Method for Measuring Accountable Care Organization Improvement on Risk-Adjusted Admission Rates

Public Comment Draft

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1. Introduction

The Centers for Medicare & Medicaid Services (CMS) is developing a method to assess year-to-year improvement in three risk-adjusted outcome measures in CMS's Accountable Care Organization (ACO) quality measure set. As part of the development process, CMS and its contractor, Yale New Haven Health Services Corporation – Center for Outcomes Research and Evaluation (CORE), are inviting the public to comment on this methodology. Specifically, CMS is developing a method for measuring ACO improvement on acute unplanned admission rates for patients with heart failure, diabetes, and multiple chronic conditions. During the public comment period, we invite comments on all aspects of the options considered and proposed approach, including alignment with ACO program goals, technical feasibility, feasibility of implementation, and usability of the methodology.

1.1. Background

CMS previously contracted with CORE to develop three ACO-level, risk-standardized measures of acute admission rates for patients with diabetes, heart failure, and multiple chronic conditions ("ACO admission measures"). These measures assess each ACO's performance relative to that of other ACOs. In the Calendar Year (CY) 2015 Medicare Physician Fee Schedule (MPFS) Final Rule, CMS added the three measures to the Medicare Shared Savings Program (Shared Savings Program) quality measure set in the Care Coordination/Patient Safety quality measure domain (79 FR 67912). Specifically, the measures are:

- ACO-36: All-Cause Unplanned Admissions for Patients with Diabetes;
- ACO-37: All-Cause Unplanned Admissions for Patients with Heart Failure; and
- ACO-38: All-Cause Unplanned Admissions for Patients with Multiple Chronic Conditions.

CMS will first report these measures publicly for the 2015 performance year.

In the 2015 MPFS Final Rule, CMS also revised its quality scoring strategy to reward ACOs that significantly improve their performance on quality measures from one year to the next (79 FR 67930). CMS uses ACO quality measure scores in determining the proportion of any savings ACOs generate that each ACO can earn based on a point system. ACOs will now have the opportunity to earn additional points if they demonstrate statistically significant improvement from one year to the next on quality measures.

Year-to-year improvement on risk-adjusted quality measures can be defined in more than one way. One approach is to compare each ACO's measure score from one year to the next. Because the three ACO admission measures (like other risk-adjusted outcome measures) assess

each ACO's performance relative to that of other providers with a similar mix of patients in a given year, comparing the ACO's score in the second year to the score in the first year evaluates whether the ACO is doing relatively better or worse than its peers in the second year compared to the first. Hence, if all providers lower their rates substantially from one year to the next but one ACO lowers its rate less than average (that is, it improves but not as much as peers), the ACO will look relatively worse compared with its peers in the second year even though it is improving in relation to how it performed in the previous year. Likewise, if a provider has much lower than expected rates in the first year (that is, it is performing very well) and other providers that are doing worse improve between the first and second years while the excellent provider holds course, the top-performing provider could look like it was performing worse in the second year if the change in measure scores between the first and second years is used to assess improvement.

An alternative approach is to define improvement as an ACO performing better in the second year compared to the first independent of trends in others' performance. This approach would reward ACOs for progress, even if they were not advancing as fast as their peers. Therefore, to inform further consideration of this approach, CMS has contracted with CORE to develop a method of measuring year-to-year improvement on the ACO admission measures that measures the ACO's progress independent of other ACOs. Creating a valid, consensus-based approach to measuring improvement in risk-adjusted outcome measures – defined as improvement independent of other providers – will help fill a current gap in our measurement methods. CMS and other organizations, public and private, could potentially adapt the methodology we develop for use in other ACO risk-adjusted outcome measures and/or in other quality reporting programs.

1.2. Methodology Development Process

To develop the methodology, we conducted a literature review of relevant publications regarding improvement measurement. We also convened, through a public process, a national Technical Expert Panel (TEP) consisting of individuals with expertise in ACO development and management, quality improvement and measurement, and quantitative methodology. With input from our TEP and from CMS, we identified four methods for consideration and conducted empirical analysis on the three options that best aligned with the conceptual goal of measuring each ACO's improvement independent of the progress of other ACOs. CMS and CORE are now holding a public comment period to obtain broader input on the options under consideration.

1.3. Outline of Report

In this report, we:

- Provide background on the program context and challenges (Section 2); specifically, we describe the Shared Savings Program's approach to rewarding improvement on quality measures and its implications for the method, the key challenges to measuring improvement in risk-adjusted outcome measures, and our criteria for evaluating methods options;
- Present our approach to developing options for measuring improvement (Section 3);
- Describe the initial options (Section 4);
- Evaluate the technical feasibility and score distributions for three options (Section 5);
- Present the results of our analyses (Section 6);
- Summarize and interpret our findings (Section 7); and
- Present our recommendation (Section 8).

2. Background and Criteria for Evaluating Methodological Options

2.1. Program Approach to Rewarding Improvement

CMS's ACO programs are innovative approaches to care for Medicare Fee-for-Service (FFS) patients and are designed to better meet CMS's Triple Aim goals of high-quality care, improved health, and lowering cost growth.[1] Under Medicare's ACO programs, providers voluntarily form ACOs that assume shared responsibility for a population of patients and work together to provide better coordinated, higher quality, and more efficient care. To share in savings they generate, ACOs must meet quality performance standards. Under CMS's largest ACO program, the Shared Savings Program, an ACO's portion of any savings is based on its performance on quality measures. As described in the CY 2015 MPFS Final Rule, CMS measures quality of care on 33 quality measures across four domains:

1) Patient/caregiver experience;
2) Care coordination/patient safety;
3) Preventive health; and
4) At-risk population.

For those measures that CMS has designated as pay-for-performance measures, the number of quality points an ACO earns is based on a sliding scale set using the distribution of ACOs' measure scores. An ACO performing below the 30th percentile on a quality measure earns zero quality points for that measure. An ACO performing at or above the 90th percentile earns two points for that measure. Each of the four domains has seven to 10 measures, and ACOs can earn a maximum of 12 to 22 points per domain.

For pay-for-performance measures, an ACO will also be allowed to earn up to four bonus points for improvement in each of the four quality domains to supplement the quality score points. The total points (inclusive of the quality and improvement bonus points) that an ACO will be able to earn for each domain cannot exceed the maximum points possible in each domain (ranges from 12 to 22 maximum points).

The approach to awarding points for performance and improvement only applies to measures designated as pay for performance. CMS award ACOs full points toward earning their shared savings for pay-for-reporting measures. The three ACO admission measures are pay-for-reporting measures for the 2015 and 2016 reporting years, so all ACOs will earn full points for

reporting these measures in these years regardless of their measure and improvement scores; the measures are pay-for-performance beginning in the 2017 reporting year.

2.2. Program Implications for ACO Improvement Measurement

Three key features of the ACO program have particularly informed the development of the improvement measurement methodology. First, CMS will allocate bonus points for statistically significant year-to-year improvement, regardless of the size of the improvement. Second, CMS will award improvement points only when ACOs improve on more measures than they do worse on in a quality domain. Therefore, the methodology must assess whether the ACO showed statistically significant improvement or was performed significantly worse on the measure. Third, ACOs that achieve a measure score at or above the 90th percentile of the performance benchmark will attain all available points for the measure, regardless of whether their performance improved, stayed the same, or worsened. Hence, ACOs with measure scores above the 90th percentile will not need to show statistically significant improvement to be awarded the full points for each domain.

2.3. Key Challenges in Measuring Year-to-Year Improvement in Risk-Adjusted Outcome Measures

The central challenge in measuring improvement from Year 1 (Y1) to Year 2 (Y2) is accounting for factors that are unrelated to quality that might affect the ACO's admission rate:

- An ACO's patients can change from one year to the next for a variety of reasons. Patients may no longer be assigned to an ACO because they utilized fewer services, died, or dis-enrolled from Medicare FFS. Therefore, the admission risk for the new ACO patients may not be similar to that of those who leave, and the measures must be designed to adjust or to control for any difference in patient risk factors.
- The admission risk of enrollees who stay in the ACO may change from Y1 to Y2 (for example, a patient's health may improve or worsen).
- Events unrelated to quality (for example, a flu pandemic) may affect an ACO's rate in any given year.
- Finally, the change in rate from Y1 to Y2 may be influenced by regression to the mean, which is the tendency of an extreme measurement to be less extreme (move toward the mean) just by chance when measured a second time.

In what follows, we propose several approaches that address each of these challenges to different extents. Given this challenge in developing methods options, we focused on

quantifying the extent of change in patient risk of admission from year to year and developing options that adequately account for change in patient risk of admission.

2.4. Criteria for Evaluating Methodological Options

We prospectively determined criteria for evaluating alternative methods for measuring improvement. In developing these criteria, we considered the National Quality Forum's major measure evaluation criteria (importance, scientific acceptability, feasibility and usability), and adapted them to the setting of measuring individual providers' improvement (versus comparing provider performance).[2] The experts we interviewed and our TEP generally agreed on the criteria we developed:

- Programmatic alignment: We considered alignment with the conceptual goal of measuring an individual ACO's improvement independent of other ACOs' progress.
- Technical feasibility: We examined whether we could fit the risk-adjustment models to each ACO.
- Feasibility of implementation: We considered the technical and personnel resources required to calculate the performance of ACOs.
- Usability: We considered several aspects of usability.
    - How well would the method reflect meaningful improvement in quality (that is, how actionable is the measure)? For example, if an ACO lowered the admission risk during the measurement year, Y2, for a particular group of patients, how well would the method capture that improvement?
    - Does the option identify statistically significantly changes in admission rates, consistent with ACO program design?
    - Does the option enable CMS to provide an approximate target admission rate to each ACO early in the measurement year, Y2, so an ACO can know what will likely constitute improvement?
    - Is the option readily understood?

3. Approach to Developing Methodological Options

3.1. Literature Review

To help inform the development of options for consideration, we reviewed literature relevant to making statistical comparisons of organization outcomes between time points. We searched the traditional biomedical and health services research literature as well as databases focused on the education and business fields. We sought to identify statistical approaches that have been used to measure change in performance on an outcome measure from one time period to another for a given entity such as a hospital, school, or company.

First, we searched the PubMed database for the following terms in the title or abstract, combining the terms with AND:

- Hospital OR clinic OR facility OR nursing home OR health system OR hospital system;
- Regression OR model OR modeling OR modelling OR modeled OR modelled OR match* OR propensity;
- Improve* OR change*;
- Significant; and
- Year OR quarter.

We limited the results to peer-reviewed articles that focused on humans from academic journals in English. The search resulted in 1,740 articles.

Second, we searched the Education Research Complete database using the Academic Search Premier engine for the following terms in the title or abstract, combining the terms with AND:

- School;
- Regression OR model OR modeling OR modelling OR modeled OR modelled OR match*; OR propensity;
- Improve* OR change*;
- Significant; and
- Year OR quarter OR semester.

We limited the results to peer-reviewed articles from academic journals in English. The search resulted in 371 articles.

Third, we searched the Business Source Complete database using the Academic Search Premier engine for the following terms in the title or abstract, combining the terms with AND:

- Business OR company OR corporation OR organization;

- Regression OR model OR modeling OR modelling OR modeled OR modelled OR match* OR propensity;
- Improve* OR change*;
- Significant; and
- Year OR quarter.

We limited the results to peer-reviewed articles from academic journals in English. The search resulted in 277 articles.

Combining the results of the three searches yielded a total of 2,388 potential articles. We reviewed the title and abstract of each of the 2,388 publications and selected articles for possible inclusion in our review.

The inclusion criteria for the abstract review were:

1. Results reported for a single entity (such as a hospital, school, or company); and
2. Statistical comparison of change in outcome from one year (or time period) to another.

We excluded abstracts from the literature review that met at least one of our exclusion criteria. The exclusion criteria for the abstract review were:

1. Time-trend analysis; and
2. Survival analysis (time-to-event data).

3.2. Stakeholder and Expert Input

To develop initial options for consideration and inform criteria for evaluating options, we convened an internal working group of clinical and methods experts at CORE. As noted in the Acknowledgements section, we also interviewed several methodological experts and asked for their feedback on the initial options and our assessment of the options. Additionally, we convened a TEP to review and comment on the initial options we developed (see Appendix A for TEP member list). The TEP also reviewed preliminary testing results. (A TEP Summary Report presents the TEP's input on the methods options and is available at https://www.cms.gov/Medicare/Quality-Initiatives-Patient-Assessment-Instruments/MMS/CallforPublicComment.html.)

4. Initial Options

4.1. Findings of Literature Review

In our literature review, we found that a limited number of approaches have been used to assess change in provider performance using outcome measures from one time period (for example, a year) to another. After applying our exclusion criteria to the 2,388 articles identified in our search, 2,367 articles were excluded. We retrieved the remaining 21 publications that were potentially eligible for inclusion and conducted a full-text review. Of these, six were excluded because they failed to meet our inclusion criteria and/or met our exclusion criteria. One additional publication was excluded because the full-text was not found. In total, we identified 14 relevant articles (Appendix B). All 14 were identified through PubMed.

Six articles were intervention studies in which outcomes were compared for separate pre/post samples using simple unadjusted analyses (χ^2 test, t-test, or non-parametric test).[3-8] Of the six studies, five were conducted at a single hospital or medical school, and one aggregated data from 16 hospitals in a hospital system.

Six articles used a modeling approach (Poisson regression, logistic regression, or linear regression, depending on the outcome measure) in which patients were pooled together across time points and an indicator variable for time was used to assess the statistical significance of outcome change from one time point to another. All six studies were conducted at a single hospital or medical school. Of the six studies, three adjusted for patient case-mix differences (for example, age, sex, disease severity, comorbidities),[9-11] and three did not.[12-14] Only one study explicitly discussed the inclusion of overlapping patients across years and used a generalized linear mixed modeling approach to adjusting for case mix.[8]

Two papers also identified matching as a strategy for accounting for differences in case mix.[15,16]

4.2. Options Considered

Based on the literature review and expert consultation, we considered four options to evaluate change in year-to-year performance for individual ACOs. Three of these options were aligned with the ACO program goal for the method of evaluating year-to-year improvement in each ACO independent of other ACOs' progress.

1. **Option 1** would estimate an expected rate of admissions in Y2 based on the relationship between patient risk factors and the outcome from an ACO's patients in Y1. Specifically, we fit the model for the heart failure ACO admission measure to the Y1 data, then use the model coefficients and Y2 patients to estimate the Y2 expected rate. To assess

improvement, we compare the observed number of admissions in Y2 to the Y2 expected number of admissions. See Appendix C for details.

2. **Option 2** would estimate a rate ratio for improvement by setting the expected rate of admissions based on the relationship between patient risk factors and the outcome from an ACO's patients in both Y1 and Y2. Specifically, we fit the heart failure ACO admission measure, ACO-37, model to a combined Y1 and Y2 dataset with an added indicator variable for Y2. To assess improvement, we test the direction and statistical significance of the Y2 indicator variable. See Appendix C for details.

3. **Option 3** would control for change in patient risk from Y1 to Y2 by developing a matched cohort of ACO patients in Y1 and Y2 with similar admission risk, using the risk factors from the heart failure ACO admission measure, ACO-37. To assess improvement, we calculate a rate ratio comparing Y1 to Y2 and test the direction and statistical significance. See Appendix C for details.

We also considered estimating an expected rate of admissions based on the relationship between patient risk factors and the outcome from all ACOs in Y1. Specifically, we could fit a model to all ACOs, then apply it to each individual ACO's Y2 data to estimate the ACO's Y2 expected admission rate. To assess improvement, we could compare the observed number of admissions in Y2 to Y2 expected number of admissions. This option has the advantage of using a large number of patients to estimate the model coefficients and possibly would facilitate ACOs achieving statistically significant change with a smaller change in the true admission rate. We chose not to further evaluate this approach, however, because it failed our first criterion of alignment with the goal of evaluating each ACO's progress independent of other ACOs' progress since the method evaluated ACOs in part based on other ACOs.

4.3. Expert Input

The experts we interviewed and our TEP generally agreed that the options we identified merited evaluation. TEP members identified a variation on Option 1 and recommended its consideration: using a single baseline for all three years (that is, deriving each year's expected rate for years one to three from the year zero performance). Although we did not further analyze this option, we invite comment on its potential use.

5. Methods for Testing Options

5.1. Alignment with ACO Admission Measure Specifications

We tested each option using the heart failure ACO acute unplanned admission measure, ACO-37 (we deferred testing of the improvement measurement method options for the other two ACO admission measures for patients with diabetes and multiple chronic conditions given resource constraints). Because our project goal is to measure ACO improvement on this particular measure, we fully aligned the methods options for assessing improvement with the design of ACO-37, using the same patient cohort (heart failure patients age 65 and older) and outcome (acute unplanned admissions per 100 person-years), and risk adjustment variables (age, 22 comorbidities, and severity of heart failure). See Appendix D for the cohort definition (Table D1) and risk variable definitions (Table D2). For all options, we used the same model form as ACO-37, a negative binomial model, which best fits the data given the relatively high variance. This model form best fits the outcome, which is a count of acute unplanned admissions. For Option 3, we matched patients in Y1 to patients in Y2 using the risk variables from ACO-37.

5.2. Data and Patient Cohort

To assess the three different options for measuring improvement on ACO-37, we assembled Medicare FFS claims data from 2011 to 2013. We used the following datasets:

- *Measure Cohort (patients included in the measure)*: For methods testing, we used 2010-2012 Chronic Conditions Data Warehouse (CCW) data. Our files included all Medicare Part A and Medicare Part B claims for patients with at least one of 27 chronic conditions as defined in the CCW.[17]

- *Outcome Identification*: Acute admissions were identified using the 2012 and 2013 Medicare Provider Analysis and Review (MedPAR) files. We obtained Medicare FFS enrollment and mortality status from the Medicare Enrollment Database, which contains beneficiary demographic, benefit, coverage, and vital status information.

- *Risk Adjustment*: To risk adjust the outcome measure, we used Medicare Part A and Part B claims from the prior year (2010 and 2011 CCW data files, respectively).

- *ACO Assignment*: Finally, we assigned patients to ACOs using a patient-ACO assignment file provided by CMS. CMS assigns patients to ACOs using the Shared Savings Program assignment algorithm.[18]

5.3. Year 1 to Year 2 Changes in Case Mix

As noted in Section 2.3, a key challenge of measuring year-to-year improvement is change in patient case mix. We therefore sought to understand how the Shared Savings Program ACO population changed from 2012 (Y1) to 2013 (Y2) within the heart failure cohort, and the magnitude and reasons for patient shifts. We calculated the percentage of patients in Y1 that were also included in Y2. In addition, we calculated the absolute change in the percentage of patients with each of the risk factors in the heart failure model. We then examined the percentage of risk factors with a standardized difference of less than 10%. This is a measure of the amount of overlap between two groups; values that are less than 10% indicate greater than 93% overlap. Finally, we compared the prevalence of risk factors in patients who stayed in an ACO from Y1 to Y2 (that is, stayers) with those who left an ACO (that is, leavers) or joined an ACO (that is, joiners).

5.4. Assessment of ACO Improvement Using Each Option

For Option 1, we fit ACO-specific models to all 114 ACOs in 2012 and then applied the model coefficients to assigned patients in 2013 to estimate a 2013 expected number of admissions per 100 person-years. We anticipated that some ACOs would have a very low or zero prevalence of certain rare risk factors, impairing model estimation. To address this situation, we developed an algorithm to assess model estimation for each ACO. If model estimation was affected by excessively high standard errors, collinearity, or a singular Hessian matrix (preventing convergence of the model), then we identified the problematic variable(s) and removed any patients with the low prevalence risk factor from the analysis.

We defined the improvement score as the difference between the observed and expected number of admissions per 100 person-years in Y2 (O2-E2). For each ACO, we determined whether there was a statistically significant change in their admission rate by calculating a 95% confidence interval around the O2-E2 statistic. If the confidence interval included zero, there was no statistically significant change in performance.

We categorized ACO performance as follows:

- "Significantly improved" if the ACO achieved a significant ($p<0.05$) negative score (that is, the observed number of admissions was less than the expected number of admissions and the confidence interval excluded zero);
- "No different" if the ACO achieved a non-significant score ($p\geq0.05$) (that is, regardless of the direction of change, the confidence interval included zero); or

- "Significantly worse" if the ACO achieved a significant ($p<0.05$) positive score (that is, the observed number of admissions was greater than the expected number of admissions and the confidence interval excluded zero).

For Option 2, we fit the heart failure model in each ACO, combining patients from Y1 and Y2 and adding an indicator variable for Y2. We had no difficulty estimating the models using this option given the larger pooled ACO sample sizes. For each ACO, we then estimated an improvement score and 95% confidence interval using the exponentiated coefficient (rate ratio) for the Y2 indicator variable. Using an approach similar to that used for Option 1, we assigned the ACOs to performance categories ("significantly improved," "no different," or "significantly worse") using the 95% confidence interval for the rate ratio. If the confidence interval was entirely below one, the ACO's performance was significantly improved; if it included one, the performance was no different; and if it was entirely above one, the ACO was significantly worse.

For Option 3, we examined the feasibility of identifying matched cohorts using a sample of 12 ACOs of varying volume and case-mix change. Specifically, we first organized the 114 2012 Shared Savings Program ACOs into four quartiles by volume and then selected three ACOs with minimum, median, and maximum multivariable standardized differences from within each quartile. Case-mix change was measured by a multivariable standardized difference, calculated as the difference in the mean summarized linear combination of risk factor coefficients ("Xbeta") from regressing a patient's year of enrollment in an ACO on the heart failure risk factors. For the 12 ACOs selected, we performed matching using the Mahalanobis distance matching (MDM) method within each of these ACOs.[19,20] This method fits a propensity score model then choses a match for each patient by selecting the propensity score nearest to the patient using the MDM.

To evaluate the ACO-specific models, we calculated the percentage of matched patients in Y1 and Y2 and examined the differences in characteristics in patients that were matched versus not matched in Y1 and Y2. We further evaluated the quality of the match using the standardized difference of the matched group.[21,22] Lastly, for the 12 ACOs selected for Option 3 testing, we calculated their improvement scores and whether the scores were statistically significant. We fit a combined Y1 and Y2 dataset with an indicator variable for Y2. To assess improvement, we test the direction and statistical significance of the Y2 indicator variable. Finally, we categorized the performance of the 12 ACOs as described in Option 2.

5.5. Comparison of Results across Options

We compared the Option 1 and Option 2 results for all 114 ACOs. We tested the level of agreement using the kappa statistic. In addition, we compared the performance of the 12 ACOs we evaluated using Option 3 with their performance assessed using Option 1 and Option 2.

5.6. Performance Results Stratified by Volume

To examine how ACO volume affects the results, we reported the results stratified by ACO volume tertiles for Option 1 and Option 2. In addition, for the 12 ACOs we assessed using all three options, we displayed the results by volume quartiles.

5.7. Solicitation of Expert Input

We asked the experts we interviewed and our TEP to review these results and consider the methods alternatives given these findings.

6. Results of Options Testing

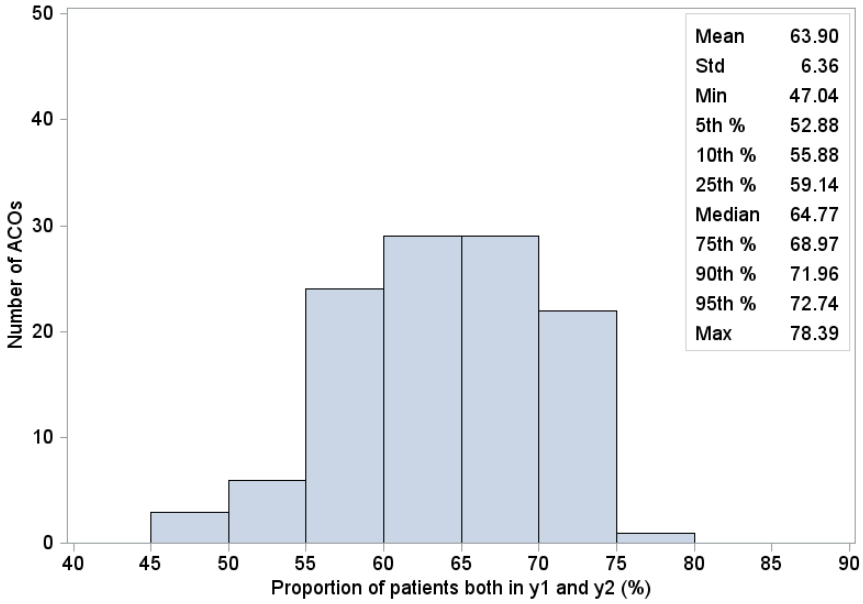
6.1. Patient Cohort

The patient cohort consisted of 258,587 heart failure patients (Y1: N=123,626; Y2: N=134,961) in the 114 ACOs in the Shared Savings Program in both 2012 and 2013. ACO volume of heart failure patients in 2012 ranged from 303 to 9,914 patients, with a median of 690.

6.2. Year 1 to Year 2 Changes in Case Mix

We observed that the percentage of patients that remain in their ACO from Y1 to Y2 varied across ACOs (Figure 1). The percentage of patients who remained ranged from 47.0% to 78.4%.

Figure 1. Distribution of the percentage of patients who remained in their ACO from Y1 to Y2



While the actual patients in ACOs in some cases changed substantially, the risk factors for ACO populations were similar between Y1 and Y2 (Appendix E, Table E1 and Table E2). Additionally, those who stayed in the same ACOs had similar frequencies of comorbidities (Table 1). Patients leaving ("leavers") tended to be sicker than those who remained in an ACO ("stayers"); however, "leavers" were similar to "joiners." Overall, the Y1 and Y2 risk factor frequencies were similar both overall and within each ACO. Our findings therefore suggested that we would be able to risk adjust for case-mix change between Y1 and Y2.

Table 1. Characteristics of the ACOs' patient populations, stayers (stay in ACO from Y1 to Y2), leavers (leave ACO in Y2), and joiners (join ACO in Y2)

Variable	Overall (N=258,587)		Stayers (N=79,942)		Leavers (N=43,684)	Joiners (N=53,488)
	Y1	Y2	Y1	Y2		
Age Mean (SD)	79.8 (7.8)	79.8 (7.8)	79.2 (7.6)	80.2 (7.6)	81.0 (8.1)	79.3 (8.1)
Race						
White	87.2%	87.0%	87.5%	87.5%	86.7%	86.4%
Black	9.2%	9.2%	8.9%	8.9%	9.6%	9.6%
Male	50.8%	50.8%	50.8%	50.8%	50.8%	50.9%
High-risk cardiovascular (CV) factors	32.8%	31.9%	30.7%	27.5%	36.6%	38.5%
Low-risk CV factors	85.4%	84.1%	84.6%	82.0%	87.0%	87.2%
Arrhythmia	64.4%	63.3%	63.0%	61.5%	67.0%	65.9%
Structural heart disease	41.5%	39.9%	40.6%	35.4%	43.3%	46.6%
Advanced cancer	7.8%	7.6%	6.7%	6.8%	9.8%	8.7%
Dementia	22.4%	21.3%	18.6%	19.5%	29.5%	23.9%
Diabetes with complications	52.6%	52.2%	52.6%	52.4%	52.6%	52.0%
Dialysis	3.1%	3.1%	2.5%	2.8%	4.3%	3.5%
Disability/Frailty	22.9%	21.8%	19.5%	19.2%	29.1%	25.7%
Gastrointestinal and genitourinary disorders	32.6%	31.5%	30.5%	28.3%	36.4%	36.4%
Hematological disorders	16.7%	15.2%	15.3%	13.3%	19.1%	17.9%
Infectious and immune disorders	6.4%	6.6%	5.7%	5.2%	7.6%	8.6%
Kidney disease	39.1%	38.9%	36.4%	37.0%	43.9%	41.8%
Liver disease	2.3%	2.2%	2.0%	1.9%	2.9%	2.7%
Neurological disease	45.0%	44.1%	42.9%	41.2%	49.0%	48.6%
Psychiatric illness/Substance abuse	36.5%	35.5%	34.1%	32.4%	41.0%	40.1%
Pulmonary disease	59.3%	56.6%	57.1%	52.1%	63.2%	63.3%
Other advanced organ failure	20.3%	19.2%	17.9%	14.6%	24.7%	26.2%
Iron deficiency anemia	54.0%	52.2%	51.0%	48.8%	59.4%	57.4%
Major organ transplant	0.4%	0.4%	0.3%	0.3%	0.4%	0.5%
Other organ transplant	0.8%	0.9%	0.8%	0.8%	0.8%	1.0%
Pacemaker/CRT/ICD	23.7%	23.1%	22.6%	25.0%	23.9%	20.2%

*Note: standard deviation (SD); cardiac resynchronization therapy (CRT); implantable cardioverter defibrillator (ICD).

6.3. Technical Performance for Each Option

Option 1. We successfully fit models to all ACOs using Option 1. Some ACOs (43%) had few or no patients with two low-prevalence risk factors (major organ transplant and other organ transplant). Our algorithm dropped these variables and the patients with these risk factors from these ACO-specific models. The maximum number of patients dropped from any ACO was 19 (0.3%) over both years. Option 1 identified 30 (26.3%) ACOs that significantly improved

(improved), 81 (71.1%) ACOs that were no different, and three (2.6%) ACOs that were significantly worse in their Y2 performance (Table 2, final column).

Option 2. We also successfully fit Option 2 models to all 114 ACOs. Option 2 identified 13 (11.4%) ACOs that significantly improved, 100 (87.7%) ACOs that were no different, and one (0.9%) ACO that was significantly worse in Y2 performance (Table 2, final row). The agreement between Options 1 and 2 was substantial (kappa=0.64).

Table 2. Comparison of ACO performance results for Option 1 and Option 2 (N=114 ACOs)

Option 1	Option 2			Option 1 total
	Significantly improved	No different	Significantly worse	
Significantly improved	**13 (11.4%)**	**17 (14.9%)**	0 (0.0%)	30 (26.3%)
No different	0 (0.0%)	**81 (71.1%)**	0 (0.0%)	81 (71.1%)
Significantly worse	0 (0.0%)	**2 (1.7%)**	**1 (0.9%)**	3 (2.6%)
Option 2 total	13 (11.4%)	100 (87.7%)	1 (0.9%)	114 (100.0%)

Option 3. Using this option, we achieved match rates of 83.8% to 98.8% for the 12 ACOs. Across the ACOs in the four volume quartiles, we saw somewhat varying degrees of matching, with the lower two observed match rates in the two lowest-volume quartiles (Table 3). Case-mix change was measured by a multivariable standardized difference, calculated as the difference in the mean summarized linear combination of risk factor coefficients ("Xbeta") from regressing a patient's year of enrollment in an ACO on the heart failure risk factors.

Table 3. Option 3 match rates for 12 ACOs by volume quartiles

Summary statistic	Match rate
Volume quartile 1 (low volume):	
Maximum standardized difference of Xbeta	93.8%
Median standardized difference of Xbeta	83.0%
Minimum standardized difference of Xbeta	98.8%
Volume quartile 2:	
Maximum standardized difference of Xbeta	85.5%
Median standardized difference of Xbeta	94.6%
Minimum standardized difference of Xbeta	97.0%
Volume quartile 3:	
Maximum standardized difference of Xbeta	90.6%
Median standardized difference of Xbeta	94.3%
Minimum standardized difference of Xbeta	96.7%
Volume quartile 4 (high volume):	
Maximum standardized difference of Xbeta	95.4%
Median standardized difference of Xbeta	94.9%
Minimum standardized difference of Xbeta	96.3%

In Table 4 below, we show the minimum and maximum standardized differences of each risk factor among the matched cohorts across the 12 ACOs. All of the standardized differences were less than 10%, which indicates a good balance between the matched groups.

Table 4. Option 3 minimum and maximum standardized differences for risk factors of matched patient cohorts for 12 ACOs

Risk factor	Standardized difference	
	Minimum %	Maximum %
Age 65-69	0.00	3.86
70-79	0.17	3.50
80-89	0.00	4.14
≥ 90	0.19	3.38
High-risk cardiovascular (CV) factors	0.10	3.95
Low-risk CV factors	0.00	3.38
Arrhythmia	0.00	4.92
Structural heart disease	0.35	5.00
Advanced cancer	0.65	8.00
Dementia	0.00	4.30
Diabetes with complications	0.00	6.65
Dialysis	0.00	3.04
Disability/Frailty	0.00	5.03
Gastrointestinal and genitourinary disorders	0.22	8.50
Hematological disease	0.00	6.06
Infectious and immune disorders	0.00	3.26
Kidney disease	0.00	1.68
Liver disease	0.79	5.50
Neurological disease	0.20	2.61
Psychiatric illness/Substance abuse	0.20	4.41
Pulmonary disease	0.12	4.31
Other advanced organ failure	0.25	4.21
Iron deficiency anemia	0.67	4.09
Major organ transplant	0.00	8.12
Other organ transplant	0.00	6.05
Pacemaker/CRT/ICD	0.00	4.10

*Note: standard deviation (SD); cardiac resynchronization therapy (CRT); implantable cardioverter defibrillator (ICD).

6.4. Comparison of Results across Options 1, 2, and 3

There was moderate agreement (83.3%) between the results for Options 1 and 2 in the 114 ACOs (Table 2).

Of the 12 ACOs that we evaluated using Option 3, ACOs were categorized similarly using Options 1, 2, and 3 (Table 5). One of 12 ACOs was categorized differently using the three options. This ACO was categorized as "significantly improved" using Options 1 and 2, and was categorized as "no different" using Option 3.

Table 5. ACO performance status by option for subset of 12 ACOs of varying size and case-mix change

ACO	Performance Status		
	Option 1	Option 2	Option 3
Volume quartile 1 (low volume):			
1	No different	No different	No different
2	No different	No different	No different
3	Significantly improved	Significantly improved	No different
Volume quartile 2:			
4	No different	No different	No different
5	No different	No different	No different
6	No different	No different	No different
Volume quartile 3:			
7	No different	No different	No different
8	No different	No different	No different
9	No different	No different	No different
Volume quartile 4 (high volume):			
10	No different	No different	No different
11	Significantly improved	Significantly improved	Significantly improved
12	No different	No different	No different

6.5. Performance Results Stratified by Volume Tertiles

For Option 1, we observed that ACOs with all volume levels were able to achieve similar significance patterns (Table 6). For Option 2, we observed a trend of higher-volume facilities reaching significant change more often (Table 6).

Table 6. ACO performance status using Options 1 and 2 stratified by ACO Y1 volume

ACO volume tertile (volume range)	Number of ACOs	Significantly improved	No different	Significantly worse
Option 1:				
Lowest tertile (303-552)	38	10 (26.3%)	27 (71.1%)	1 (2.6%)
Middle tertile (553-932)	38	6 (15.8%)	31 (81.6%)	1 (2.6%)
Highest tertile (933-9,914)	38	14 (36.8%)	23 (60.6%)	1 (2.6%)
Option 2:				
Lowest tertile (303-552)	38	4 (10.5%)	34 (89.5%)	0 (0.0%)
Middle tertile (553-932)	38	2 (5.3%)	35 (92.1%)	1 (2.6%)
Highest tertile (933-9,914)	38	11 (28.9%)	27 (71.1%)	0 (0.0%)

6.6. Expert Input

The TEP reviewed the majority of these results. The TEP encouraged CORE to fully consider Options 3 and to further consider a fourth option, fitting a model using all ACOs' Y1 data and using it to estimate individual ACO's Y2 expected (as noted above, we decided not to further evaluate the fourth option because it was inconsistent with our conceptual goal of evaluating each ACO independent of other ACOs). Several TEP members emphasized that the findings on risk factor changes are consistent with their experience that patients joining or leaving ACOs (or dying) between years are higher utilizers than those staying in ACOs. A TEP member also noted that the relatively large number of ACOs demonstrating a statistically significant change under Option 1 compared to Option 2 may be due to chance.

Several TEP members also stated that in weighing the options, they would prioritize approaches that allow CMS to provide ACOs with a target admission rate that would achieve statistically significant improvement early in the measurement year. Option 1 best facilitates estimating a target rate because, of the three options, it is the only option which requires us to know only the patient outcomes (acute unplanned admission) in Y1 to estimate a target admission rate for the ACOs Y2 patients. Options 2 and 3 require the use of Y2 patient outcomes to assess improvement, which will not be known until the end of Y2.

7. Summary and Interpretation of Findings

We are developing a method to assess year-to-year change in ACOs on the three ACO risk-standardized acute unplanned admission measures for diabetes, heart failure, and multiple chronic condition patients (ACO-36, ACO-37, ACO-38). CMS is using these three measures of relative performance in the Shared Savings Program beginning with the 2015 performance year. ACO scores on these measures are scores of relative performance in the measurement year (compared with other ACO providers with similar patients). The improvement methodology will create a method CMS could use to evaluate each ACO's improvement on the outcome of acute unplanned admissions independent of other ACOs' progress. The improvement score for each ACO is designed to be reported in conjunction with the relative score, since both the relative measure and the improvement methodology provide important but distinct information. CMS compares ACO performance on each relative measure score to a benchmark to determine (for measures in pay-for-performance programs) the proportion of possible points each ACO can earn toward its shared savings. The improvement methodology could be used to calculate the bonus points that ACOs would earn toward their shared savings. We developed and tested the improvement methodology using the heart failure cohort (ACO-37) and evaluated it in the context of the Shared Savings Program policy for rewarding improvement.

Overall, we observed that among the 114 ACOs, patients can change substantially from year to year; however, the patients who leave are generally similar to the patients who join, making adequate risk adjustment across the three options likely achievable.

We fully implemented Options 1 and 2 in our test dataset and observed that ACOs of different sizes were able to achieve statistically meaningful changes from Y1 to Y2 for Option 1. For Option 2, fewer ACOs were able to achieve statistically significant change; however, the results are likely less subject to chance or regression to the mean. As expected, under this option there was a trend toward higher-volume ACOs achieving statistical significance more often.

We implemented Option 3 in a subset of 12 ACOs that varied in size and case-mix change. We were able to match a varying amount of patients in each ACO with the lowest match rates observed in the two lowest-volume quartiles. The matching algorithms adequately balanced patient characteristics across Y1 and Y2, making the calculation of the improvement from Y1 to Y2 feasible. However, the matching algorithms require considerably more statistical analyst time and some subjective judgment.

The results were largely concordant across the three options. Overall, Options 1 and 2 showed high concordance of results; however, a handful of ACOs had a different performance category for Option 1, compared to Option 2. The results using Option 3 for the subset of the 12 ACOs were also concordant, with the exception of one of the lower-volume ACOs.

Given the technical feasibility of Options 1, 2, and 3 and relative concordance of results, the choice of method can be informed by the review of the broader criteria, including the alignment with the conceptual goal, technical feasibility, implementation feasibility, and usability.

8. Recommendation

Based on a review of the options against our criteria (Table 7), we recommend using Option 1 to assess year-to-year improvement in individual ACOs. Option 1 is most consistent with the conceptual goal of wanting to measure improvement from one year to the next, independent of other ACOs' progress. Additionally, Option 1 would allow CMS to provide ACOs with a target admission rate that will likely demonstrate statistically significant improvement.

As noted above, we invite comments on the options tested, the tests conducted, the results and interpretation of the test results, and the recommended approach.

Table 7. Evaluation against criteria

Criterion	Expected admissions set for each ACO using each ACO's experience		
	Option 1	**Option 2**	**Option 3**
Alignment with conceptual goal	Fully aligned (uses Y1 performance and patients to set Y2 expected)	Largely aligned (uses Y1 and Y2 performance and Y2 patients to set Y2 expected)	Fully aligned (but evaluates improvement with potentially more limited group of patients)
Technical feasibility	Feasible	Feasible	Feasible in 12 ACOs evaluated
Requirements for implementation	Estimate and evaluate models for each ACO: • Automated calculation • High-level check: check estimates, standard error	Estimate and evaluate models for each ACO: • Automated calculation • High-level check: check estimates, standard error	Evaluate matching quality for each ACO: • Automated matching requires some monitoring • Manually check matching quality; excluded beneficiaries
Usability	Can provide a mechanism to monitor progress in advance for ACO using preliminarily assigned patients; risk factor coefficients can suggest targets for quality improvement	Cannot provide a mechanism to monitor progress in advance for ACO or provide risk factor coefficients in advance	Cannot provide a mechanism to monitor progress in advance for ACO

Criterion	Expected admissions set for each ACO using each ACO's experience		
	Option 1	**Option 2**	**Option 3**
Key pros	• Most conceptually aligned with intent to measure each ACO's improvement independently • Risk factor coefficients are informative for quality improvement • Possibly more actionable year over year • ACO can monitor its progress intermittently with year-to-date data	• More stable risk factor estimates versus #1	• Tightest control for risk factor differences between Y1 and Y2
Key cons	• Less precise estimates for risk factors (wider confidence interval) • Most affected by regression to the mean	• Slightly more difficult to explain/use • Averages patient risk across two years • Less likely to capture real single-year changes versus Option 1	• Resource intensive • Evaluation may not include many eligible patients who are unmatched • Subjective decisions about matching criteria could affect score and are resource-intensive

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10. Appendices

Appendix A: Technical Expert Panel Members

Table A1. Technical Expert Panel (TEP) members

Name	Organization (Title)	Location
Michael Barrett, BS	Universal American/Collaborative Health System (Senior Vice President ACO Southeast Region and National Development)	Reunion, FL
Larry Becker, BS	Xerox (Director, Strategic Partnerships, Alliances, and Analytics for Xerox Corporation)	Rochester, NY
Scott Berkowitz, MD, MBA	Johns Hopkins Medicine Alliance For Patients, LLC. (Executive Director); Office of Johns Hopkins Physicians (Senior Medical Director, Accountable Care Office); Johns Hopkins Medicine (Assistant Professor)	Baltimore, MD
Alex Blum, MD, MPH	Evergreen Health Co-op (Chief Medical Officer)	Baltimore, MD
Erin Deloreto, MPAP	QualCare Alliance Network, Inc. (Assistant Vice President, Operations)	Piscataway, NJ
Aparna Higgins, MA	America's Health Insurance Plans ([AHIP] Senior Vice President, Private Market Innovations)	Washington DC
Mimi Huizinga, MD, MPH	Premier, Inc. (Vice President, Chief Clinical Officer of PACT Collaborative)	Nashville, TN
David Introcaso, PhD	National Association of ACOs ([NAACOS] Vice President, Policy and Operations)	Alexandria, VA
John Michael McWilliams, MD, PhD	Harvard Medical School (Associate Professor of Health Care Policy and Medicine)	Boston, MA
David Muhlestein, JD, PhD, MHA, MS	Leavitt Partners (Senior Director of Research and Development)	Salt Lake City, UT
Ami Parekh, MD, JD	University of California, San Francisco (Assistant Clinical Professor)	San Francisco, CA
Denise Prince, MBA, MPH	Geisinger Health System (System Vice President, Value Based Care) Keystone Accountable Care Organization, LLC (Chief Administrative Officer)	Danville, PA
Jeff Stensland, PhD	Medicare Payment Advisory Commission ([MedPAC] Principal Policy Analyst)	Washington DC

Appendix B: Literature Review Results

Table B1. Literature review results

Author (Year)	Context	Relevant analytic method	Notes
Barker et al. (2013)[12]	This article is a report of a study of associations between occurrence of serious fall-related injuries and implementation of low-low beds at The Northern Hospital, Victoria, Australia	• Poisson regression • Time periods as indicator variables • Rate ratios (RRs) reported for different time periods compared with reference period • Risk adjustment: no	• Also tried negative binomial • Poisson was considered appropriate since data were not over-dispersed
Barnett et al. (2009)[13]	To examine acute myocardial infarction (AMI) hospital admissions – at one hospital – in Christchurch, New Zealand, before and after the implementation of the smoke-free legislation in December 2004	• Poisson regression • RR comparing AMI hospitalization rates before (2003/04) and after (2005/06) legislation • Risk adjustment: no	None
Bunik et al. (2011)[9]	To determine if a quality improvement intervention for asthma care in a teaching clinic was associated with improved outcomes	• Generalized linear mixed model regression for binary outcomes • Extended the Kleinman and Norton method for converting ORs to RRs • Indicator variables for 2007, 2008, and 2009 compared with 2006 • Risk adjustment: yes	None
Jungfer et al. (2014)[3]	To examine the effects of the change from closed to open wards on the frequency of seclusion and forced	• χ^2 tests were performed to compare the percentage of seclusions and forced medications during the two analysis periods	None

Author (Year)	Context	Relevant analytic method	Notes
	medication in a hospital-wide setting		
Lee et al. (2010)[4]	To evaluate the impact of dedicated trauma intensivists in terms of ICU throughput and also to assess the possibility of any mortality outcome differences	• Kruskal-Wallis nonparametric tests to assess for differences across the variables of interest • Pre (2003-2005) – Post (2006-2008) comparisons	None
Loftus et al. (2014)[5]	This study is a retrospective cohort study over a 2-year period comparing before and after results following the implementation of a simplified TKA care pathway	• The means for each outcome and covariate were compared between the baseline cohort and TKA pathway cohort using a t-test	It was performed in acute care facilities providing this operation within the system. Sixteen hospitals (ranging in size from an 18-bed critical access facility to a 668-bed level 1 trauma center), along with 104 orthopedic surgeons, participated in the initiative.
Mayo et al. (1996)[6]	To assess the effectiveness of a program to improve care of adult patients hospitalized for asthma	• Data were evaluated using the χ^2 test, the t-test, and the Wilcoxon two-sample test as appropriate • Pre/Post comparisons	None
McKeown et al. (2003)[14]	To assess the impact of curricular changes on medical students' knowledge of surface anatomy	• To enhance linear response and enable the use of linear models for analysis, all data were adjusted using probit transformations of the proportion of correct answers for each item within each year group	None

Author (Year)	Context	Relevant analytic method	Notes
		• The transformed data were then analyzed using general linear models with question and year as main effects • Risk-adjustment: no	
Novick et al. (2007)[10]	To compare outcomes before and following the opening of a specialized cardiac surgery recovery unit (CSRU) in April 2005	• Multivariable stepwise logistic regression, allowing for entry of variables at the 0.05 level and removal at the 0.10 level, to determine the independent predictors of in-hospital mortality or major complications • Indicator variable for year (pre/post) • Risk adjustment: yes	None
O'Mahony et al. (2007)[7]	To determine the effect of multidisciplinary rounds (MDR) on quality core measure performance, resident education, and hospital length of stay	• Pre-post comparisons of aggregate categorical data were conducted with χ^2 tests, and continuous variables with t-tests	None
Ostapchuk et al. (2010)[8]	Evaluation of a campus-wide residents as teachers program based on the bringing education and service together curriculum	• Mann–Whitney U test compared the items between 2007 and 2008	None
Shultz et al. (2014)[11]	To understand the impact of management recommendations on practice patterns for immune thrombocytopenia (updated guidelines in 2011)	• Multivariable logistic regression • Indicator variable for pre (2007-2010) vs. post (2011-2012) • Risk adjustment: yes	• Secondary analysis: GEE to account for clustering by attending physician

Author (Year)	Context	Relevant analytic method	Notes
Silber et al. (2014a)[15]	To develop an improved method for auditing hospital cost and quality	• Template matching	None
Silber et al. (2014b)[16]	To develop an improved method for auditing hospital cost and quality tailored to a specific hospital's patient population	• The authors introduce what they define as "hospital-specific template matching," a form of direct standardization with a hospital's own patients	None

Appendix C: Calculation Algorithm for Options 1, 2, and 3

Option 1 is defined by the following equations:
Let y_i be the number of admissions during time t_i for patient i in Year 1 (Y1). Assuming y_i follows a negative binomial distribution with mean μ_i, for negative binomial regression, μ_i can be modeled as:

$$\log(\mu_i) = \beta_0 + \beta_1 RF_{i1} + \beta_2 RF_{i2} + \cdots \beta_p RF_{ip} + \log(t_i),$$

where p is the number of risk factors and RF_{ip} is the pth risk factor for patient i. The coefficients from this model are applied to Year 2 (Y2) patients such that:

$$e_j = \exp(\beta_0 + \beta_1 RF_{j1} + \beta_2 RF_{j2} + \cdots \beta_p RF_{jp} + \log(t_j)),$$

where e_j is the expected number of admissions for patient j in Y2. The expected admission rate of Y2 patients E_2 is calculated as:

$$E_2 = \sum_{j=1}^{n} e_j \Big/ \sum_{j=1}^{n} t_j$$

where n is the number of patients in Y2. The improvement is then calculated as $O_2 - E_2$, where O_2 is the observed admission rate of Y2 patients. A 95% confidence interval is constructed using the Delta method.

Option 2 is defined by the following equations:
Let y_i be the number of admissions during time t_i for patient i across Y1 and Y2. Assuming y_i follows a negative binomial distribution with mean μ_i, for negative binomial regression, μ_i can be modeled as:

$$\log(\mu_i) = \beta_0 + \beta_1 RF_{i1} + \beta_2 RF_{i2} + \cdots \beta_p RF_{ip} + \beta_t Year_i + \log(t_i),$$

where p is the number of risk factors and RF_{ip} is the pth risk factor for patient i and β_t is the beta coefficient of the time indicator $Year_i$ taking on the value one if patient i was assigned to an ACO in Y2 and the value zero if the patient i was assigned to the ACO in Y1.

Improvement is then calculated as: $\exp(\beta_t)$

Option 3 is defined by the following equations:
Let y_i be the number of admissions during time t_i for patient i across Y1 and Y2 in the matched cohort. Assuming y_i follows a negative binomial distribution with mean μ_i, for negative binomial regression, μ_i can be modeled as:

$$\log(\mu_i) = \beta_0 + \beta_t Year_i + \log(t_i),$$

where β_t is the beta coefficient of the time indicator $Year_i$ taking on the value one if patient i was assigned to an ACO in Y2 and the value zero if the patient i was assigned to the ACO in Y1 in the matched cohort.

Improvement is then calculated as: $\exp(\beta_t)$.

Appendix D: Measure Specifications for Heart Failure ACO Admission Measure (ACO-37)

Table D1. Diagnostic codes used to define heart failure patients in the heart failure ACO admission measure (ACO-37)

Note: ICD-9-CM refers to International Classification of Diseases, Ninth Revision, Clinical Modification

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 D2. Condition categories and ICD-9-CM codes used to define risk model variables in heart failure ACO admission measure (ACO-37)

Note: CC refers to Condition Categories and ICD-9-CM refers to International Classification of Diseases, Ninth Revision, Clinical Modification

CC or ICD-9-CM code	Description
High risk cardiovascular (CV) factors	
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
Low risk CV factors	
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
Arrhythmia	
CC 92	Specified Heart Arrhythmias
CC 93	Other Heart Rhythm and Conduction Disorders
Structural heart disease	
CC 86	Valvular and Rheumatic Heart Disease
CC 87	Major Congenital Cardiac/Circulatory Defect
CC 88	Other Congenital Heart/Circulatory Disease
Advanced cancer	
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
Dementia	
CC 49	Dementia/Cerebral Degeneration
CC 50	Nonpsychotic Organic Brain Syndromes/Conditions
Diabetes w/ complications	
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 or ICD-9-CM code	Description
CC 119	Proliferative Diabetic Retinopathy and Vitreous Hemorrhage
CC 120	Diabetic and Other Vascular Retinopathies
Dialysis status	
CC 130	Dialysis Status
Disability/frailty	
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
Gastrointestinal and genitourinary disorders (GI/GU)	
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
Hematological disorders	
CC 44	Severe Hematological Disorders
CC 46	Coagulation Defects and Other Specified Hematological Disorders
Infectious and immune disorders	
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
Kidney disease	
CC 128	Kidney Transplant Status
CC 131	Renal Failure
CC 132	Nephritis
Liver disease	
CC 25	End-Stage Liver Disease
CC 26	Cirrhosis of Liver

CC or ICD-9-CM code	Description
CC 27	Chronic Hepatitis
CC 28	Acute Liver Failure/Disease
Neurological disease	
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
Psychiatric illness/Substance abuse	
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
Pulmonary disease	
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
Other advanced organ failure	

CC or ICD-9-CM code	Description
CC 79	Cardio-Respiratory Failure and Shock
CC 77	Respirator Dependence/Tracheostomy Status
Iron deficiency anemia	
CC 47	Iron Deficiency and Other/Unspecified Anemias and Blood Disease
Major organ transplant	
CC 174	Major Organ Transplant Status
Other organ transplant	
CC 175	Other Organ Transplant/Replacement
Pacemaker/cardiac resynchronization therapy (CRT)/implantable cardiac device (ICD)	
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
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

CC or ICD-9-CM code	Description
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 E: Additional Results

Table E1. Distribution of absolute risk factor rate change (%) from Y1 to Y2 across 114 Shared Savings Program ACOs

Risk variable	Distribution of absolute risk factor rate change (%)										
	Min	1st	5th	10th	25th	Median	75th	90th	95th	99th	Max
Age (mean difference)	0.00	0.00	0.01	0.04	0.07	0.19	0.34	0.54	0.81	0.99	1.49
High risk cardiovascular (CV) factors	0.00	0.05	0.11	0.20	0.76	1.66	3.13	4.68	6.41	7.24	11.99
Low risk CV factors	0.00	0.03	0.11	0.25	0.78	1.36	2.65	3.84	5.17	6.14	6.30
Arrhythmia	0.03	0.06	0.08	0.29	0.88	1.65	2.81	4.20	6.14	6.84	8.84
Structural heart disease	0.08	0.09	0.21	0.43	0.85	1.98	4.11	5.67	7.02	7.88	8.76
Advanced cancer	0.01	0.01	0.05	0.09	0.29	0.61	1.15	2.08	2.85	4.70	5.27
Dementia	0.02	0.07	0.13	0.28	0.75	1.55	2.73	4.17	5.29	7.00	7.34
Diabetes w/ complications	0.01	0.01	0.05	0.19	0.66	1.30	2.64	4.12	5.39	6.45	8.70
Dialysis	0.00	0.03	0.05	0.09	0.19	0.47	0.76	1.10	1.48	2.15	2.71
Disability/Frailty	0.03	0.04	0.11	0.28	0.88	1.74	2.82	3.99	4.75	8.16	8.32
Gastrointestinal and Genitourinary disorders (GI/GU)	0.00	0.03	0.10	0.23	0.76	1.74	3.06	4.53	6.77	7.57	7.99
Hematological disease	0.00	0.00	0.19	0.38	0.87	1.92	3.08	4.15	4.83	6.36	6.64
Infection and immune disorders	0.00	0.01	0.07	0.20	0.44	0.76	1.23	2.08	2.46	2.97	3.69
Kidney disease	0.00	0.03	0.17	0.28	0.76	1.49	2.54	4.76	5.25	6.32	7.84
Liver disease	0.01	0.02	0.06	0.09	0.22	0.39	0.70	1.15	1.29	1.79	1.97
Neurological disease	0.01	0.10	0.22	0.50	0.87	1.85	3.37	5.06	5.64	8.09	8.95
Psychiatric illness/Substance abuse	0.05	0.06	0.16	0.42	0.93	2.12	3.41	4.81	6.14	7.88	8.38
Pulmonary disease	0.01	0.03	0.10	0.38	1.44	2.64	4.49	5.78	6.96	8.74	8.77
Other advanced organ failure	0.03	0.05	0.11	0.21	0.62	1.72	2.59	3.62	4.85	5.74	6.55
Iron deficiency anemia	0.02	0.11	0.16	0.31	1.08	2.03	3.52	4.70	6.52	6.95	11.69
CRT/ICD/Pacemaker	0.00	0.04	0.13	0.28	0.79	1.30	2.10	3.56	4.40	5.86	5.95

Table E2. Distribution of standardized difference (%) of risk factors between Y1 and Y2 across 114 Shared Savings Program ACOs

Risk variable	Distribution of standardized difference (%)										
	Min	1st	5th	10th	25th	Median	75th	90th	95th	99th	Max
Age (mean difference)	0.00	0.00	0.15	0.52	0.93	2.41	4.43	7.32	10.44	12.68	20.00
High-risk cardiovascular (CV) factors	0.01	0.10	0.23	0.42	1.62	3.52	6.73	9.77	13.31	16.65	24.79
Low-risk CV factors	0.01	0.10	0.35	0.66	2.24	3.84	7.08	11.20	13.94	15.95	18.33
Arrhythmia	0.05	0.13	0.17	0.61	1.82	3.50	5.97	8.57	12.38	15.29	17.79
Structural heart disease	0.16	0.18	0.47	0.88	1.70	3.99	8.61	11.50	14.48	16.13	17.80
Advanced cancer	0.05	0.05	0.20	0.37	1.12	2.46	4.39	7.58	10.17	17.06	17.68
Dementia	0.05	0.17	0.35	0.72	1.94	3.78	6.75	9.91	12.51	17.25	18.22
Diabetes with complications	0.02	0.02	0.09	0.39	1.33	2.60	5.29	8.28	10.86	12.94	17.46
Dialysis	0.01	0.16	0.30	0.57	1.28	2.77	4.38	6.11	8.16	12.91	16.49
Disability/Frailty	0.08	0.10	0.24	0.70	2.18	4.18	6.99	9.81	11.40	18.15	18.60
Gastrointestinal and genitourinary disorders (GI/GU)	0.00	0.06	0.21	0.49	1.74	3.83	6.49	9.71	14.10	16.22	17.12
Hematological disease	0.00	0.00	0.57	1.12	2.31	5.34	8.75	10.38	11.86	15.31	17.62
Infection and immune disorders	0.01	0.04	0.27	0.75	1.69	3.22	5.07	9.04	11.25	13.35	13.47
Kidney disease	0.00	0.06	0.35	0.59	1.59	3.03	5.31	9.67	10.78	12.70	17.08
Liver disease	0.12	0.15	0.37	0.59	1.40	2.81	4.69	7.62	9.90	11.65	13.22
Neurological disease	0.01	0.20	0.44	1.03	1.76	3.81	6.78	10.21	11.66	16.38	18.08
Psychiatric illness/Substance abuse	0.12	0.13	0.33	0.86	1.90	4.59	7.32	10.23	13.26	16.20	17.31
Pulmonary disease	0.03	0.07	0.20	0.76	2.96	5.41	9.11	12.01	14.24	17.55	17.67
Other advanced organ failure	0.08	0.14	0.29	0.48	1.52	4.26	6.45	9.99	12.45	15.05	16.67
Iron deficiency anemia	0.04	0.21	0.32	0.62	2.18	4.08	7.21	9.49	13.10	14.27	24.18
CRT/ICD/Pacemaker	0.01	0.11	0.29	0.71	1.81	3.03	5.29	8.87	10.35	12.90	16.86