low SES patients in their cohort into quartiles (first quartile [Q1] indicating few low SES patients, fourth quartile [Q4] indicating many low SES patients). Similarly, we categorized ACOs by the proportion of Medicaid dual-eligible patients in their cohort into ACOs caring for 'few' (Q1) and 'many' (Q4) Medicaid dual-eligible patients. For more information on the derivation of the AHRQ SES index and the selection of a low SES thresholds for patients and ACOs, see Appendix D.

### Assessment of Sex Disparities

To assess the effect of sex on model performance, we compared deviance R-squared values with and without sex included in the models. We compared the correlation between measure scores with and without sex in the models using the Spearman correlation.

### Assessment of SES Disparities

To assess the effect of SES on model performance, we compared deviance R-squared values with and without low SES included as a patient-level variable in the models. We compared the correlation between measure scores with and without low SES included in the models, using the Spearman correlation.

We also assessed ACO performance among groups of ACOs caring for similar proportions of low SES patients. To do this, we categorized ACOs into quartiles (Q1 indicating ACOs with few low SES patients, Q4 indicating ACOs with many low SES patients). We used boxplots to compare the distribution of RSAARs across ACOs by low SES quartiles.

Finally, we repeated these analyses comparing ACO performance by low SES quartiles, however in these analyses ACO performance was determined using a risk adjustment model that included low SES as a covariate.

All of these analyses were performed using both the AHRQ SES index (i.e., low SES, binary variable described above) and Medicaid dual-eligibility status as a proxy for patients' SES status.

#### *3.5.8. Statistical Software*

Statistical analyses were performed using SAS version 9.3 (SAS Institute Inc., Cary, NC).

## 4. Results

### 4.1. Development and Validation Samples

#### 4.1.1. *Diabetes Measure*

Out of the total number of Medicare FFS patients with diabetes ( $n = 6,746,776$ ), we excluded 225,314 (3.3%) due to non-continuous enrollment in Medicare Part A in 2012. The 2012 Medicare Full Sample included 6,521,462 patients with diabetes. The majority of patients were female (54.7%), and the average age of patients was 76.4 years. There were 114 ACOs in the 2012 Medicare Full Sample. Among the 6,521,462 patients with diabetes, 341,193 (5.2%) were assigned to one of 114 ACOs.

The 2012 Development and Validation Samples each included 3,260,731 patients with diabetes. In each sample, the majority of patients were female (54.7%), and the average age of patients was 76.4 years.

#### 4.1.2 *Heart Failure Measure*

Out of the total number of Medicare FFS patients with heart failure ( $n = 2,649,829$ ), we excluded 67,939 (2.6%) – 66,909 did not have continuous enrollment in Medicare Part A in 2012 and 1,048 had an LVAD procedure. The 2012 Medicare Full Sample included 2,581,892 patients with heart failure. The majority of patients were female (56.9%), and the average age of patients was 80.4 years. There were 114 ACOs in the 2012 Medicare Full Sample. Among the 2,581,892 patients with heart failure, 123,626 (4.8%) were assigned to one of 114 ACOs.

The 2012 Development and Validation Samples each included 1,290,946 heart failure patients. In the 2012 Development Sample,, the majority of patients were female (56.9%), and the average age of patients was 80.5 years. In the 2012 Validation Sample, the majority of patients were female (56.9%), and the average age of patients was 80.4 years.

### 4.2. Patient-Level Risk-Adjustment Model

#### 4.2.1. *Candidate and Final Variables*

We identified 24 candidate risk-adjustment variables for each measure. For both the diabetes and heart failure measures, the best combination of variables (i.e., with the lowest AIC value) resulted in a distinct set of 23 variables, all of which were significantly associated with the outcome ( $p < 0.05$ ). We identified final 23 risk-adjustment variables for each measure Appendix C, Table 4, and Table 5). For the diabetes measure, of the 24 candidate variables, the only

variable that was not included in the final model was structural heart disease, which was not statistically significant in the model. For the heart failure measure, the only variable that was not included was the hip and other major fractures variable, which was not statistically significant in the model.

#### *4.2.2. Model Performance*

Model performance metrics for both measures are summarized in Table 6 and Table 7. For the diabetes measure, the final deviance R-squared in the 2012 Development Sample was 0.217, which indicates that the model explains 21.7% of the variation. For the heart failure measure, the final deviance R-squared in the 2012 Development Sample was 0.122, which indicates that the model explains 12.2% of the variation. The overfitting index of  $\gamma_0$  close to 0 and  $\gamma_1$  close to 1 indicates good calibration of the models. Additionally, the plots of observed and predicted probabilities for each number of hospital admissions (0, 1, 2, ..., 10) across four risk groups show that the models perform well across a broad range of risk (see Figure 4 and Figure 5). In the highest risk group, we observed that the observed and predicted probabilities of the number of zero, one, or two admissions differed slightly. However, these differences were small and somewhat expected among the highest risk group of patients.

#### *4.2.3. Model Validation*

For both the diabetes and heart failure measures, model performance was similar in the Development and Validation Samples, with strong model fit and good calibration (Table 6 and Table 7).

#### *4.2.4. ACO-Level Measure Score*

##### *Diabetes Measure*

Over the period of the measurement year, there were 2,940,537 hospital admissions, with 353,192 (12.0%) classified as planned admissions, resulting in a total of 2,587,345 (88.0%) acute, unplanned admissions.

Among patients with diabetes, the crude U.S. national Medicare FFS rate of acute, unplanned admissions was 41.4 per 100 person-years. Among ACOs, the mean RSAAR for calendar year 2012 was 39.6 admissions per 100 person-years (standard deviation = 7.3). The median RSAAR was 39.1 admissions per 100 person-years (interquartile range [IQR] 34.8 to 43.9). The minimum RSAAR was 23.9 per 100 person-years; the 5<sup>th</sup> percentile was 28.6 admissions per 100 person-years; the 95<sup>th</sup> percentile was 53.0 admissions per 100 person-years; and the maximum score was 68.1 admissions per 100 person-years (Figure 2).

We observed that 51 ACOs (44.7%) had RSAARs that were ‘no different’ from the U.S. national Medicare FFS rate among patients with diabetes. An additional 45 ACOs (39.5%) had RSAAR scores ‘better than national rate’ and 18 ACOs (15.8%) ‘worse than national rate.’

#### Heart Failure Measure

Over the period of the measurement year, there were 2,123,190 hospital admissions, with 145,443 (6.9%) classified as planned admissions, resulting in a total of 1,977,747 (93.1%) acute, unplanned admissions.

Among patients with heart failure, the crude U.S. national Medicare FFS rate of acute, unplanned admissions was 85.5 per 100 person-years. Among ACOs, the mean RSAAR for calendar year 2012 was 81.9 per 100 person-years (standard deviation = 11.6). The median RSAAR was 81.5 per 100 person-years (IQR] 73.6 to 88.8). The minimum RSAAR score was 53.7 per 100 person-years; the fifth percentile was 64.6 per 100 person-years; the 95th percentile was 101.7 per 100 person-years; and the maximum score was 120.7 per 100 person-years (Figure 3).

We observed that 61 ACOs (53.5%) had RSAARs that were ‘no different’ from the U.S. national Medicare FFS rate among patients with heart failure. An additional 37 ACOs (32.5%) had RSAAR scores ‘better than national rate’ and 16 (14.0%) ‘worse than national rate.’

#### *4.2.5. Measure Score Reliability*

The ICC was 0.89 for the diabetes measure and 0.81 for the heart failure measure, which according to the conventional interpretation is considered “excellent.”<sup>34</sup>

#### *4.2.6. Additional Analyses*

##### Disparities by Sex

For the diabetes measure, the deviance R-squared values were 0.218 and 0.217 for the models with and without adjustment of sex, respectively. Comparing the RSAAR with and without sex included in the model resulted in a high degree of correlation (Spearman correlation = 0.999; see Figure 6).

For the heart failure measure, the deviance R-squared values were 0.123 and 0.122 for the models with and without adjustment of sex, respectively. Comparing the RSAAR with and without sex included in the model resulted in a high degree of correlation (Spearman correlation = 0.999; see Figure 9).

For both the diabetes and heart failure measures, these results indicate that adjustment for sex explained the same variation in the models and did not provide incremental benefit. The high degree of correlation means that ACOs performed similar with and without risk adjustment for sex.

### Disparities by SES

#### **Adjustment for low SES**

For the diabetes and heart failure measures, the deviance R-squared values for models with and without low SES (based on the AHRQ SES index), as well as with and without Medicaid dual-eligibility status were nearly the same (see Table 8). These values indicate that adjustment for low SES or Medicaid dual-eligibility status explained the same variation in the models and did not provide incremental benefit. In addition, there was a high degree of correlation between RSAAR with and without low SES/Medicaid dual-eligibility status included in the models (for the diabetes measure, Spearman correlations for RSAARs with and without adjustment for low SES and Medicaid dual eligibility were 0.981 and 0.976 as shown in Figure 7 and Figure 8, respectively; for the heart failure models, Spearman correlations for RSAARs with and without adjustment for low SES and Medicaid dual-eligibility status were 0.990 and 0.991 as shown in Figure 10 and Figure 11, respectively). The graphs demonstrate that, compared with *not* adjusting for low SES/Medicaid dual-eligibility status, adjusting for low SES/Medicaid dual-eligibility status results in some ACOs having slightly lower RSAAR scores (below the line) and other ACOs having higher RSAAR scores (above the line).

For both diabetes and heart failure measures, these results demonstrate that adjusting for low SES or Medicaid dual-eligibility status at the patient level has little, if any, effect on the measure score.

### ACO performance categorized by the proportion of low SES/Medicaid dual-eligible patients cared for by ACOs

#### **Diabetes Measure**

The distribution of the proportion of low SES is presented in Figure 12, and the distribution of Medicaid dual-eligible patients cared for by ACOs is presented in Appendix E. The median proportion of low SES patients in ACOs was 15.0% (IQR: 4.5% to 28.7%). The median proportion of Medicaid dual-eligible patients was 10.6% (IQR: 7.5% to 16.3%).

Using the AHRQ SES Index, 29 out of the 114 ACOs were identified as caring for few low SES patients (Q1, proportion of low SES patients, 0.0% to 4.5%) and 28 ACOs were categorized as caring for many low SES patients (Q, proportion of low SES patients, 28.7% to 96.6%). Using

Medicaid dual eligibility as an indicator of SES status, among the 114 ACOs, 29 ACOs were identified as caring for few Medicaid dual-eligible patients (Q1, proportion of Medicaid dual-eligible patients, 2.4-7.5%) and 28 ACOs were categorized as caring for many Medicaid dual-eligible patients' (Q4, proportion of Medicaid dual-eligible patients, 16.3-78.7%). Using these two indicators of SES status, 17 ACOs were categorized as serving few low-SES patients by both indicators, and 14 ACOs were categorized as serving many low-SES patients by both indicators.

Among the 29 ACOs caring for few low SES patients (based on the AHRQ SES Index), 1 (3.4%) performed worse than national rate, 15 (51.7%) performed no different, and 13 (44.8%) performed better than national rate. Among the 28 ACOs caring for many low SES patients, 9 (32.1%) performed worse than national rate, 11 (39.3%) performed no different, and 8 (28.6%) performed better than national rate.

Among the 29 ACOs with few Medicaid dual-eligible patients, 1 (3.4%) performed worse than national rate, 12 (41.4%) performed no different, and 16 (55.2%) performed better than national rate. Among the 28 ACOs with many Medicaid dual-eligible patients, 8 (28.6%) performed worse than national rate, 13 (46.4%) performed no different, and 7 (25.0%) performed better than national rate. These data are represented in Table 9.

The distribution of RSAARs, without risk-adjustment for low SES, reveals 2 patterns: (1) ACOs in Q1 and Q2 (few low SES patients) tend to have lower RSAARs than ACOs in Q3 and Q4 (many low SES patients); and (2) there is less variation in RSAARs among ACOs in Q1 (narrower distribution); ACOs in Q3 to Q4 tend to have more variation in RSAARs (wider distribution). After adjusting for low SES, the patterns are similar, though there is slightly less variation in RSAARs among ACOs in Q4 (see Figure 14). There are small differences in these patterns when analyses are performed using Medicaid dual-eligibility status as an indicator of SES status (see Figure 15).

### **Heart Failure Measure**

The distribution of the proportion of low SES is presented in Figure 13, and the distribution of Medicaid dual-eligible patients cared for by ACOs is presented in Appendix E. The median proportion of low SES patients in ACOs was 14.6% (IQR: 3.9% to 27.3%). The median proportion of Medicaid dual-eligible patients was 15.2% (IQR: 9.7% to 22.5%).

Using the AHRQ SES Index, 29 out of the 114 ACOs were identified as caring for few low SES patients (Q1, proportion of low SES from 0.0 to 3.9%) and 28 ACOs were categorized as caring for many low SES patients (Q4, proportion of low SES patients from 27.3 to 97.1%). Using Medicaid dual eligibility as an indicator of SES status, among the 114 ACOs, 29 ACOs were identified as caring for few Medicaid dual-eligible patients (Q1, proportion of Medicaid dual-eligible patients from 3.2 to 9.7%) and 29 ACOs were categorized as caring for many Medicaid



dual-eligible patients (Q4, proportion of Medicaid dual-eligible patients from 22.5 to 70.9%). Using these two indicators of SES status, 17 ACOs were categorized as serving few low-SES patients by both indicators, and 15 ACOs were categorized as serving many low-SES patients by both indicators.

Among the 29 ACOs caring for few many low SES patients (based on the AHRQ SES Index), 2 (6.9%) performed worse than national rate, 17 (58.6%) performed no different, and 10 (34.5%) performed better than national rate. Among the 28 ACOs caring for many low SES patients, 7 (25.0%) performed worse than national rate, 16 (57.1%) performed no different, and 5 (17.9%) performed better than national rate.

Among the 29 ACOs with few Medicaid dual-eligible patients, 1 (3.4%) performed worse than national rate, 14 (48.3%) performed no different, and 14 (48.3%) performed better than national rate. Among the 29 ACOs with many Medicaid dual-eligible patients, 7 (24.1%) performed worse than national rate, 17 (58.6%) performed no different, and 5 (17.2%) performed better than national rate. These data are represented in Table 10.

The distribution of RSAARs, without risk-adjustment for low SES, reveals 2 patterns: (1) ACOs in Q1 (few low SES patients) tend to have lower RSAARs than ACOs in Q4 (many low SES patients); (2) there is more variation in RSAARs among ACOs in Q4 as compared with ACOs in Q1-3. After adjusting for low SES, the patterns are similar, though there is slightly less variation in RSAARs among ACOs in Q4 (see Figure 16). There are small differences in these patterns when analyses are performed using Medicaid dual eligibility as an indicator of SES status (see Figure 17).

### **4.3. Summary of Disparities Analyses**

For both diabetes and heart failure, these results indicate that ACOs serving a high proportion of low-SES patients (as indicated by either the AHRQ SES Index or Medicaid dual-eligibility status) tended to perform worse than national rate more commonly than ACOs serving few low-SES patients. However, in both measures, nearly 25% of ACOs serving high proportions of low-SES patients performed better than national rate on these measures. Adjustment for low-SES status as a patient variable in the models did not substantially affect these results.

## 5. Summary

Diabetes and heart failure are complex, high-prevalence chronic diseases that affect 18% and 14% of Medicare beneficiaries, respectively. Both of these conditions impact people's functional status as well as their daily living. They also represent high-cost conditions, with Medicare diabetes beneficiaries accounting for 32% of Medicare spending and Medicare heart failure beneficiaries accounting for 43% of total Medicare spending.<sup>36</sup> Patients with diabetes and heart failure are vulnerable to complications that result from their underlying disease, as well as to a range of other acute illnesses, placing them at relatively high risk for hospitalization.<sup>8,37</sup> Provision of coordinated care that is focused on improving health for the whole patient, across all stages of disease, and in the context of coexisting comorbidities and life circumstances should lower the risk of hospital admission for these patients.<sup>6,8-13,37-40</sup>

The proposed measures comparing the risk-adjusted rates of acute hospital admissions per person-year are consistent with consensus standards for publicly reported outcomes measures, and will incentivize ACOs to provide more efficient, coordinated, partnered care for their patients in order to reduce the rates of admission. In these measures, we observed substantial variation in ACO performance, with nearly half of the ACOs having significantly higher or lower risk-standardized admission rates compared with the national rate. The heterogeneity in performance persisted when stratified by the proportion of low-SES patients being served by that ACO, demonstrating that ACOs can and do mitigate the risk associated with serving high proportion of low-SES patients.

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## 7. Tables and Figures

**Table 1. Examples of potential strategies to lower admissions for acute illness among patients with chronic conditions.**

Strategies	Examples
Provide optimal and accessible chronic disease management to reduce catastrophic sequela of chronic disease	Support healthy lifestyle behaviors and optimize medical management to minimize the risk for cardiovascular events such as stroke and heart attacks
	Carefully monitor and act early to address chronic problems that require major interventions if allowed to progress (e.g., assessment and treatment of peripheral artery disease in unresolving infections in order to prevent amputation)
	Encourage exercise-based cardiac rehabilitation therapy to improve the functional status of patients and decrease risk of hospitalization
Manage patients' comorbidities	Assess and treat obstructive sleep apnea to reduce the risk of heart failure
	Assess and treat depression to improve self-efficacy and self-management of chronic disease
Provide optimal primary prevention of acute illnesses	Provide recommended immunizations (example, influenza)
	Perform recommended screening (e.g., colonoscopy)
Facilitate rapid, effective ambulatory intervention when acute illness does occur, whether related or unrelated to the chronic condition.	Timely prescription of antibiotics for presumed bacterial pneumonia or diuretic treatment for fluid overload in heart failure
	Empower patients to recognize symptoms and seek timely care
	Create accessible care options for patients (e.g., weekend or evening hours; capacity to deliver IV medications)
Partner with government, local businesses, and community organizations to improve support for patients with chronic illness	Collaborate with home nursing programs
	Partner with local businesses to increase opportunities to engage in healthy lifestyle behaviors

**Table 2. Diagnostic codes used to define diabetes patients in the diabetes measure**

ICD-9-CM code	Description
250.00	Diabetes without mention of complication, controlled
250.01	Diabetes without mention of complication, T1, controlled
250.02	Diabetes without mention of complication, T2, uncontrolled
250.03	Diabetes without mention of complication, T1, uncontrolled
250.10	Diabetes with ketoacidosis, T2, diabetes controlled
250.11	Diabetes with ketoacidosis, T1, diabetes controlled
250.12	Diabetes with ketoacidosis, T2, diabetes uncontrolled
250.13	Diabetes with ketoacidosis, T1, diabetes uncontrolled
250.20	Diabetes with hyperosmolarity, T2, diabetes controlled
250.21	Diabetes with hyperosmolarity, T1, diabetes controlled
250.22	Diabetes with hyperosmolarity, T2, diabetes uncontrolled
250.23	Diabetes with hyperosmolarity, T1, diabetes uncontrolled
250.30	Diabetes with other coma, T2, diabetes controlled
250.31	Diabetes with other coma, T1, diabetes controlled
250.32	Diabetes with other coma, T2, diabetes uncontrolled
250.33	Diabetes with other coma, T1, diabetes uncontrolled
250.40	Diabetes with renal manifestations, T2 controlled
250.41	Diabetes with renal manifestations, T1 controlled
250.42	Diabetes with renal manifestations, T2 uncontrolled
250.43	Diabetes with renal manifestations, T1 uncontrolled
250.50	Diabetes with ophthalmic manifestations, T2 controlled
250.51	Diabetes with ophthalmic manifestations, T1 controlled
250.52	Diabetes with ophthalmic manifestations, T2 uncontrolled
250.53	Diabetes with ophthalmic manifestations, T1 uncontrolled
250.60	Diabetes with neurological manifestations, T2 controlled
250.61	Diabetes with neurological manifestations, T1 controlled
250.62	Diabetes with neurological manifestations, T2 uncontrolled
250.63	Diabetes with neurological manifestations, T1 uncontrolled
250.70	Diabetes with peripheral circulatory disorders, T2 controlled
250.71	Diabetes with peripheral circulatory disorders, T1 controlled
250.72	Diabetes with peripheral circulatory disorders, T2 uncontrolled
250.73	Diabetes with peripheral circulatory disorders, T1 uncontrolled
250.80	Diabetes with other specified manifestations (Diabetic hypoglycemia NOS, Hypoglycemic shock NOS), T2 controlled
250.81	Diabetes with other specified manifestations (Diabetic hypoglycemia NOS, Hypoglycemic shock NOS), T1 controlled
250.82	Diabetes with other specified manifestations (Diabetic hypoglycemia NOS, Hypoglycemic shock NOS), T2 uncontrolled



ICD-9-CM code	Description
250.83	Diabetes with other specified manifestations (Diabetic hypoglycemia NOS, Hypoglycemic shock NOS), T1 uncontrolled
250.90	Diabetes with unspecified complication, T2 controlled
250.91	Diabetes with unspecified complication, T1 controlled
250.92	Diabetes with unspecified complication, T2 uncontrolled
250.93	Diabetes with unspecified complication, T1 uncontrolled
357.20	Polyneuropathy in diabetes
362.01	Background diabetic retinopathy
362.02	Proliferative diabetic retinopathy
362.03	Nonproliferative diabetic retinopathy NOS
362.04	Mild nonproliferative diabetic retinopathy
362.05	Moderate nonproliferative diabetic retinopathy
362.06	Severe nonproliferative diabetic retinopathy
366.41	Diabetic cataract

**Table 3. Diagnostic codes used to define heart failure patients in the heart failure measure**

ICD-9-CM code	Description
398.91	Rheumatic heart failure
402.01	Malignant hypertensive heart disease with congestive heart failure (CHF)
402.11	Benign hypertensive heart disease with CHF
402.91	Hypertensive heart disease with CHF
404.01	Malignant hypertensive/renal disease with CHF
404.03	Malignant hypertensive/renal disease with CHF/Renal Failure
404.11	Benign hypertensive/renal disease with CHF
404.13	Benign hypertensive/renal disease with CHF/Renal Failure
404.91	Hypertensive/renal disease NOS with CHF
404.93	Hypertensive/renal disease NOS with CHF/Renal Failure
428.0	Congestive heart failure
428.1	Left heart failure
428.20	Systolic heart failure NOS
428.21	Acute systolic heart failure
428.22	Chronic systolic heart failure
428.23	Acute on chronic systolic heart failure
428.30	Diastolic heart failure NOS
428.31	Acute diastolic heart failure
428.32	Chronic diastolic heart failure
428.33	Acute on chronic diastolic heart failure
428.4	Systolic/diastolic heart failure NOS
428.41	Acute systolic/diastolic heart failure
428.42	Chronic systolic/diastolic heart failure
428.43	Acute/chronic systolic/diastolic heart failure
428.9	Heart failure NOS

**Table 4. Risk-adjustment variables, their prevalence, and rate ratios for the diabetes measure**

Variable	Prevalence of risk factors (%)		Rate ratio
	Development Sample N = 3,260,731	Validation Sample N = 3,260,731	Development Sample N = 3,260,731
Age: Mean (Standard deviation [SD])	76.4 (7.2)	76.4 (7.2 )	1.0
High risk cardiovascular (CV) factors	16.8	16.9	1.2
Low risk CV factors	57.0	57.0	1.2
Arrhythmia	29.1	29.1	1.2
Advanced cancer	5.6	5.6	1.5
Dementia	14.2	14.2	1.3
Heart failure	23.0	23.1	1.5
Dialysis	1.5	1.5	1.9
Disability/Frailty	13.5	13.5	1.4
Gastrointestinal and Genitourinary disorders (GI/GU)	23.4	23.3	1.1
Hematology	8.5	8.5	1.1
Infectious and immune disorders	3.4	3.4	1.2
Kidney disease	22.6	22.6	1.2
Liver disease	1.7	1.7	1.5
Neurological disease	26.1	26.0	1.1
Psychiatric illness/Substance abuse	26.7	26.7	1.3
Pulmonary disease	37.1	37.2	1.4
Other advanced organ failure	7.6	7.6	1.4
Iron deficiency anemia	36.8	36.8	1.2
Major organ transplant	0.2	0.2	1.3
Other organ transplant	0.6	0.6	1.1
Hip fracture/Major fracture	3.4	3.4	1.1
Diabetes severity index: Mean (SD)	1.7 (1.4)	1.7 (1.4)	1.1

**Table 5. Risk-adjustment variables, their prevalence, and rate ratios for the heart failure measure**

Variable	Prevalence of risk factors (%)		Rate ratio
	Development Sample N = 1,290,946	Validation Sample N = 1,290,946	Development Sample N = 1,290,946
Age			Categorical
65-70 years	10.5	10.5	
70-80 years	35.0	35.1	
80-90 years	40.1	40.1	
>90 years	14.4	14.4	
High risk cardiovascular (CV) factors	32.5	32.5	1.2
Low risk CV factors	84.4	84.4	1.1
Arrhythmia	62.6	62.7	1.2
Structural heart disease	39.7	39.7	1.1
Advanced cancer	7.4	7.3	1.3
Dementia	25.7	25.7	1.1
Diabetes with complications	51.7	51.7	1.2
Dialysis status	3.0	3.0	1.7
Disability/Frailty	24.2	24.3	1.3
Gastrointestinal and genitourinary disorders (GI/GU)	32.1	32.2	1.1
Hematological disorders	16.0	16.1	1.1
Infectious and immune disorder	6.1	6.1	1.1
Kidney disease	38.2	38.2	1.3
Liver disease	2.3	2.4	1.3
Neurological disease	45.8	45.8	1.1
Psychiatric illness/Substance abuse	38.6	38.8	1.2
Pulmonary diseases	60.3	60.4	1.4
Other advanced organ failure	21.2	21.2	1.4
Iron deficiency anemia	54.1	54.0	1.1
Major organ transplant	0.3	0.3	1.2
Other organ transplant	0.8	0.8	1.1
Pacemaker/cardiac resynchronization therapy/implantable cardiac device	21.9	21.9	1.0

**Table 6. Model performance in the 2012 Development and Validation Samples for the diabetes measure**

Model	Overfitting indices	Deviance R-squared
Development Sample	(0.0000, 1.0000)	0.217
Validation Sample	(0.0017, 1.0031)	0.218

**Table 7. Model performance in the 2012 Development and Validation Samples for the heart failure measure**

Model	Overfitting indices	Deviance R-squared
Development Sample	(0.0000, 1.0000)	0.122
Validation Sample	(-0.0020, 0.9998)	0.123

**Table 8. Comparison of model fit with and without risk adjustment for low SES status.**

Measure	Deviance R-squared
<b>Risk-adjusted diabetes model</b>	
With AHRQ SES Index*	0.218
Without AHRQ SES Index	0.217
With Medicaid dual-eligibility status	0.220
Without Medicaid dual-eligibility status	0.217
<b>Risk-adjusted heart failure model</b>	
With AHRQ SES Index	0.123
Without AHRQ SES Index	0.122
With Medicaid dual-eligibility status	0.124
Without Medicaid dual-eligibility status	0.122

\* AHRQ SES Index was included in the model as a binary variable (defined as AHRQ SES Index <45)

**Table 9. ACO performance by proportion of low SES patients with diabetes (using AHRQ SES Index and Medicaid dual-eligibility status, separately, to indicate patients' SES)**

ACO Performance					
	Total	Better than national rate	No different than national rate	Worse than national rate	P-value
<b>Number of ACOs</b>	114	45	51	18	
<b>Number of patients in ACO: median (IQR)</b>	2,094 (1,474-3,355)	2,298 (1,628-4,551)	1,856 (1,421-3,036)	1,857 (1,535-3,290)	
<b>Proportion of low SES patients in ACO (%)*</b>					
<b>Quartile 1</b>	29 (25.4%)	13 (44.8%)	15 (51.7%)	1 (3.4%)	0.0504
<b>Quartile 2</b>	28 (24.6%)	15 (53.6%)	10 (35.7%)	3 (10.7%)	
<b>Quartile 3</b>	29 (25.4%)	9 (31.0%)	12 (41.4%)	8 (27.6%)	
<b>Quartile 4</b>	28 (24.6%)	8 (28.6%)	11 (39.3%)	9 (32.1%)	
<b>Proportion of dual-eligible patients in ACO (%)<sup>+</sup></b>					
<b>Quartile 1</b>	29 (25.4%)	16 (55.2%)	12 (41.4%)	1 (3.4%)	0.0876
<b>Quartile 2</b>	28 (24.6%)	13 (46.4%)	11 (39.3%)	4 (14.3%)	
<b>Quartile 3</b>	29 (25.4%)	9 (31.0%)	12 (41.4%)	8 (27.6%)	
<b>Quartile 4</b>	28 (24.6%)	7 (25.0%)	13 (46.4%)	8 (28.6%)	

\* Divided into quartiles, Quartile 1 indicating lowest proportion and Quartile 4 highest proportion of low SES patients.

<sup>+</sup> Among 114 ACOs, 17 ACOs were in both Quartile 1 (lowest quartile) of proportion of low SES and dual-eligible patients, 13 ACOs were in both Quartile 4 (highest quartile) of proportion of low SES and dual-eligible patients.

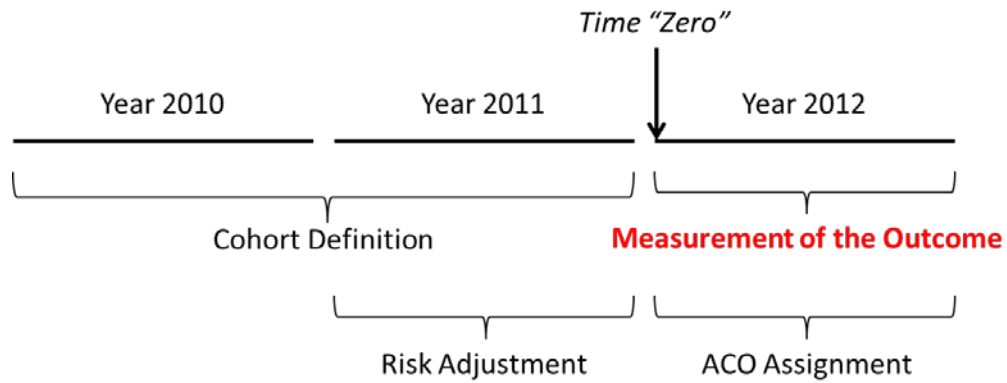
**Table 10. ACO performance by proportion of low SES patients with heart failure (using AHRQ SES Index and Medicaid dual-eligibility status, separately, to indicate patients' SES)**

ACO Performance					
	Total	Better than national rate	No different than national rate	Worse than national rate	P-value
Number of ACOs	114	37	61	16	
Number of patients in ACO: median (IQR)	689 (524–1,180)	893 (550–1,734)	642 (524–936)	736 (478–1,147)	
Proportion of low SES patients in ACO (%) <sup>*</sup>					
Quartile 1	29 (25.4%)	10 (34.5%)	17 (58.6%)	2 (6.9%)	0.3552
Quartile 2	28 (24.6%)	11 (39.3%)	14 (50.0%)	3 (10.7%)	
Quartile 3	29 (25.4%)	11 (37.9%)	14 (48.3%)	4 (13.8%)	
Quartile 4	28 (24.6%)	5 (17.9%)	16 (57.1%)	7 (25.0%)	
Proportion of dual-eligible patients in ACO (%) <sup>+</sup>					
Quartile 1	29 ( 25.4%)	14 (48.3%)	14 (48.3%)	1 (3.4%)	0.0521
Quartile 2	29 ( 25.4%)	7 (24.1%)	19 (65.5%)	3 (10.3%)	
Quartile 3	27 ( 23.7%)	11 (40.7%)	11 (40.7%)	5 (18.5%)	
Quartile 4	29 ( 25.4%)	5 (17.2%)	17 (58.6%)	7 (24.1%)	

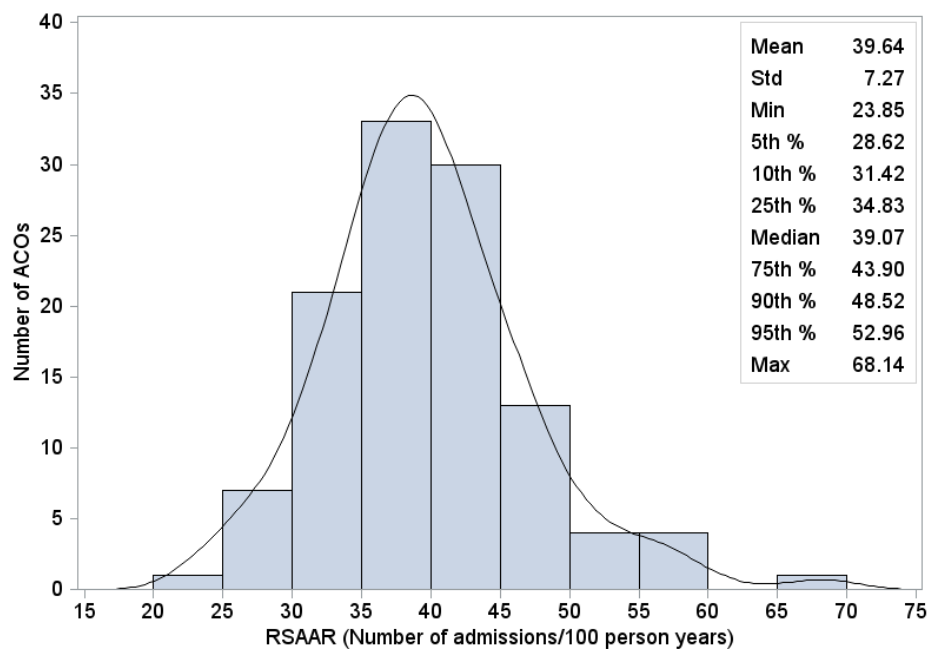
<sup>\*</sup> Divided into quartiles, Quartile 1 indicating lowest proportion and Quartile 4 highest proportion of low SES patients.

<sup>+</sup> Among 114 ACOs, 17 ACOs were in both Quartile 1 (lowest quartile) of proportion of low SES and dual-eligible patients, 15 ACOs were in both Quartile 4 (highest quartile) of proportion of low SES and dual-eligible patients.

**Figure 1. Time periods used to develop measures**

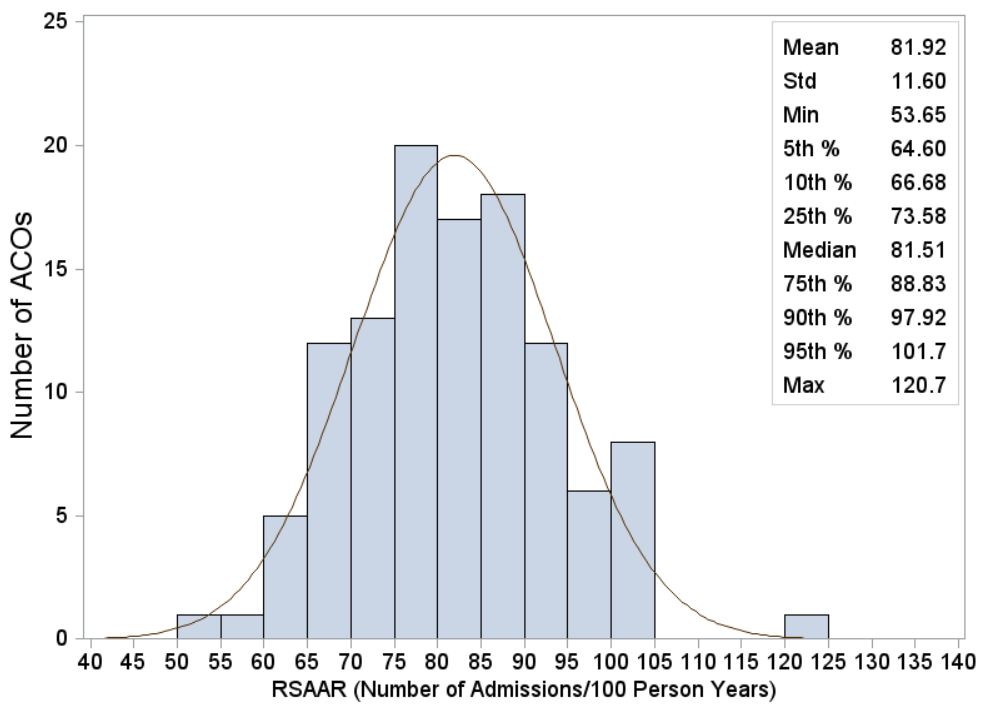


**Figure 2. Distribution of risk-standardized acute admission rates (RSAARs) across ACOs for the diabetes measure**



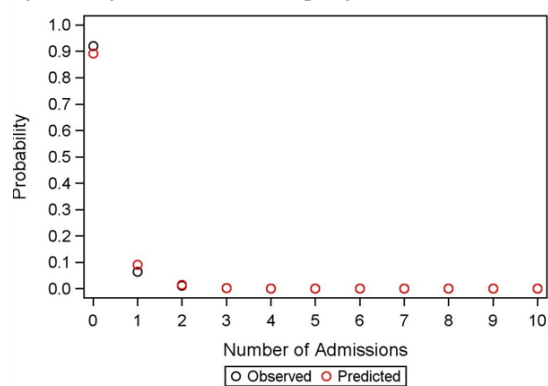


**Figure 3. Distribution of risk-standardized acute admission rates (RSAARs) across ACOs for the heart failure measure**



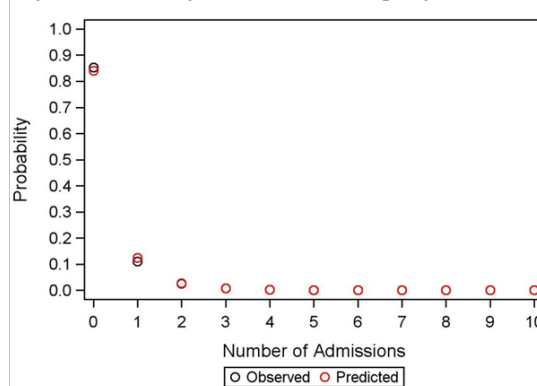
**Figure 4. Comparison of observed versus predicted probability of each number of hospital admissions (0, 1, 2, ..., 10) among diabetes patients in the diabetes measure by risk quartile**

**A) Lowest predicted admission group**



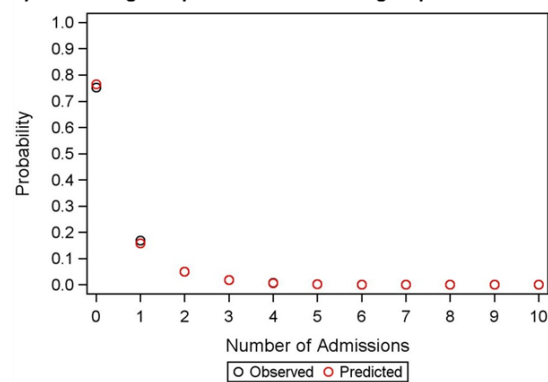
Range of predicted admission rate: 8 to 17 admissions per 100 person-years  
 Median: 13  
 IQR: 11 to 15

**B) Second lowest predicted admission group**



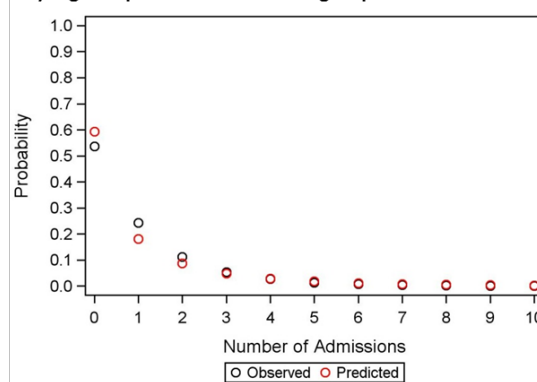
Range of predicted admission rate: 17 to 27 admissions per 100 person-years  
 Median: 21  
 IQR: 19 to 24

**C) Second highest predicted admission group**



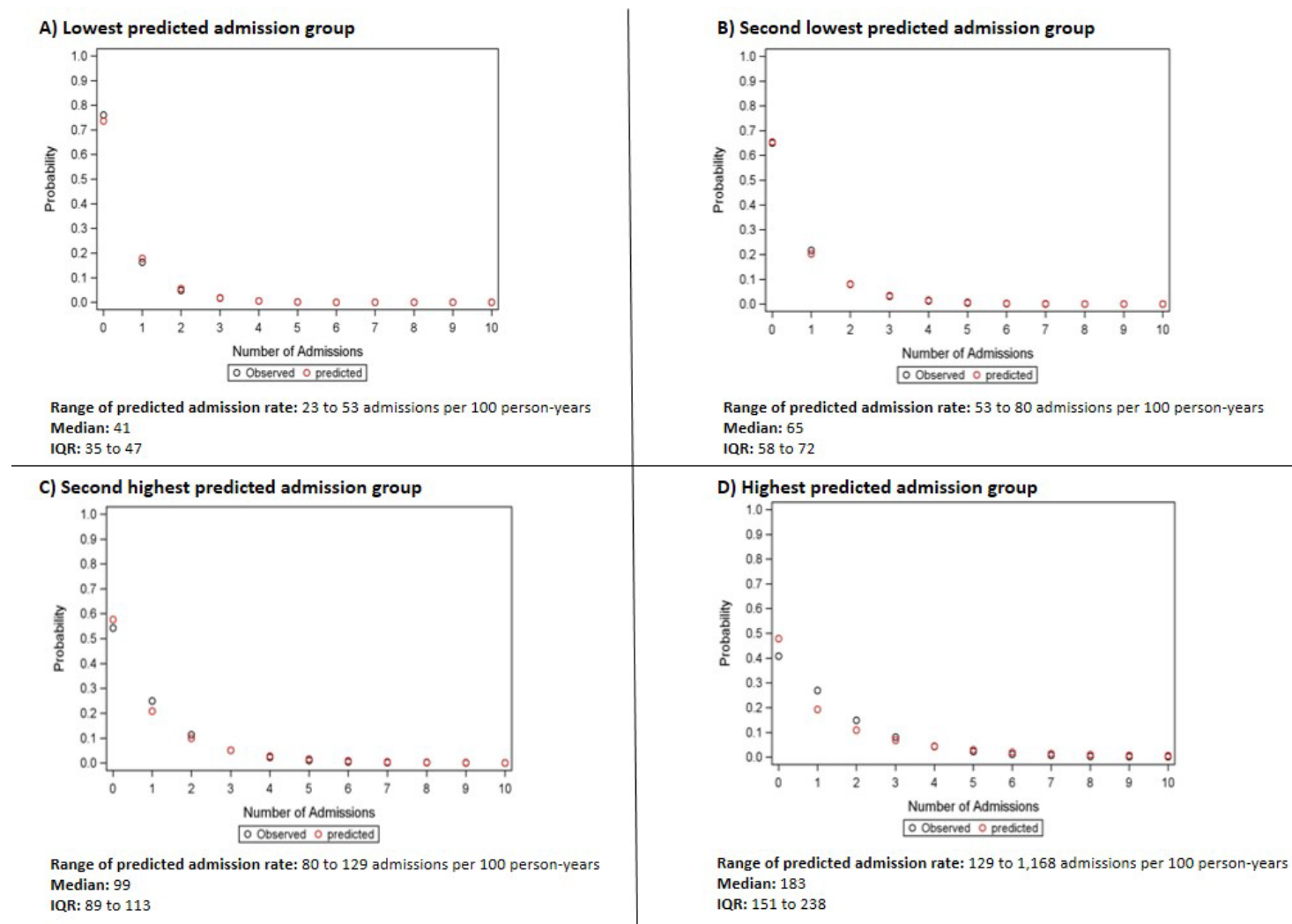
Range of predicted admission rate: 27 to 53 admissions per 100 person-years  
 Median: 36  
 IQR: 31 to 43

**D) Highest predicted admission group**

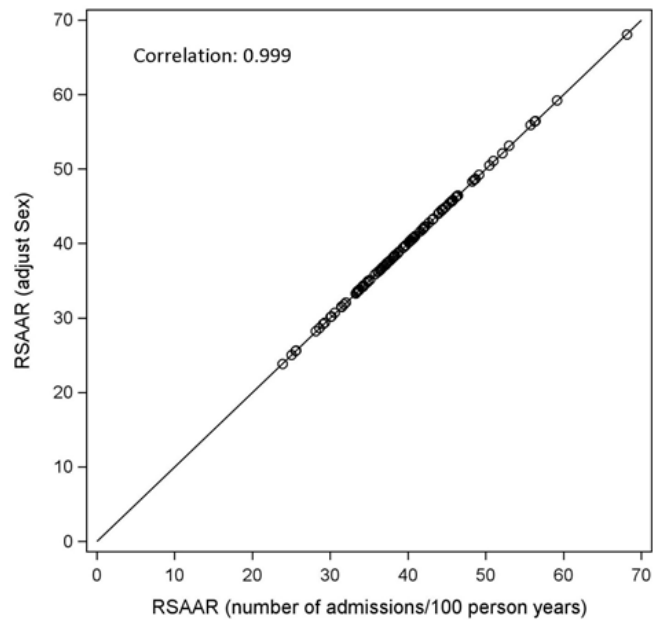


Range of predicted admission rate: 53 to 2,783 admissions per 100 person-years  
 Median: 96  
 IQR: 69 to 158

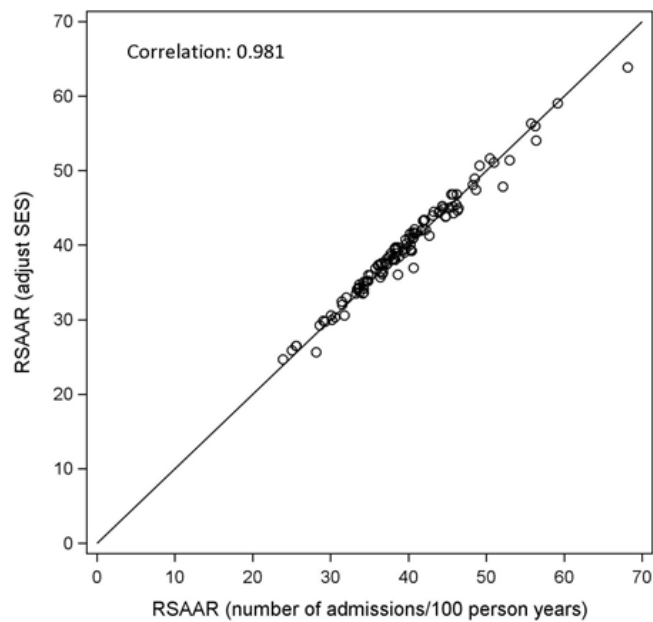
**Figure 5. Comparison of observed versus predicted probability of each number of hospital admissions (0, 1, 2, ..., 10) among heart failure patients in the heart failure measure by risk quartile**



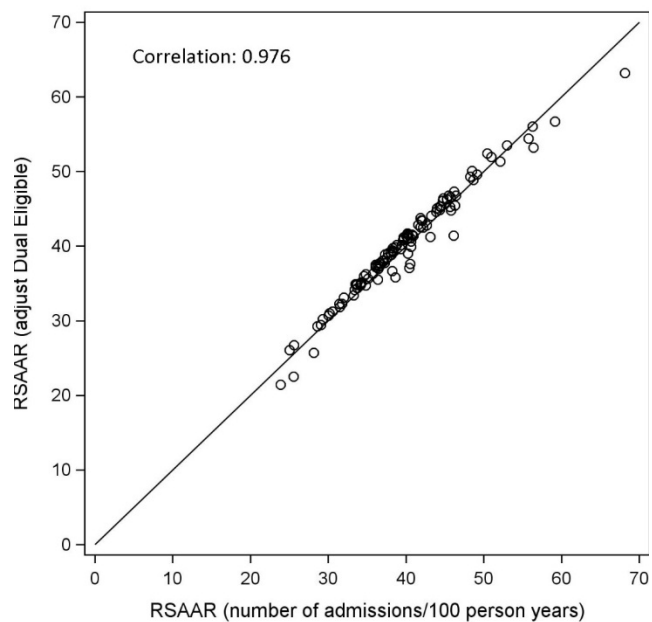
**Figure 6. Plot of risk-standardized acute admission rates (RSAARs) with and without adjustment for sex among patients with diabetes**



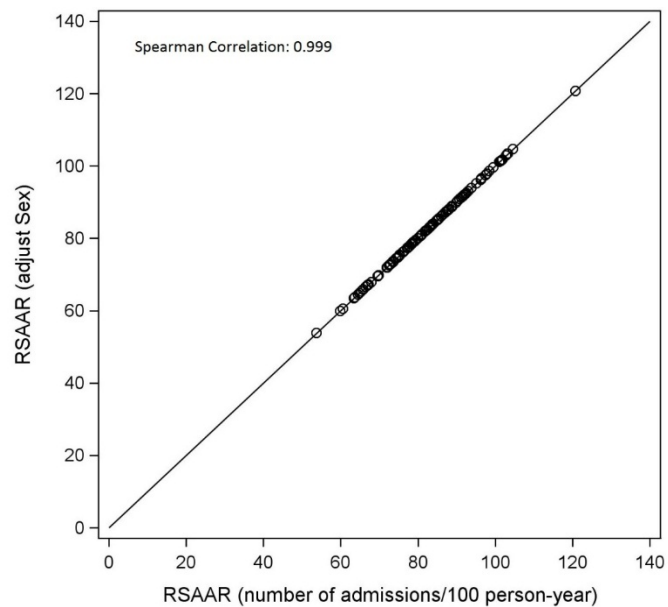
**Figure 7. Plot of risk-standardized acute admission rates (RSAARs) with and without adjustment for AHRQ SES Index among patients with diabetes**



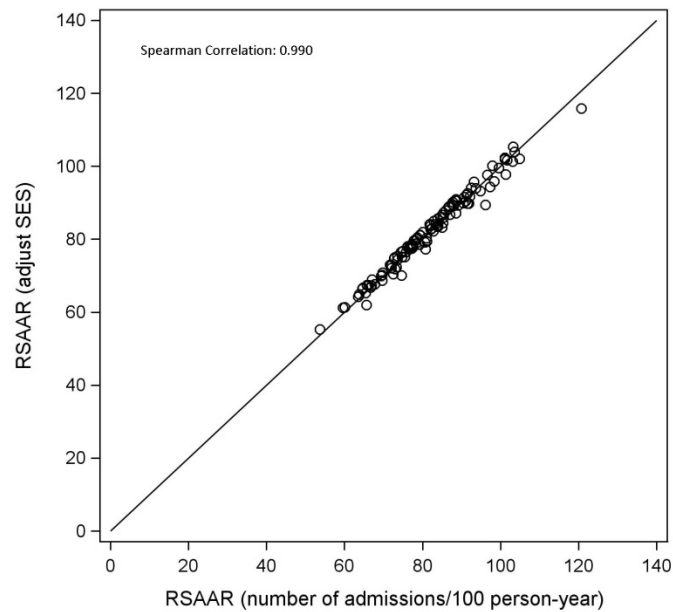
**Figure 8. Plot of risk-standardized acute admission rates (RSAARs) with and without adjustment for Medicaid dual-eligibility status among patients with diabetes**



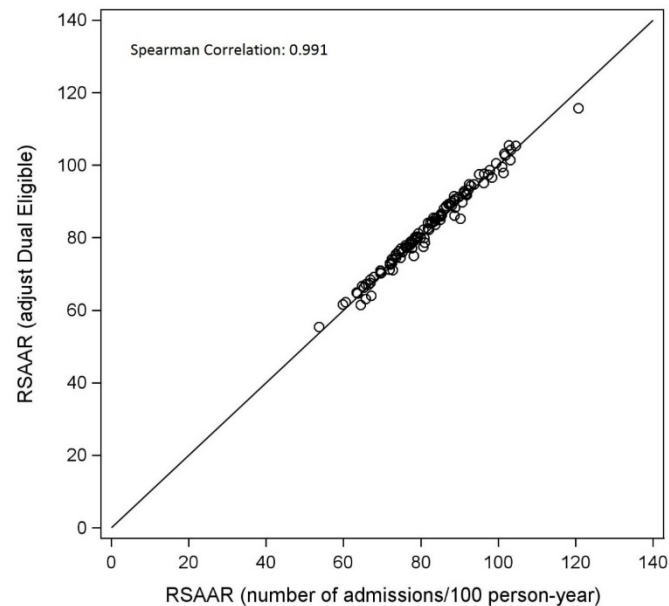
**Figure 9. Plot of risk-standardized acute admission rates (RSAARs) with and without adjustment for sex among patients with heart failure**



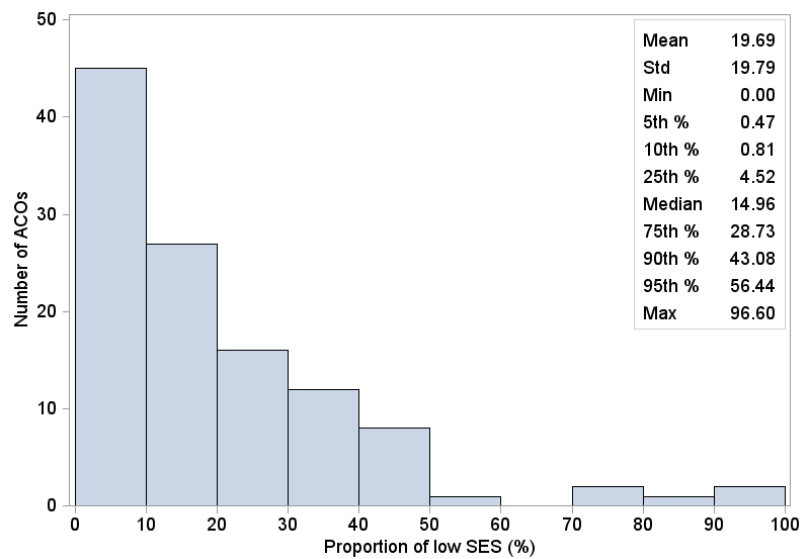
**Figure 10. Plot of risk-standardized acute admission rates (RSAARs) with and without adjustment for AHRQ SES Index among patients with heart failure**



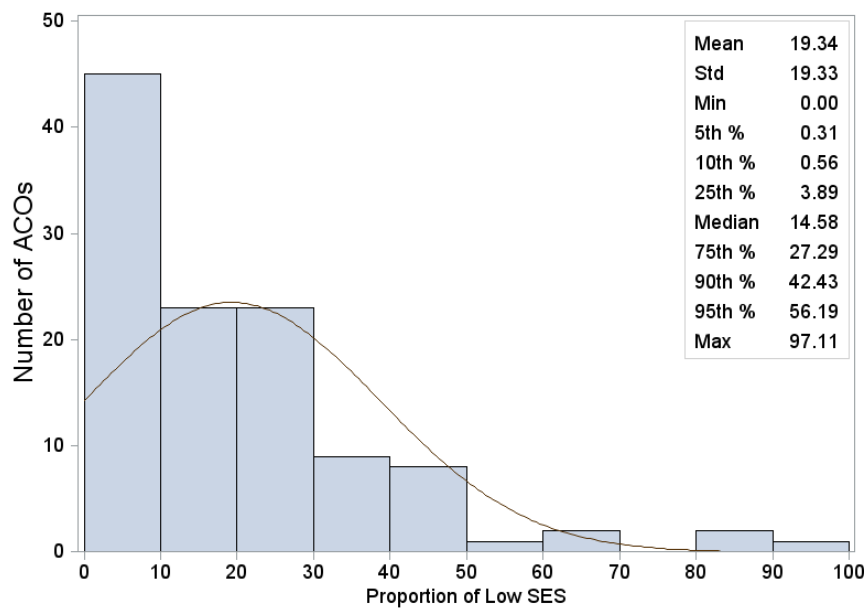
**Figure 11. Plot of risk-standardized acute admission rates (RSAARs) with and without adjustment for Medicaid dual-eligibility status among patients with heart failure**



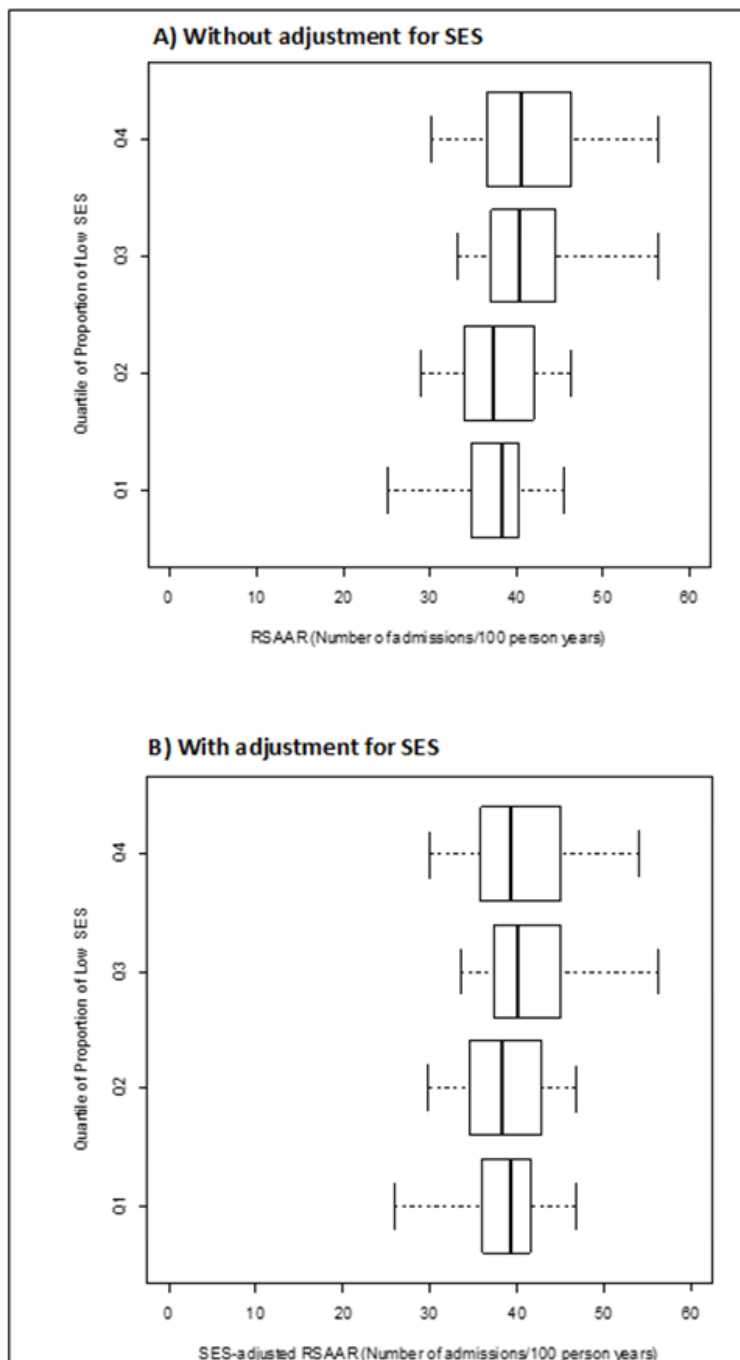
**Figure 12. Distribution of proportion of low SES patients (based on AHRQ SES Index) across ACOs; diabetes measure**



**Figure 13. Distribution of proportion of low SES patients (based on AHRQ SES Index) across ACOs; heart failure measure**



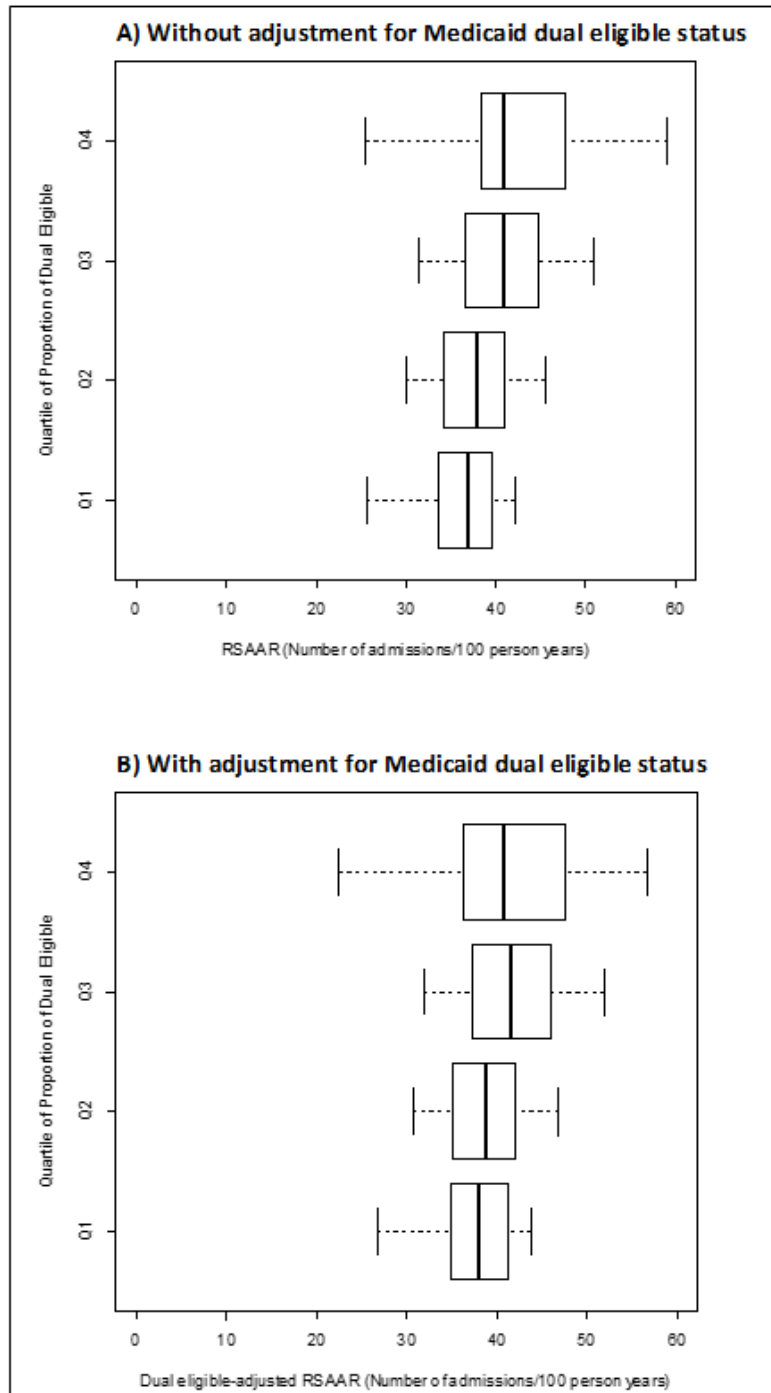
**Figure 14. Boxplot of risk-standardized acute admission rates (RSAARs), comparing ACOs with varying proportions of low SES patients with diabetes (based on AHRQ SES Index; Quartile 1 [Q1]: ACOs with few low SES patients; Quartile 4 [Q4]: ACOs with many low SES patients)**



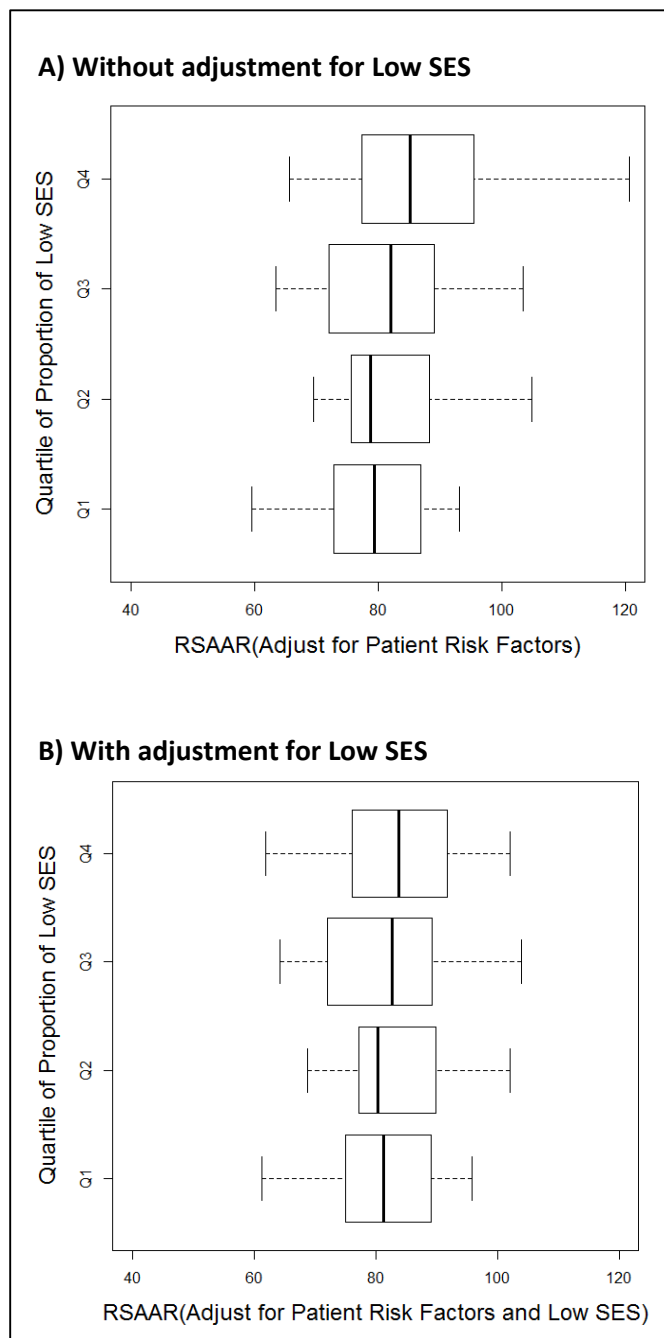
The median is indicated by the vertical line that runs down the center of the box. The box indicates values in the interquartile range (from Quartile 1 [Q1] – Quartile 3 [Q3]). In this boxplot, the whiskers (the two horizontal lines) extend to the 5<sup>th</sup> and 95<sup>th</sup> percentiles.



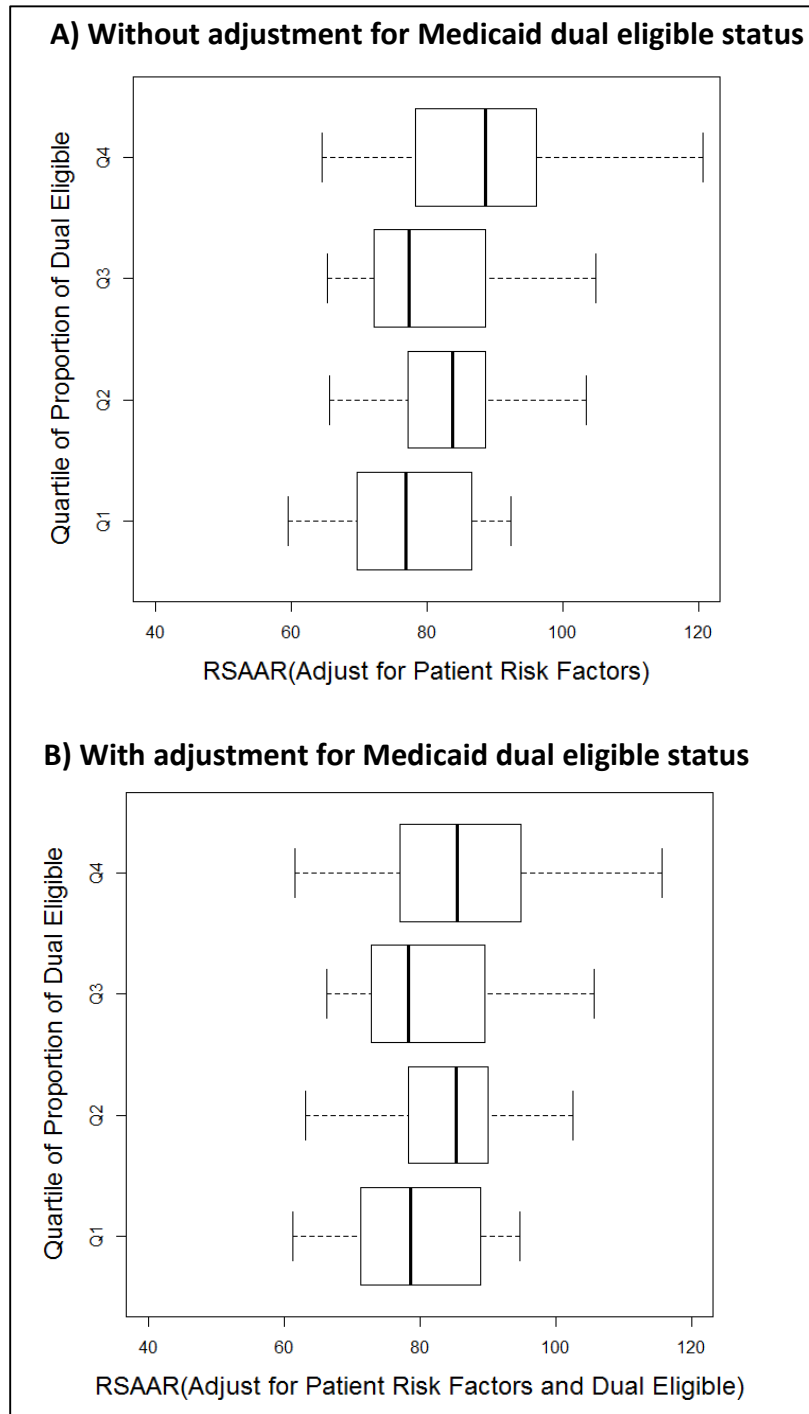
**Figure 15. Boxplot of risk-standardized acute admission rates (RSAARs), comparing ACOs with varying proportions of Medicaid dual-eligible patients with diabetes (Quartile 1 [Q1]: ACOs with few Medicaid dual-eligible patients; Quartile 4 [Q4]: ACOs with many Medicaid dual-eligible patients)**



**Figure 16. Boxplot of risk-standardized acute admission rates (RSAARs), comparing ACOs with varying proportions of low SES patients with heart failure (based on AHRQ SES Index; Quartile 1 [Q1]: ACOs with few low SES patients; Quartile 4 [Q4]: ACOs with many low SES patients)**



**Figure 17. Boxplot of risk-standardized acute admission rates (RSAARs), comparing ACOs with varying proportions of Medicaid dual-eligible patients with heart failure (Quartile 1 [Q1]: ACOs with few Medicaid dual-eligible patients; Quartile 4 [Q4]: ACOs with many Medicaid dual-eligible patients)**



## 8. Appendices

## **Appendix A: CMS Planned Readmission Algorithm Version 3.0, Adapted to Identify Planned Admissions for Diabetes and Heart Failure Patients**

### *A.1. Planned Admission Algorithm Overview*

The planned admission algorithm used in the development of these admission measures is adapted from the CMS Planned Readmission Algorithm Version 3.0.<sup>27</sup> The algorithm is a set of criteria for classifying admissions as planned or unplanned using Medicare claims. CMS seeks to count only unplanned admissions in the measure outcome, because variation in planned admissions does not reflect quality differences.

CORE developed the planned readmission algorithm under contract to CMS based on a hospital-wide (not condition-specific) cohort of patients. The current algorithm, Version 3.0, was modified slightly from Version 2.1, which has been reviewed and endorsed by the National Quality Forum.<sup>41</sup> Version 3.0 incorporates improvements made following a validation study of the algorithm using data from a review of 634 medical records at seven hospitals.<sup>42</sup>

We have adapted the planned admission algorithm for the two specific cohorts of diabetes and heart failure patients. The adapted algorithm classifies admissions as planned or unplanned using a flow chart (Figure PA1) and four tables of procedures and conditions (Table PA1-Table PA4). Table PA1 identifies procedures that, if present in an admission, classify the admission as planned.

Table PA2 identifies principal discharge diagnoses that classify admissions as planned. Table PA3 identifies procedures that, if present, classify an admission as planned as long as that admission does not have an acute (unplanned) principal discharge diagnosis. Table PA4 lists the acute principal discharge diagnoses that disqualify admissions with a potentially planned procedure in Table PA3 as planned.

The algorithm uses the AHRQ's Clinical Classification Software (CCS) codes<sup>43</sup> to group thousands of individual procedure and diagnosis ICD-9-CM codes into clinically coherent, mutually exclusive procedure CCS categories and mutually exclusive diagnosis CCS categories, respectively.

In applying the algorithm to the diabetes and heart failure populations, our team reviewed the General Population version of the planned readmission algorithm in the context of these specific groups of patients. Where clinically indicated, we adapted the content of the tables to better reflect the likely clinical experience of diabetes and/or heart failure patients.

After detailed review, we determined that the General Population algorithm applies accurately to the specific populations of diabetes and heart failure patients, with two exceptions: we removed cardiac catheterization (procedure CCS 47) and amputation of lower extremity (procedure CCS 152) as potentially planned procedures. There were several reasons for excluding these from planned procedures. First, medical record reviews indicate that these two procedures are frequently unplanned.<sup>42</sup> Cardiac catheterization in the absence of percutaneous transluminal coronary angioplasty (PTCA) does not generally require a hospital admission, and when a hospital admission does occur, it is generally in the context of acute illness. Similarly, amputation of the lower extremity is generally performed when a chronic complication (such as an ulcer) fails to be addressed or treated, or progresses despite treatment, to the point that an acute intervention is required. Thus, the medical record review findings and clinical judgment indicated these two procedures should not be counted as planned for this population.

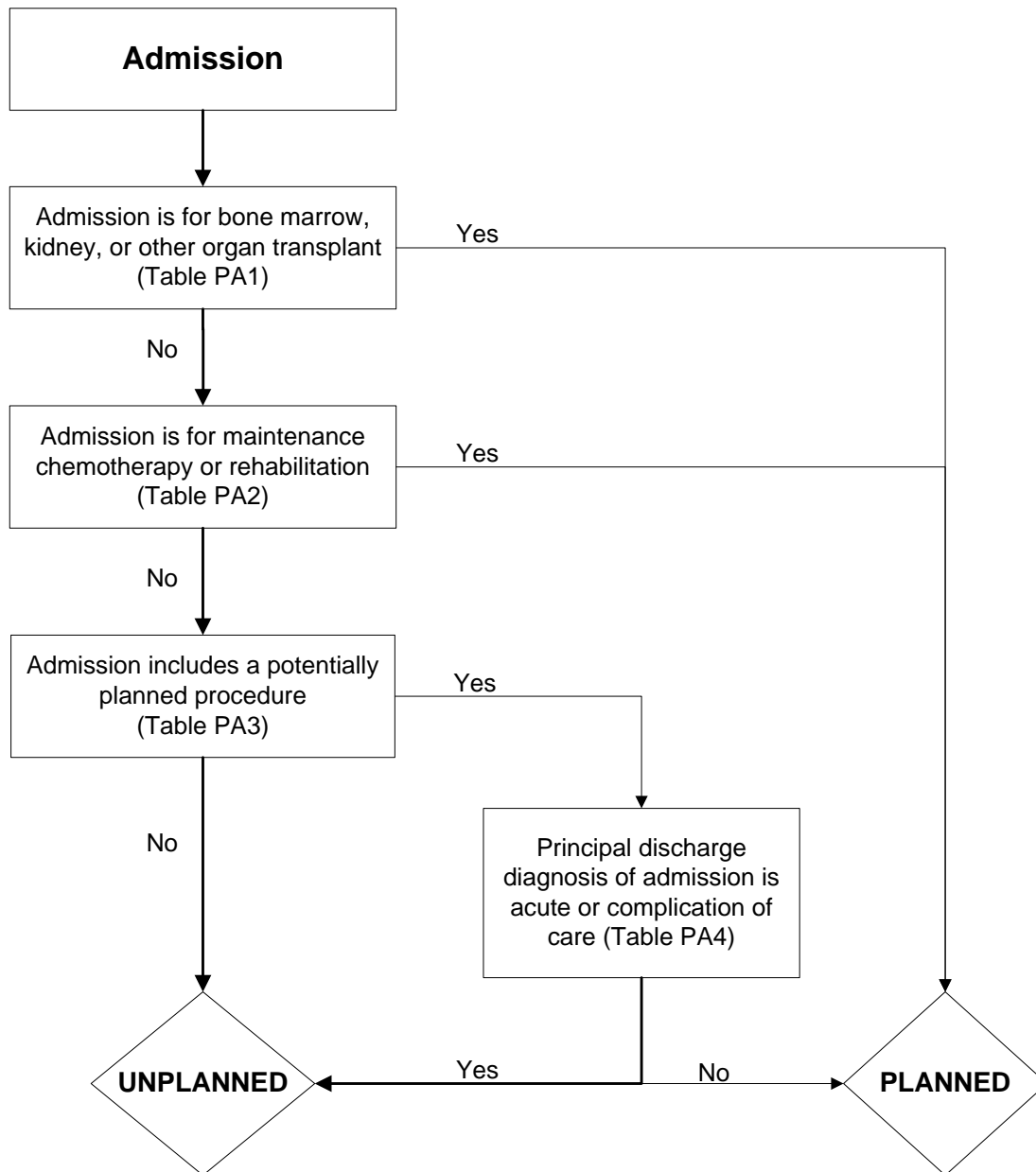
## *A.2. Detailed Description of Planned Admission Algorithm – Diabetes and Heart Failure Populations*

The adapted admission algorithm uses the flow chart (Figure PA1) and Table PA1-Table PA4, adapted for the diabetes/heart failure population, to identify specific procedure categories and discharge diagnosis categories to classify admissions as planned or unplanned. As illustrated in the flow chart (Figure PA1), admissions that include certain procedures (Table PA1) or are for certain diagnoses (Table PA2) are always considered planned. If the admission does not include a procedure or diagnosis in Table PA1 or Table PA2 that is always considered planned, the algorithm checks whether the admission has at least one procedure that is considered potentially planned (Table PA3). If the admission has no procedures from Table PA3, the admission is considered unplanned. Table PA3 includes 64 AHRQ procedure CCS categories from among 231 AHRQ procedure CCS. Examples of potentially planned procedures are total and partial hip replacement (Procedure CCS 153) and coronary artery bypass graft (CABG) (Procedure CCS 44).

If an admission has at least one potentially planned procedure from Table PA3, the algorithm checks for a principal discharge diagnosis that is considered acute (Table PA4). If the admission has an acute principal discharge diagnosis from Table PA4, the admission is considered unplanned. Otherwise, it is considered planned. The list of acute principal discharge diagnoses includes 101 diagnosis groups from among 285 AHRQ condition categories and six groupings of individual ICD-9-CM diagnosis codes that represent cardiac diagnoses that would not be associated with a planned admission. Examples of acute principal discharge diagnoses that would flag admissions with potentially planned procedures as unplanned are pneumonia (Diagnosis CCS 122) and cardiac arrest (Diagnosis CCS 107).

### A.3. Figures and Tables for Planned Admission Algorithm

**Figure PA1. Planned admission algorithm flow chart**



**Table PA1. Procedure categories that are always planned (diabetes and heart failure populations; no change from general population)**

Procedure CCS	Description
64	Bone marrow transplant
105	Kidney transplant
134	Cesarean section*
135	Forceps; vacuum; and breech delivery
176	Other organ transplantation

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

**Table PA2. Diagnosis categories that are always planned (diabetes and heart failure populations; no change from general population)**

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

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



**Table PA3. Potentially planned procedure categories (diabetes and heart failure populations)**

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

Code Type	Code	Description
Procedure CCS	113	Transurethral resection of prostate (TURP)
Procedure CCS	114	Open prostatectomy
Procedure CCS	119	Oophorectomy, unilateral and bilateral
Procedure CCS	120	Other operations on ovary
Procedure CCS	124	Hysterectomy, abdominal and vaginal
Procedure CCS	129	Repair of cystocele and rectocele, obliteration of vaginal vault
Procedure CCS	132	Other OR therapeutic procedures, female organs
Procedure CCS	142	Partial excision bone
Procedure CCS	152	Knee arthroplasty
Procedure CCS	153	Hip replacement, total and partial
Procedure CCS	154	Arthroplasty other than hip or knee
Procedure CCS	158	Spinal fusion
Procedure CCS	159	Other diagnostic procedures on musculoskeletal system
Procedure CCS	166	Lumpectomy; quadrantectomy of breast
Procedure CCS	167	Mastectomy
Procedure CCS	169	Debridement of wound; infection or burn
Procedure CCS	170	Excision of skin lesion
Procedure CCS	172	Skin graft
ICD-9 Codes	30.1, 30.29, 30.3, 30.4, 31.74, 34.6	Laryngectomy, revision of tracheostomy, scarification of pleura (from Procedure CCS 42: Other OR Rx procedures on respiratory system and mediastinum)
ICD-9 Codes	38.18	Endarterectomy leg vessel (from Procedure CCS 60: Embolectomy and endarterectomy of lower limbs)
ICD-9 Codes	55.03, 55.04	Percutaneous nephrostomy with and without fragmentation (from Procedure CCS 103: Nephrotomy and nephrostomy)
ICD-9 Codes	94.26, 94.27	Electroshock therapy (from Procedure CCS 218: Psychological and psychiatric evaluation and therapy)

**Table PA4. Acute diagnosis categories (diabetes and heart failure populations; no change from general population)**

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

Code Type	Code	Description
Diagnosis CCS	120	Hemorrhoids
Diagnosis CCS	122	Pneumonia (except that caused by TB or sexually transmitted disease)
Diagnosis CCS	123	Influenza
Diagnosis CCS	124	Acute and chronic tonsillitis
Diagnosis CCS	125	Acute bronchitis
Diagnosis CCS	126	Other upper respiratory infections
Diagnosis CCS	127	Chronic obstructive pulmonary disease and bronchiectasis
Diagnosis CCS	128	Asthma
Diagnosis CCS	129	Aspiration pneumonitis; food/vomitus
Diagnosis CCS	130	Pleurisy; pneumothorax; pulmonary collapse
Diagnosis CCS	131	Respiratory failure; insufficiency; arrest (adult)
Diagnosis CCS	135	Intestinal infection
Diagnosis CCS	137	Diseases of mouth; excluding dental
Diagnosis CCS	139	Gastroduodenal ulcer (except hemorrhage)
Diagnosis CCS	140	Gastritis and duodenitis
Diagnosis CCS	142	Appendicitis and other appendiceal conditions
Diagnosis CCS	145	Intestinal obstruction without hernia
Diagnosis CCS	146	Diverticulosis and diverticulitis
Diagnosis CCS	148	Peritonitis and intestinal abscess
Diagnosis CCS	153	Gastrointestinal hemorrhage
Diagnosis CCS	154	Noninfectious gastroenteritis
Diagnosis CCS	157	Acute and unspecified renal failure
Diagnosis CCS	159	Urinary tract infections
Diagnosis CCS	165	Inflammatory conditions of male genital organs
Diagnosis CCS	168	Inflammatory diseases of female pelvic organs
Diagnosis CCS	172	Ovarian cyst
Diagnosis CCS	197	Skin and subcutaneous tissue infections
Diagnosis CCS	198	Other inflammatory condition of skin
Diagnosis CCS	225	Joint disorders and dislocations; trauma-related
Diagnosis CCS	226	Fracture of neck of femur (hip)
Diagnosis CCS	227	Spinal cord injury
Diagnosis CCS	228	Skull and face fractures
Diagnosis CCS	229	Fracture of upper limb
Diagnosis CCS	230	Fracture of lower limb
Diagnosis CCS	232	Sprains and strains
Diagnosis CCS	233	Intracranial injury
Diagnosis CCS	234	Crushing injury or internal injury
Diagnosis CCS	235	Open wounds of head; neck; and trunk
Diagnosis CCS	237	Complication of device; implant or graft
Diagnosis CCS	238	Complications of surgical procedures or medical care

Code Type	Code	Description
Diagnosis CCS	239	Superficial injury; contusion
Diagnosis CCS	240	Burns
Diagnosis CCS	241	Poisoning by psychotropic agents
Diagnosis CCS	242	Poisoning by other medications and drugs
Diagnosis CCS	243	Poisoning by nonmedicinal substances
Diagnosis CCS	244	Other injuries and conditions due to external causes
Diagnosis CCS	245	Syncope
Diagnosis CCS	246	Fever of unknown origin
Diagnosis CCS	247	Lymphadenitis
Diagnosis CCS	249	Shock
Diagnosis CCS	250	Nausea and vomiting
Diagnosis CCS	251	Abdominal pain
Diagnosis CCS	252	Malaise and fatigue
Diagnosis CCS	253	Allergic reactions
Diagnosis CCS	259	Residual codes; unclassified
Diagnosis CCS	650	Adjustment disorders
Diagnosis CCS	651	Anxiety disorders
Diagnosis CCS	652	Attention-deficit, conduct, and disruptive behavior disorders
Diagnosis CCS	653	Delirium, dementia, and amnestic and other cognitive disorders
Diagnosis CCS	656	Impulse control disorders, NEC
Diagnosis CCS	658	Personality disorders
Diagnosis CCS	660	Alcohol-related disorders
Diagnosis CCS	661	Substance-related disorders
Diagnosis CCS	662	Suicide and intentional self-inflicted injury
Diagnosis CCS	663	Screening and history of mental health and substance abuse codes
Diagnosis CCS	670	Miscellaneous disorders
ICD-9*	03282	Diphtheritic myocarditis
ICD-9*	03640	Meningococcal carditis NOS
ICD-9*	03641	Meningococcal pericarditis
ICD-9*	03642	Meningococcal endocarditis
ICD-9*	03643	Meningococcal myocarditis
ICD-9*	07420	Coxsackie carditis NOS
ICD-9*	07421	Coxsackie pericarditis
ICD-9*	07422	Coxsackie endocarditis
ICD-9*	07423	Coxsackie myocarditis
ICD-9*	11281	Candidal endocarditis
ICD-9*	11503	Histoplasma capsulatum pericarditis
ICD-9*	11504	Histoplasma capsulatum endocarditis
ICD-9*	11513	Histoplasma duboisii pericarditis
ICD-9*	11514	Histoplasma duboisii endocarditis
ICD-9*	11593	Histoplasmosis pericarditis

Code Type	Code	Description
ICD-9*	11594	Histoplasmosis endocarditis
ICD-9*	1303	Toxoplasma myocarditis
ICD-9*	3910	Acute rheumatic pericarditis
ICD-9*	3911	Acute rheumatic endocarditis
ICD-9*	3912	Acute rheumatic myocarditis
ICD-9*	3918	Acute rheumatic heart disease NEC
ICD-9*	3919	Acute rheumatic heart disease NOS
ICD-9*	3920	Rheumatic chorea w heart involvement
ICD-9*	3980	Rheumatic myocarditis
ICD-9*	39890	Rheumatic heart disease NOS
ICD-9*	39899	Rheumatic heart disease NEC
ICD-9*	4200	Acute pericarditis in other disease
ICD-9*	42090	Acute pericarditis NOS
ICD-9*	42091	Acute idiopath pericarditis
ICD-9*	42099	Acute pericarditis NEC
ICD-9*	4210	Acute/sub-acute bacterial endocarditis
ICD-9*	4211	Acute endocarditis in other diseases
ICD-9*	4219	Acute/sub-acute endocarditis NOS
ICD-9*	4220	Acute myocarditis in other diseases
ICD-9*	42290	Acute myocarditis NOS
ICD-9*	42291	Idiopathic myocarditis
ICD-9*	42292	Septic myocarditis
ICD-9*	42293	Toxic myocarditis
ICD-9*	42299	Acute myocarditis NEC
ICD-9*	4230	Hemopericardium
ICD-9*	4231	Adhesive pericarditis
ICD-9*	4232	Constrictive pericarditis
ICD-9*	4233	Cardiac tamponade
ICD-9*	4290	Myocarditis NOS
ICD-9†	4260	Atrioventricular block, complete
ICD-9†	42610	Atrioventricular block NOS
ICD-9†	42611	Atrioventricular block-1st degree
ICD-9†	42612	Atrioventricular block-Mobitz II
ICD-9†	42613	Atrioventricular block-2nd degree NEC
ICD-9†	4262	Left bundle branch hemiblock
ICD-9†	4263	Left bundle branch block NEC
ICD-9†	4264	Right bundle branch block
ICD-9†	42650	Bundle branch block NOS
ICD-9†	42651	Right bundle branch block/left posterior fascicular block
ICD-9†	42652	Right bundle branch block/left ant fascicular block
ICD-9†	42653	Bilateral bundle branch block NEC

Code Type	Code	Description
ICD-9 <sup>†</sup>	42654	Trifascicular block
ICD-9 <sup>†</sup>	4266	Other heart block
ICD-9 <sup>†</sup>	4267	Anomalous atrioventricular excitation
ICD-9 <sup>†</sup>	42681	Lown-Ganong-Levine syndrome
ICD-9 <sup>†</sup>	42682	Long QT syndrome
ICD-9 <sup>†</sup>	4269	Conduction disorder NOS
ICD-9 <sup>‡</sup>	4272	Paroxysmal tachycardia NOS
ICD-9 <sup>‡</sup>	7850	Tachycardia NOS
ICD-9 <sup>‡</sup>	42789	Cardiac dysrhythmias NEC
ICD-9 <sup>‡</sup>	4279	Cardiac dysrhythmia NOS
ICD-9 <sup>‡</sup>	42769	Premature beats NEC
ICD-9 <sup>§</sup>	39891	Rheumatic heart failure
ICD-9 <sup>§</sup>	4280	Congestive heart failure
ICD-9 <sup>§</sup>	4281	Left heart failure
ICD-9 <sup>§</sup>	42820	Unspecified systolic heart failure
ICD-9 <sup>§</sup>	42821	Acute systolic heart failure
ICD-9 <sup>§</sup>	42823	Acute on chronic systolic heart failure
ICD-9 <sup>§</sup>	42830	Unspecified diastolic heart failure
ICD-9 <sup>§</sup>	42831	Acute diastolic heart failure
ICD-9 <sup>§</sup>	42833	Acute on chronic diastolic heart failure
ICD-9 <sup>§</sup>	42840	Unspecified combined systolic & diastolic heart failure
ICD-9 <sup>§</sup>	42841	Acute combined systolic & diastolic heart failure
ICD-9 <sup>§</sup>	42843	Acute on chronic combined systolic & diastolic heart failure
ICD-9 <sup>§</sup>	4289	Heart failure NOS
ICD-9 <sup>**</sup>	5740	Calculus of gallbladder with acute cholecystitis
ICD-9 <sup>**</sup>	57400	Calculus of gallbladder with acute cholecystitis without mention of obstruction
ICD-9 <sup>**</sup>	57401	Calculus of gallbladder with acute cholecystitis with obstruction
ICD-9 <sup>**</sup>	5743	Calculus of bile duct with acute cholecystitis
ICD-9 <sup>**</sup>	57430	Calculus of bile duct with acute cholecystitis without mention of obstruction
ICD-9 <sup>**</sup>	57431	Calculus of bile duct with acute cholecystitis with obstruction
ICD-9 <sup>**</sup>	5746	Calculus of gallbladder and bile duct with acute cholecystitis
ICD-9 <sup>**</sup>	57460	Calculus of gallbladder and bile duct with acute cholecystitis without mention of obstruction
ICD-9 <sup>**</sup>	57461	Calculus of gallbladder and bile duct with acute cholecystitis with obstruction
ICD-9 <sup>**</sup>	5748	Calculus of gallbladder and bile duct with acute and chronic cholecystitis
ICD-9 <sup>**</sup>	57480	Calculus of gallbladder and bile duct with acute and chronic cholecystitis without mention of obstruction

Code Type	Code	Description
ICD-9**	57481	Calculus of gallbladder and bile duct with acute and chronic cholecystitis with obstruction
ICD-9**	5750	Acute cholecystitis
ICD-9**	57512	Acute and chronic cholecystitis
ICD-9**	5761	Cholangitis
ICD-9††	5770	Acute pancreatitis

\*These ICD-9 codes represent acute ICD-9 codes within Diagnosis (Dx) CCS 97: Peri-, endo-, and myocarditis; cardiomyopathy

†These ICD-9 codes represent acute ICD-9 codes within Dx CCS 105: Conduction disorders

‡These ICD-9 codes represent acute ICD-9 codes within Dx CCS 106: Dysrhythmia

§These ICD-9 codes represent acute ICD-9 codes within Dx CCS 108: Congestive heart failure; non-hypertensive

\*\* These ICD-9 codes represent acute ICD-9 codes within Dx CCS 149: Biliary tract disease

†† This ICD-9 code represents acute ICD-9 codes within Dx CCS 152: Pancreatic disorders



## Appendix B: Calculation Algorithm

As the first step in model development, we looked at the effects of patient-level risk factors on the outcome (by fitting a generalized linear model [GLM]) based on all patients in FFS Medicare included in the diabetes and heart failure cohorts, regardless of whether they were assigned to an ACO. Next, in order to measure ACO performance, we computed the ratio of the predicted admissions to expected admissions. To do this, we fitted a hierarchical generalized linear model (HGLM) to account for the natural clustering of patients within ACOs and estimated ACOs' predicted performance based on the effects of the risk factors estimated in the first step. We calculated the number of expected admissions for each ACO based on the performance of an average ACO with the same case-mix of patients. Since the effects that risk factors exert on the number of admissions are estimated based on data from all ACO and non-ACO patients in the cohorts (diabetes and heart failure), the expected outcome reflects "nationwide" expectation. This approach allows for the possibility of all ACOs performing better (or worse) than the national average.

We selected the model form based on statistical considerations. Since our outcome is the number of acute hospital admissions, we considered three models appropriate for this outcome: negative binomial, Poisson, and quasi-Poisson models. For our analyses, we used the entire diabetes and heart failure cohorts and then restricted the analyses to diabetes and heart failure beneficiaries assigned to ACOs. We examined parameters for assessing goodness of fit, including the Akaike information criterion (AIC), the Bayesian information criterion (BIC), and deviance. In all of our analyses, the negative binomial model exhibited the best model fit.

We followed the following steps in developing these models:

1. First, we fitted a generalized linear model linking the outcome (the number of acute all-cause admissions per patient-years of risk exposure during the measurement period) to the risk factors using data from all of the included people in the diabetes cohort and the heart failure cohort, respectively, regardless of whether they were assigned to an ACO or not. Beta-coefficients for our risk factors were therefore derived from ACO and non-ACO patients in each cohort.

Let  $Y_j$  denote the outcome for the  $j^{th}$  patient,  $X_j$  a set of patient specific risk factors, and  $J$  the total number of patients. We assume the outcome is related linearly to the covariates via a known linked function  $h$ , where:

$$\text{GLM} \quad h(Y_j) = \alpha_0 + \beta X_j \quad (1)$$

$X_j = (X_{1j}, X_{2j}, \dots, X_{pj})$  is a set of  $p$  patient-specific covariates for the  $j^{th}$  patient.  $N_j$  denotes the total number of admissions during the measurement period and  $M_j$  denotes the person-years of risk exposure for the  $j^{th}$  patient. Then  $Y_j = N_j / M_j$  is the number of hospital

admissions per person-years of risk exposure.  $h$  is the log link function. We can rewrite equation (1) as:

$$\log(N_j) = \alpha_0 + \beta X_j + \log(M_j) \quad (2)$$

We fitted the negative binomial model defined by equation (2) and estimated the parameters  $\hat{\alpha}_0, \hat{\beta}$ .

2. To account for the natural clustering of observations within ACOs, we estimated a hierarchical generalized linear model (HGLM) only among patients assigned to ACOs.

Let  $Y_{ij}$  denote the outcome for the  $j^{th}$  patient assigned to the  $i^{th}$  ACO,  $X_{ij}$  a set of risk factors for this patient, which is equal to  $X_j$  as defined above. Let  $I$  denote the total number of ACOs and  $n_i$  the number of patients in  $i^{th}$  ACO.

In this step, we did not estimate the coefficients for  $X_{ij}$ . Instead, we applied the coefficient estimates of  $X_{ij}$  from the first step to the HGLM. Specifically,

$$\text{HGLM} \quad h(Y_{ij}) = \alpha_i + \hat{\beta} X_{ij} \quad (3)$$

By replacing  $Y_{ij}$  with  $N_{ij}/M_{ij}$ , we rewrite the equation (3) as:

$$\log(N_{ij}) = \alpha_i + \hat{\beta} X_{ij} + \log(M_{ij}) \quad (4)$$

$$\alpha_i = \mu + \omega_i; \omega_i \sim N(0, \tau^2) \quad (5)$$

Where  $\alpha_i$  represents the ACO-specific mean outcomes,  $\mu$  the adjusted average outcome over all ACOs among ACO patients, and  $\tau^2$  the between-ACO variance component.  $X_{ij}$  and  $Y_{ij}$  are defined as above. This model separates within-ACO variation from between-ACO variation. However, we accounted for the within-ACO variation based on the estimates of the entire cohort. In this step we needed to estimate the random effects of different ACOs and between variance of these ACOs.

3. We compared ACO performance with national performance.

By applying  $\hat{\beta}$  from the first step to the second step of fitting HGLM, we wanted to ensure that the fixed effects of the predicted and expected portions of the model remain the same. We fitted the HGLM defined by equations (4)-(5) and estimated the parameter  $\{\hat{\alpha}_1, \hat{\alpha}_2, \dots, \hat{\alpha}_I\}, \hat{\mu}$  and  $\hat{\tau}^2$ . We calculated a standardized outcome,  $s_i$ , for each ACO by computing the ratio of the predicted to expected mean outcomes multiplied by the unadjusted national rate. Specifically, we calculated:

$$\text{Predicted } \hat{p}_{ij}(X) = h^{-1}(\hat{\alpha}_i + \hat{\beta}X_{ij})$$

$$\text{Expected } \hat{e}_{ij}(X) = h^{-1}(\hat{\alpha}_0 + \hat{\beta}X_{ij})$$

$$\hat{s}_i(X) = \frac{\sum_{j=1}^{n_i} \hat{p}_{ij}(X)}{\sum_{j=1}^{n_i} \hat{e}_{ij}(X)} \times \bar{y}$$

4. We compared ACO performance with national performance.

By applying  $\hat{\beta}$  from the first step to the second step of fitting HGLM, we wanted to ensure that the fixed effects of the predicted and expected portions of the model remain the same. We fitted the HGLM defined by equations (4)-(5) and estimated the parameter  $\{\hat{\alpha}_1, \hat{\alpha}_2, \dots, \hat{\alpha}_I\}, \hat{\mu}$  and  $\hat{\tau}^2$ . We calculated a standardized outcome,  $s_i$ , for each ACO by computing the ratio of the predicted to expected mean outcomes multiplied by the unadjusted national mean. Specifically, we calculated:

$$\text{Predicted } \hat{p}_{ij}(X) = h^{-1}(\hat{\alpha}_i + \hat{\beta}X_{ij})$$

$$\text{Expected } \hat{e}_{ij}(X) = h^{-1}(\hat{\alpha}_0 + \hat{\beta}X_{ij})$$

$$\hat{s}_i(X) = \frac{\sum_{j=1}^{n_i} \hat{p}_{ij}(X)}{\sum_{j=1}^{n_i} \hat{e}_{ij}(X)} \times \bar{y}$$

## Appendix C: Risk-Adjustment Model

### C.1. Final Variables for the Diabetes Measure

**Table C1. Condition categories (CCs) and International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes used to define risk model variables in diabetes measure**

CC or ICD-9-CM code	Description
<b>High risk cardiovascular (CV) factors</b>	
CC 81	Acute myocardial infarction
CC 82	Unstable Angina and Other Acute Ischemic Heart Disease
CC 89	Hypertensive Heart and Renal Disease or Encephalopathy
CC 104	Vascular Disease with Complications
<b>Low risk CV factors</b>	
CC 83	Angina Pectoris/Old Myocardial Infarction
CC 84	Coronary Atherosclerosis/Other Chronic Ischemic Heart Disease
CC 94	Other and Unspecified Heart Disease
CC 105	Vascular Disease
CC 106	Other Circulatory Disease
<b>Arrhythmia</b>	
CC 92	Specified Heart Arrhythmias
CC 93	Other Heart Rhythm and Conduction Disorders
<b>Advanced cancer</b>	
CC 7	Metastatic Cancer and Acute Leukemia
CC 8	Lung, Upper Digestive Tract, and Other Severe Cancers
CC 9	Lymphatic, Head and Neck, Brain, and Other Major Cancers
CC 11	Other Respiratory and Heart Neoplasms
<b>Dementia</b>	
CC 49	Dementia/Cerebral Degeneration
CC 50	Nonpsychotic Organic Brain Syndromes/Conditions
<b>Heart failure</b>	
CC 80	Congestive Heart Failure
<b>Dialysis status</b>	
CC 130	Dialysis Status
<b>Disability/frailty</b>	
CC 21	Protein-Calorie Malnutrition
CC 67	Quadriplegia, Other Extensive Paralysis
CC 68	Paraplegia

CC or ICD-9-CM code	Description
CC 69	Spinal Cord Disorders/Injuries
CC 100	Hemiplegia/Hemiparesis
CC 116	Legally Blind
CC 148	Decubitus Ulcer of Skin
CC 149	Chronic Ulcer of Skin, Except Decubitus
CC 157	Vertebral Fractures without Spinal Cord Injury
CC 177	Amputation Status, Lower Limb/Amputation Complications
CC 178	Amputation Status, Upper Limb
<b>GI/GU Gastrointestinal and Genitourinary disorders</b>	
CC 29	Other Hepatitis and Liver Disease
CC 30	Gallbladder and Biliary Tract Disorders
CC 31	Intestinal Obstruction/Perforation
CC 33	Inflammatory Bowel Disease
CC 34	Peptic Ulcer, Hemorrhage, Other Specified Gastrointestinal Disorders
CC 133	Urinary Obstruction and Retention
CC 176	Artificial Openings for Feeding or Elimination
<b>Hematological disorders</b>	
CC 44	Severe Hematological Disorders
CC 46	Coagulation Defects and Other Specified Hematological Disorders
<b>Infectious and immune disorders</b>	
CC 1	HIV/AIDS
CC 3	Central Nervous System Infection
CC 4	Tuberculosis
CC 5	Opportunistic Infections
CC 45	Disorders of Immunity
CC 85	Heart Infection/Inflammation, Except Rheumatic
<b>Kidney disease</b>	
CC 128	Kidney Transplant Status
CC 131	Renal Failure
CC 132	Nephritis
<b>Liver disease</b>	
CC 25	End-Stage Liver Disease
CC 26	Cirrhosis of Liver
CC 27	Chronic Hepatitis
CC 28	Acute Liver Failure/Disease
<b>Neurological disease</b>	
CC 48	Delirium and Encephalopathy
CC 61	Profound Mental Retardation/Developmental Disability
CC 65	Other Developmental Disability
CC 70	Muscular Dystrophy

CC or ICD-9-CM code	Description
CC 72	Multiple Sclerosis
CC 73	Parkinson's and Huntington's Diseases
CC 74	Seizure Disorders and Convulsions
CC 75	Coma, Brain Compression/Anoxic Damage
CC 95	Cerebral Hemorrhage
CC 96	Ischemic or Unspecified Stroke
CC 97	Precerebral Arterial Occlusion and Transient Cerebral Ischemia
CC 98	Cerebral Atherosclerosis and Aneurysm
CC 99	Cerebrovascular Disease, Unspecified
CC 101	Cerebral Palsy and Other Paralytic Syndromes
CC 102	Speech, Language, Cognitive, Perceptual Deficits
CC 103	Cerebrovascular Disease Late Effects, Unspecified
CC 155	Major Head Injury
<b>Psychiatric illness/Substance abuse</b>	
CC 51	Drug/Alcohol Psychosis
CC 52	Drug/Alcohol Dependence
CC 53	Drug/Alcohol Abuse, Without Dependence
CC 54	Schizophrenia
CC 55	Major Depressive, Bipolar, and Paranoid Disorders
CC 56	Reactive and Unspecified Psychosis
CC 57	Personality Disorders
CC 58	Depression
CC 59	Anxiety Disorders
CC 60	Other Psychiatric Disorders
<b>Pulmonary disease</b>	
CC 114	Pleural Effusion/Pneumothorax
CC 107	Cystic Fibrosis
CC 108	Chronic Obstructive Pulmonary Disease
CC 109	Fibrosis of Lung and Other Chronic Lung Disorders
CC 110	Asthma
CC 115	Other Lung Disorders
<b>Other advanced organ failure</b>	
CC 79	Cardio-Respiratory Failure and Shock
CC 77	Respirator Dependence/Tracheostomy Status
<b>Iron deficiency anemia</b>	
CC 47	Iron Deficiency and Other/Unspecified Anemias and Blood Disease
<b>Major organ transplant</b>	
CC 174	Major Organ Transplant Status
<b>Other organ transplant</b>	
CC 175	Other Organ Transplant/Replacement

CC or ICD-9-CM code	Description
<b>Hip fracture/major fracture</b>	
CC 158	Hip Fracture/Dislocation
CC 159	Major Fracture, Except of Skull, Vertebrae, or Hip
<b>Variable definition: Diabetes severity index</b>	
*Diabetes severity index is based on the number of complications associated with diabetes, ranges from zero to seven, and has been adapted from Young et al. <sup>30</sup>	

## C.2. Final Variables for the Heart Failure Measure

**Table C2. Condition categories (CCs) and International Classification of Diseases, Ninth Revision, Clinical Modification (ICD-9-CM) codes used to define risk model variables in heart failure measure**

CC or ICD-9-CM code	Description
<b>High risk cardiovascular (CV) factors</b>	
CC 81	Acute myocardial infarction
CC 82	Unstable Angina and Other Acute Ischemic Heart Disease
CC 89	Hypertensive Heart and Renal Disease or Encephalopathy
CC 104	Vascular Disease with Complications
<b>Low risk CV factors</b>	
CC 83	Angina Pectoris/Old Myocardial Infarction
CC 84	Coronary Atherosclerosis/Other Chronic Ischemic Heart Disease
CC 94	Other and Unspecified Heart Disease
CC 105	Vascular Disease
CC 106	Other Circulatory Disease
<b>Arrhythmia</b>	
CC 92	Specified Heart Arrhythmias
CC 93	Other Heart Rhythm and Conduction Disorders
<b>Structural heart disease</b>	
CC 86	Valvular and Rheumatic Heart Disease
CC 87	Major Congenital Cardiac/Circulatory Defect
CC 88	Other Congenital Heart/Circulatory Disease
<b>Advanced cancer</b>	
CC 7	Metastatic Cancer and Acute Leukemia
CC 8	Lung, Upper Digestive Tract, and Other Severe Cancers
CC 9	Lymphatic, Head and Neck, Brain, and Other Major Cancers
CC 11	Other Respiratory and Heart Neoplasms
<b>Dementia</b>	

CC or ICD-9-CM code	Description
CC 49	Dementia/Cerebral Degeneration
CC 50	Nonpsychotic Organic Brain Syndromes/Conditions
<b>Diabetes w/ complications</b>	
CC 15	Diabetes with Renal or Peripheral Circulatory Manifestation
CC 16	Diabetes with Neurologic or Other Specified Manifestation
CC 17	Diabetes with Acute Complications
CC 18	Diabetes with Ophthalmologic or Unspecified Manifestation
CC 19	Diabetes without Complication
CC 119	Proliferative Diabetic Retinopathy and Vitreous Hemorrhage
CC 120	Diabetic and Other Vascular Retinopathies
<b>Dialysis status</b>	
CC 130	Dialysis Status
<b>Disability/frailty</b>	
CC 21	Protein-Calorie Malnutrition
CC 67	Quadriplegia, Other Extensive Paralysis
CC 68	Paraplegia
CC 69	Spinal Cord Disorders/Injuries
CC 100	Hemiplegia/Hemiparesis
CC 116	Legally Blind
CC 148	Decubitus Ulcer of Skin
CC 149	Chronic Ulcer of Skin, Except Decubitus
CC 157	Vertebral Fractures without Spinal Cord Injury
CC 177	Amputation Status, Lower Limb/Amputation Complications
CC 178	Amputation Status, Upper Limb
<b>Gastrointestinal and Genitourinary disorders</b>	
CC 29	Other Hepatitis and Liver Disease
CC 30	Gallbladder and Biliary Tract Disorders
CC 31	Intestinal Obstruction/Perforation
CC 33	Inflammatory Bowel Disease
CC 34	Peptic Ulcer, Hemorrhage, Other Specified Gastrointestinal Disorders
CC 133	Urinary Obstruction and Retention
<b>Hematological disorders</b>	
CC 44	Severe Hematological Disorders
CC 46	Coagulation Defects and Other Specified Hematological Disorders
<b>Infectious and immune disorders</b>	
CC 1	HIV/AIDS
CC 3	Central Nervous System Infection
CC 4	Tuberculosis
CC 5	Opportunistic Infections
CC 45	Disorders of Immunity



CC or ICD-9-CM code	Description
CC 85	Heart Infection/Inflammation, Except Rheumatic
<b>Kidney disease</b>	
CC 128	Kidney Transplant Status
CC 131	Renal Failure
CC 132	Nephritis
<b>Liver disease</b>	
CC 25	End-Stage Liver Disease
CC 26	Cirrhosis of Liver
CC 27	Chronic Hepatitis
CC 28	Acute Liver Failure/Disease
<b>Neurological disease</b>	
CC 48	Delirium and Encephalopathy
CC 61	Profound Mental Retardation/Developmental Disability
CC 65	Other Developmental Disability
CC 70	Muscular Dystrophy
CC 71	Polyneuropathy
CC 72	Multiple Sclerosis
CC 73	Parkinson's and Huntington's Diseases
CC 74	Seizure Disorders and Convulsions
CC 75	Coma, Brain Compression/Anoxic Damage
CC 95	Cerebral Hemorrhage
CC 96	Ischemic or Unspecified Stroke
CC 97	Precerebral Arterial Occlusion and Transient Cerebral Ischemia
CC 98	Cerebral Atherosclerosis and Aneurysm
CC 99	Cerebrovascular Disease, Unspecified
CC 101	Cerebral Palsy and Other Paralytic Syndromes
CC 102	Speech, Language, Cognitive, Perceptual Deficits
CC 103	Cerebrovascular Disease Late Effects, Unspecified
CC 155	Major Head Injury
<b>Psychiatric illness/Substance abuse</b>	
CC 51	Drug/Alcohol Psychosis
CC 52	Drug/Alcohol Dependence
CC 53	Drug/Alcohol Abuse, Without Dependence
CC 54	Schizophrenia
CC 55	Major Depressive, Bipolar, and Paranoid Disorders
CC 56	Reactive and Unspecified Psychosis
CC 57	Personality Disorders
CC 58	Depression
CC 59	Anxiety Disorders
CC 60	Other Psychiatric Disorders

CC or ICD-9-CM code	Description
<b>Pulmonary disease</b>	
CC 114	Pleural Effusion/Pneumothorax
CC 107	Cystic Fibrosis
CC 108	Chronic Obstructive Pulmonary Disease
CC 109	Fibrosis of Lung and Other Chronic Lung Disorders
CC 110	Asthma
CC 115	Other Lung Disorders
<b>Other advanced organ failure</b>	
CC 79	Cardio-Respiratory Failure and Shock
CC 77	Respirator Dependence/Tracheostomy Status
<b>Iron deficiency anemia</b>	
CC 47	Iron Deficiency and Other/Unspecified Anemias and Blood Disease
<b>Major organ transplant</b>	
CC 174	Major Organ Transplant Status
<b>Other organ transplant</b>	
CC 175	Other Organ Transplant/Replacement
<b>Pacemaker/cardiac resynchronization therapy/implantable cardiac device</b>	
ICD-9-CM code 0.50	Implantation of cardiac resynchronization pacemaker without mention of defibrillation, total system [CRT-P]
ICD-9-CM code 0.51	Implantation of cardiac resynchronization defibrillator, total system [CRT-D]
ICD-9-CM code 0.52	Implantation or replacement of transvenous lead [electrode] into left ventricular coronary venous system
ICD-9-CM code 0.53	Implantation or replacement of cardiac resynchronization pacemaker pulse generator only [CRT-P]
ICD-9-CM code 0.54	Implantation or replacement of cardiac resynchronization defibrillator, pulse generator only (CRT-D)
ICD-9-CM code V45.01	Cardiac pacemaker in situ
ICD-9-CM code V53.31	Fitting and adjustment of cardiac pacemaker
ICD-9-CM code V53.39	Fitting and adjustment of other cardiac device
ICD-9-CM code 37.70	Insertion, revision, replacement, and removal of lead(s); insertion of temporary pacemaker system; or revision of cardiac device pocket
ICD-9-CM code 37.71	Initial insertion of transvenous lead [electrode] into ventricle
ICD-9-CM code 37.72	Initial insertion of transvenous leads [electrodes] into atrium and ventricle
ICD-9-CM code 37.73	Initial insertion of transvenous lead [electrode] into atrium
ICD-9-CM code 37.74	Insertion or replacement of epicardial lead (electrode) into epicardium
ICD-9-CM code 37.75	Revision of lead (electrode)
ICD-9-CM code 37.76	Replacement of transvenous atrial and/or ventricular lead(s) (electrode[s])
ICD-9-CM code 37.77	Removal of lead(s) (electrodes) without replacement

CC or ICD-9-CM code	Description
ICD-9-CM code 37.78	Insertion of temporary transvenous pacemaker system
ICD-9-CM code 37.79	Revision or relocation of pacemaker pocket
ICD-9-CM code 37.80	Insertion of permanent pacemaker, initial or revision, type of device not specified
ICD-9-CM code 37.81	Initial insertion of single-chamber pacemaker device, not specified as rate responsive
ICD-9-CM code 37.82	Initial insertion of single-chamber pacemaker device, rate responsive
ICD-9-CM code 37.83	Initial insertion of dual-chamber pacemaker device
ICD-9-CM code 37.85	Replacement of any type pacemaker device with single chamber device, not specified as rate responsive
ICD-9-CM code 37.86	Replacement of any type pacemaker device with single chamber device, rate responsive
ICD-9-CM code 37.87	Replacement of any type pacemaker device with dual chamber device
ICD-9-CM code 37.89	Revision or removal of pacemaker device
ICD-9-CM code V45.02	Automatic implantable cardiac defibrillator in situ
ICD-9-CM code V53.32	Fitting and adjustment of automatic implantable cardiac defibrillator
ICD-9-CM code 37.94	Implantation or replacement of automatic cardioverter-defibrillator (AICD), total system
ICD-9-CM code 37.95	Implantation of automatic cardioverter/defibrillator lead(s) only
ICD-9-CM code 37.96	Implantation or replacement of automatic cardioverter-defibrillator pulse generator only
ICD-9-CM code 37.97	Replacement of automatic cardioverter/defibrillator lead(s) only
ICD-9-CM code 37.98	Replacement of automatic cardioverter-defibrillator (AICD), pulse generator only
ICD-9-CM code 37.99	Other operations on heart and pericardium

## **Appendix D: Derivation of AHRQ SES Variable**

### *D.1. AHRQ SES Index*

We adapted methodology employed by AHRQ to derive an indicator of Medicare beneficiaries' SES status. The original AHRQ SES index was created specifically for use in the Medicare population for the purpose of distinguishing disparities due to race/ethnicity from disparities due to SES, age, and gender. The single, composite AHRQ SES Index is comprised of several domains related to SES (e.g., income, education, housing and employment).<sup>35</sup> In the original AHRQ SES index, data for these SES domains came from the 2000 U.S. Census Bureau, which were used to derive a composite SES score for each U.S. Census block (or nine-digit zip code). These composite scores were then applied to Medicare beneficiaries from that U.S. Census block. The AHRQ SES Index scores were validated with responses from the national probability sample of Medicare fee-for-service Consumer Assessment of Healthcare Providers and Systems (CAHPS) surveys from 2002-2004, as well as income-related information for CAHPS survey respondents.<sup>44</sup>

For this measure, we used updated data from the U.S. Census Bureau, American Community Survey (2008-2012), creating a composite SES index at the five-digit zip code level (the smallest unit by which we could identify Medicare beneficiaries' home address). As in the original AHRQ SES index, the updated composite index is based on seven measures previously shown to contribute to SES. They are: (1) median household income; (2) percentage of persons living below the federal poverty level; (3) percentage of persons who aged  $\geq 16$  years and in the labor force but not employed; (4) median value of owner-occupied homes; (5) percentage of persons aged  $\geq 25$  years who completed at least a 12<sup>th</sup> grade education; (6) percentage of persons aged  $\geq 25$  years who completed at least four years of college; and (7) percentage of households that average one or more persons per room. Using principal component analysis, we derived an AHRQ SES Index score for each five-digit zip code. The AHRQ SES Index is a continuous variable whereby lower scores indicate lower SES zip codes and higher scores indicate higher SES zip codes. The principal component analysis revealed that the 'principal component' accounted for 45% of the variance in the seven variables. Stated another way, the principal component, which represents a transformation and combination of the seven variables into a single factor, accounts for the greatest variation of the seven variables among the five-digit zip codes and is independent of any other component that emerges from the analysis. The factor loadings for the principal component of each of the measures are included in Table D1.

### *D.1.1. Defining low SES zip codes (creating a dichotomous variable of SES)*

To create a dichotomous variable (low SES vs. non-low SES), we first reviewed the literature to identify thresholds for low-SES. The original AHRQ SES Index demonstrated that patients in the lowest SES quartile (scores 0 to 49) had substantially higher rates of Medicaid insurance (in addition to Medicare) compared with the second lowest quartile (21.5% vs. 9.5%), as well as lower rates of other insurance in addition to Medicare, excluding Medicaid (62.2% vs. 78.9%), other insurance to cover prescription costs (50.2% vs. 56.6%), and higher rates of self-reported fair or poor health 44.7% vs. 35.1%).<sup>35</sup> Based on these findings, *a priori*, we set a benchmark of 20% dual-eligible Medicaid to inform a cut-point to define a low SES group with our data.

Applying our AHRQ SES index to Medicare beneficiaries in the 2011 5% Medicare FFS sample, we assessed the distribution of scores in decile arrays and evaluated the distribution of the seven indicators of SES and dual-eligibility status by AHRQ SES decile. We did not observe any inflection points among the seven SES indicators (i.e., there was a near-linear trend in the prevalence of each indicator across deciles); however, we did observe that the two lowest deciles accounted for a disproportionate number of Medicaid dual-eligible patients (>20%). We therefore recategorized the population into quintiles, defining low SES as the lowest quintile. In this lowest quintile, the proportion of dual-eligible patients was 21.9%, compared with the second lowest quintile which included 13.7% dual-eligible patients (see Table D1).

**Table D1. Description of AHRQ SES Index scores in the FFS 5% Medicare sample (2011) categorized by quintiles (Quintile 1: lowest SES zip codes; Quintile 5: highest SES zip codes)**

	Zip Codes of FFS 5% Sample			SES Index Score Categorized by Quintile				
	Original AHRQ SES factor loadings	Updated AHRQ SES factor loadings	Median	Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Median household income	0.85	0.48	51,282	34,272	43,382	51,141	63,200	86,250
Percentage of persons below the federally defined poverty line	-0.79	-0.39	12.6	25.1	16.4	12.1	8.4	5.5
Median value of owner-occupied homes	0.64	0.39	169,900	94,800	122,200	162,400	223,400	388,000
Percentage of persons aged >25 years with less than a 12th-grade education	-0.84	-0.41	11.6	24.5	15.2	11	7.9	4.9
Percentage of persons aged >25 years with $\geq 4$ years of college	0.79	0.46	24	12.3	17.2	23.4	33.2	50.9
Percentage of persons aged 16 years or older in the labor force who are unemployed (and actively seeking work)	-0.66	-0.25	8.7	13.3	10.1	8.6	7.5	6.4
Percentage of households containing one or more person per room	-0.56	-0.20	1.7	3.5	2.0	1.7	1.3	1.0
Percentage of Medicaid dual-eligible patients			11.4	21.9	13.7	10.6	8.5	7.4

Note: AHRQ SES Index was included in the model as a binary variable (defined as AHRQ SES Index <45)

## Appendix E: Disparities Data

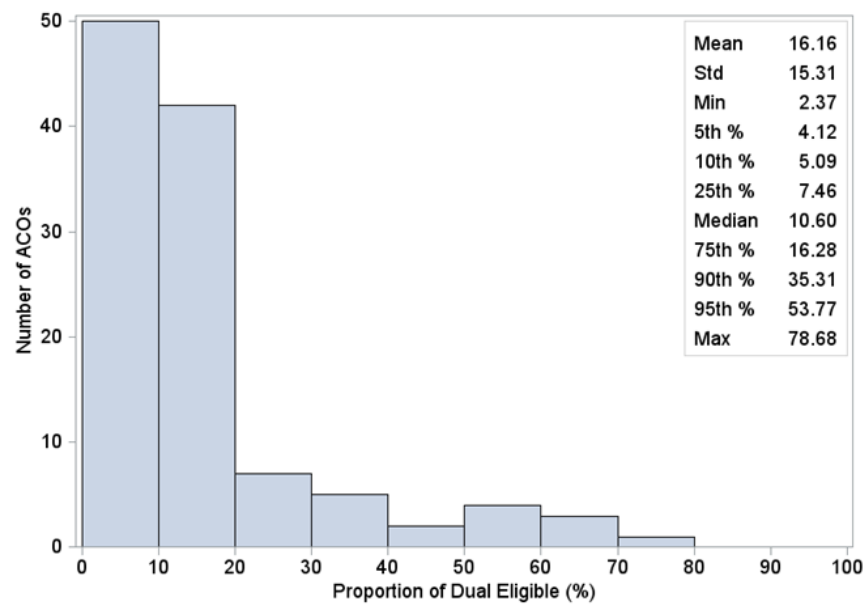
### Identification of ACOs caring for few versus many low SES patients

To determine a threshold to qualify ACOs caring for many low SES patients (AHRQ SES score <45.4) we assessed the distribution of low-SES patients among ACOs (Figure 12 and Figure 13). Based on this distribution, we categorized ACOs into quartiles.

Using a similar approach, we categorized ACOs by the proportion of Medicaid dual-eligible patients based on the distribution among ACOs . We also categorized ACOs into quartiles based on the proportion of Medicaid dual-eligible patients being cared for by each ACO Figure E1 and Figure E2.

Using these categorizations, we examined disparities in ACO performance based on the proportion of patients of low SES being cared for by each ACO (Table 9 and Table 10)

**Figure E1. Distribution of the proportion of Medicaid dual-eligible patients with diabetes among 114 ACOs**



**Figure E2. Distribution of the proportion of Medicaid dual-eligible patients with heart failure among 114 ACOs**

