Additional testing of gaps in mortality/complication measure score performance among selected subpopulations of interest defined by social risk factor (SRF) for the 2024 MUC submissions

Overview

As part of the 2024 MUC submissions, we present additional testing results in Hospital-Level, Risk-Standardized Complication Rate (RSCR) Following Elective Primary Total Hip Arthroplasty (THA) and/or Total Knee Arthroplasty (TKA) (MUC2024-042) and Hospital 30-Day, All-Cause, Risk-Standardized Mortality Rate (RSMR) Following Acute Ischemic Stroke Hospitalization with Claims-Based Risk Adjustment for Stroke Severity measure (MUC2024-043) score performance among selected subpopulations defined by social risk factors. We found that,

1. Patients with social risk factors had higher observed outcome rates, yet risk models performed consistently well in subgroups stratified by social risk factors.
2. When adding social risk factors to the risk models, for Stroke Mortality measure, patients with dual eligibility indicator showed a lower risk of mortality after adjusting for other clinical risk factors in a multivariable model, while patient with a high area deprivation index were associated with increased risk. For the THA/TKA Complication measure, neither of the two social risk factors showed significant effect. Minimal difference in model discrimination was observed when adding the social risk factors to the model.
3. Additional testing was conducted to quantify the impact of social risk factors on measure scores. The testing results showed that measure scores estimated for hospitals with and without adjusting for either social risk factor were highly correlated, and differences in measure scores between the social-risk-factor unadjusted and adjusted measures were minimal.

Given these findings and the complex pathways that could explain any relationship between social risk and mortality/complications, we do not adjust for social risk variables in the measures.

Introduction

CMS uses outcome measures to evaluate and improve the quality of care received by patients enrolled in Medicare. Mortality measures assess mortality within 30-day period from the date of the index admission. All deaths are considered an outcome, regardless of cause. The THA/TKA complication measure assesses a dichotomous *yes* or *no* outcome regarding whether each admitted patient experiences one or more of the defined complications.

Outcome measures, including Stroke Mortality and THA/TKA Complication measures, are designed to evaluate hospital performance and assess the quality of care provided to all patients, regardless of socioeconomic status. Evidence shows that patients negatively impacted by social determinants of health often experience lower quality of care and worse outcomes than other patients. The current models for the two measures do not adjust for social risk factors (SRFs).

This document completes the additional testing of SRFs for the 2024 MUC submission. We selected two SRFs for the additional testing: dual eligible (DE) status (enrolled in both Medicare and Medicaid) and area deprivation index (ADI) status. The testing results will answer the following questions:

1. How does the risk adjustment model perform in subgroups defined by the selected SRFs and how do they affect the model performance in the overall population?
    - We assessed the performance of the model in subgroups with and without the SRFs.

- We added the two SRFs separately and then simultaneously into the current risk models which included the clinical risk factors only. We then examined the parameter estimates and statistical significances for the SRFs in the models with SRFs. Subsequently, we assessed the impact of adding SRFs on model performance.

2. How do the selected SRFs impact the measure scores?
   - We calculated and compared measure scores (i.e., risk-standardized mortality/complication rate) with and without SRFs.

Methodology

Data sources

We used one year (January 1, 2022 – December 30, 2022) of Medicare Fee-For-Service and Medicare Advantage administrative claims data. The dataset included inpatient and outpatient administrative data on each patient for the 12 months prior to the index admission and the 30 days (for Stroke Mortality measure) or 90 days (THA/TKA Complication measure) following it. The dataset contained inpatient, outpatient and professional claims and Medicare enrollment data. For the SRFs, the dual eligible variable was obtained through enrollment data and ADI was obtained through Neighborhood Atlas data.

Social risk factors

We selected SRF variables after reviewing the literature and examining available national data sources. We sought variables that are consistently captured in a reliable fashion for all patients in this measure. There is a large body of literature linking various SRFs to worse health status, greater use of the emergency department, and higher readmissions. Income, education, housing quality, and occupation are the most commonly examined SRFs studied. Unfortunately, these variables are not available at the patient-level for this measure. Therefore, proxy measures of income, education level and economic status were selected.

The conceptual relationship, or potential causal pathways by which the possible SRFs influence the risk of mortality or complications following an acute illness or major surgery, like the factors themselves, are varied and complex. There are at least four potential pathways that are important to consider:

1. Patients with SRFs may have worse health at the time of hospital admission.
2. Patients with SRFs often receive care at lower quality hospitals.
3. Patients with SRFs may receive differential care within a hospital.
4. Patients with SRFs may experience worse health outcomes beyond the control of the health care system.

Although we analytically aimed to separate these pathways to the extent possible, we acknowledge that risk factors often act on multiple pathways simultaneously, and as such, individual pathways can be complex to distinguish analytically. Further, some SRFs, despite having a strong conceptual relationship with worse outcomes, may not have statistically meaningful effects on the risk model. They also have different implications on the decision to risk adjust or not. Based on these conceptual considerations, the SRFs used for the additional testing and the rationale were:

• Dual eligible status: Dual eligible (DE) status (i.e., enrolled in both Medicare and Medicaid) for a discharge is derived using the beneficiary enrollment data file in the Integrated Data Repository (IDR). The data includes monthly enrollment status, and a patient is considered DE for an index admission if they are enrolled in both Medicare and Medicaid in the month of discharge date of the admission. Following guidance from the Office of the Assistant Secretary for Planning and Evaluation (ASPE) and a body of literature demonstrating differential health care and health outcomes among dual eligible patients, we identified dual eligibility as a key variable. We recognized that Medicare-Medicaid dual eligibility has limitations as a proxy for patients' income or assets because it is a dichotomous outcome and does not provide a range of values. However, the threshold for over 65-year-old Medicare patients is valuable, as this qualification takes into account both income and assets and is consistently applied across states for the older population.

• Area Deprivation Index status: The Area Deprivation Index (ADI) is a multidimensional measure of socioeconomic status of a geographical area. It considers 4 socioeconomic domains, including education, income/employment, housing, household characteristics. It measures at the census block group level and is calculated as a ranking from 0 to 100, with 0 meaning least deprived and 100 meaning most deprived. A census block group is a geographical unit used by the US Census Bureau and is the smallest geographical unit for which the bureau publishes sample data. The target size for block groups is 1,500, with a typical population of 600 to 3,000 people. We dichotomized the ADI rankings to greater than or equal to 85 (High ADI) versus less than 85 (Low ADI) per recommendation by the developer of ADI. For this analysis, we linked ADI at the census block group level to a 9-digit zip code.

Statistical methods

We first assessed the relationship between the SRF variables with the outcome by summarizing the prevalence of SRFs across hospitals and comparing the outcome rate between patients with and without the SRFs. We also looked at the calibration plots to determine whether the original model predicts similarly well for different social risk groups.

Next, we examined the impact on model performance by adding the SRFs into the model. Specifically, we evaluated parameter estimates, and we also examined the extent to which the addition of any one of these variables improved model performance (c-statistic). Then, we calculated the hospital measure score differences and correlation coefficients of scores with and without the SRFs.

Lastly, our analyses revealed a slight underprediction for high ADI patients, so we sought to additionally investigate the relationship between the hospital proportion of high ADI patients and measure scores, as well as focusing on the quartile of hospitals with the highest proportion of high ADI patients.

Results

Prevalence of SRFs across measured entities

Table 1. Variation in prevalence of SRFs across measured entities

Measure	Number of Hospitals (>=25 admissions)	Median Percentage of Prevalence, (IQR)	
		DE	High ADI
Stroke Mortality	2033	12.61 (8.65 – 19.05)	8.41 (1.69 – 22.86)
THA/TKA Complication	1270	5.13 (2.48 – 10.00)	6.78 (1.22 – 18.75)

Table 1 shows that the prevalence of SRFs varied across measured entities. For Stroke Mortality cohort, the median percentage of DE patients was 12.61 (IQR: 8.65 - 19.05) and the median percentage of high ADI patients was 8.41 (IQR: 1.69 - 22.86). For THA/TKA Complication cohort, the median percentage of DE patients was 5.13 (IQR: 2.48 - 10.00) and the median percentage of high ADI patients was 6.78 (1.22 -

18.75). Additionally, the proportion of DE or high ADI patients was higher for Stroke Mortality measures, compared to THA/TKA Complication measure.

Table 2. Comparison of observed outcome rate (%) between patients with and without SRFs

Measure	Observed Outcome Rate (%)			
	DE	Non-DE	High ADI	Low ADI
Stroke Mortality	14.07	12.63	13.20	12.78
THA/TKA Complication	4.00	3.37	3.96	3.30

Table 2 shows that patient-level outcome rate was higher for DE patients compared with non-DE patients. Similarly, the outcome rate for high ADI patients was higher compared with low ADI patients.

Calibration plots for social risk groups

Figure 1 presents the calibration plot for overall Stroke Mortality measure cohort. The x-axis is the decile ranked by patient-level predicted mortality rate and the y-axis is the mean of observed/predicted mortality rate that falls in the corresponding decile.

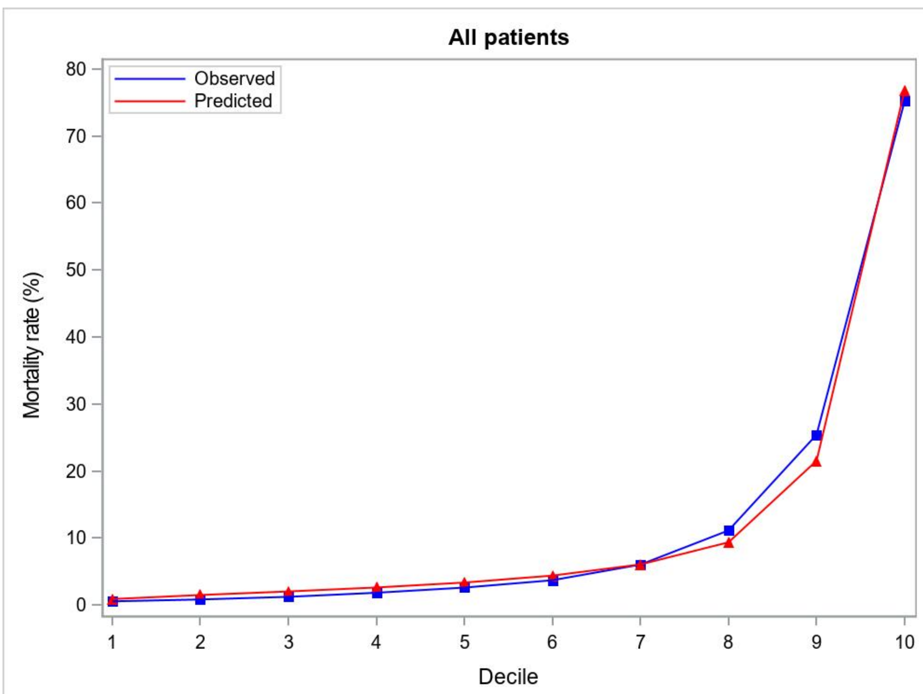

Figure 1. Calibration plot of Stroke Mortality measure for all patients

Figure 1 shows there was a minimal difference across deciles between observed mortality rate and predicted mortality rate based on all patients for Stroke Mortality measure. It indicates that the original risk-adjustment model performed well in accurately predicting the mortality rate for all patients.

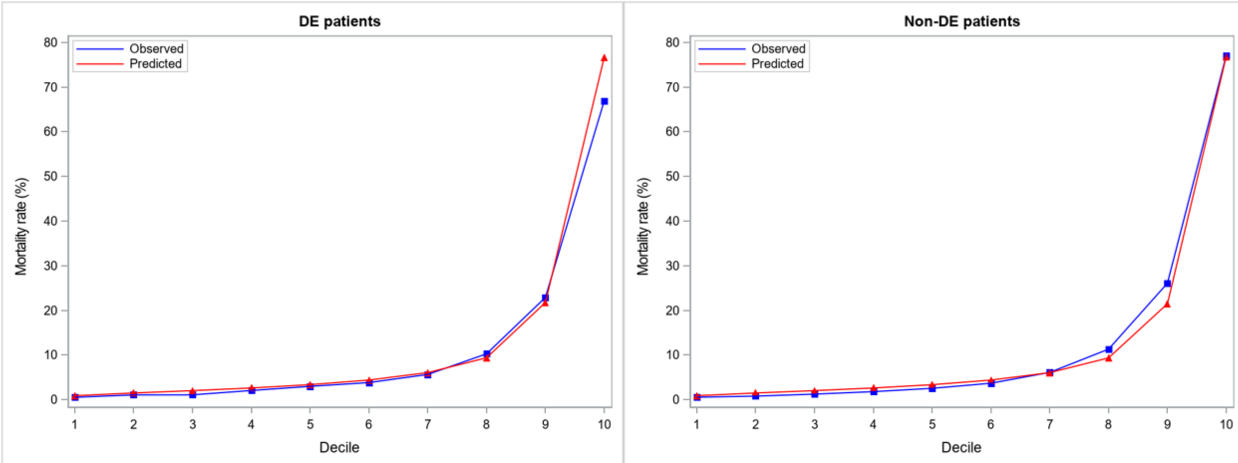

Figure 2. Calibration plot of Stroke Mortality measure between DE/non-DE patients

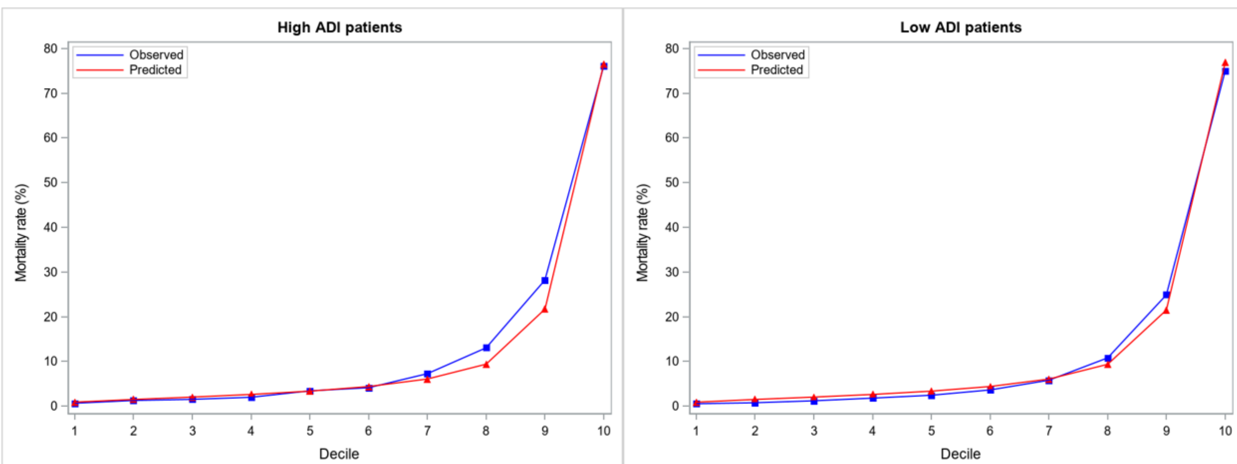

Figure 3. Calibration plot of Stroke Mortality measure between high/low ADI patients

Figures 2 and 3 present the calibration plots for Stroke Mortality measure cohort stratified by DE and ADI status. The calibration plots in Figure 2 demonstrated that the model performed similarly well for both DE and non-DE patients, while there was over-prediction for DE patients at the highest decile. From Figure 3, we observed that there was a slight underprediction of mortality rate for high ADI patients.

In addition, the calibration plots of THA/TKA Complication measure, presented in Figures 4, 5, and 6, also showed good calibration for DE and non-DE patients while showing slight underprediction for high ADI patients.

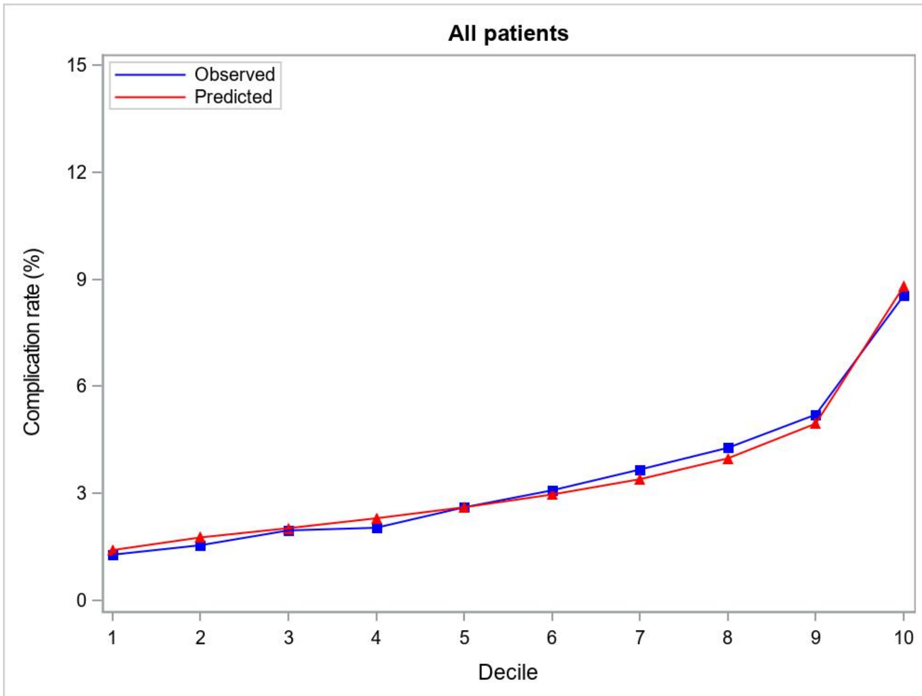

Figure 4. Calibration plot of THA/TKA Complication measure for all patients

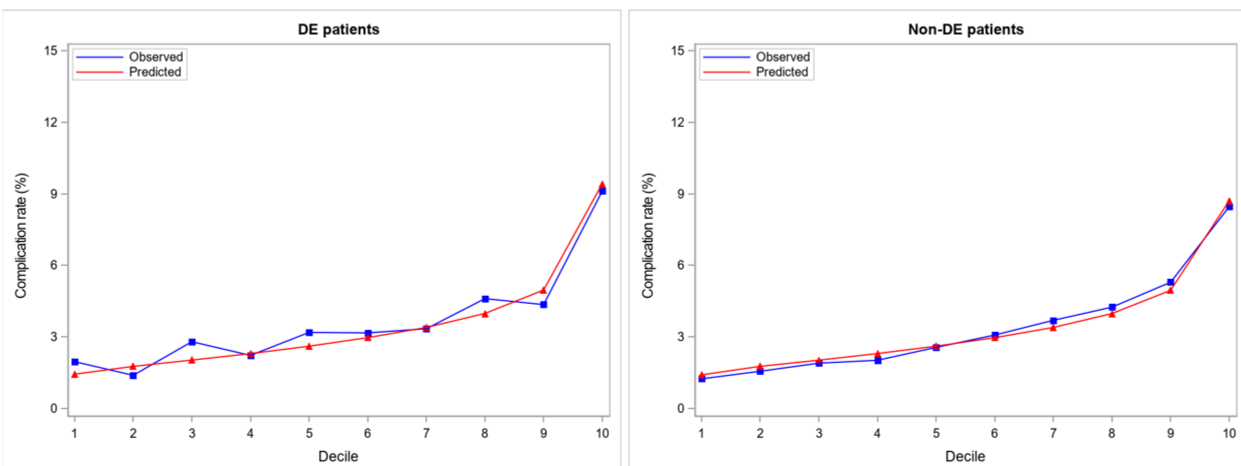

Figure 5. Calibration plot of THA/TKA Complication measure between DE/non-DE patients

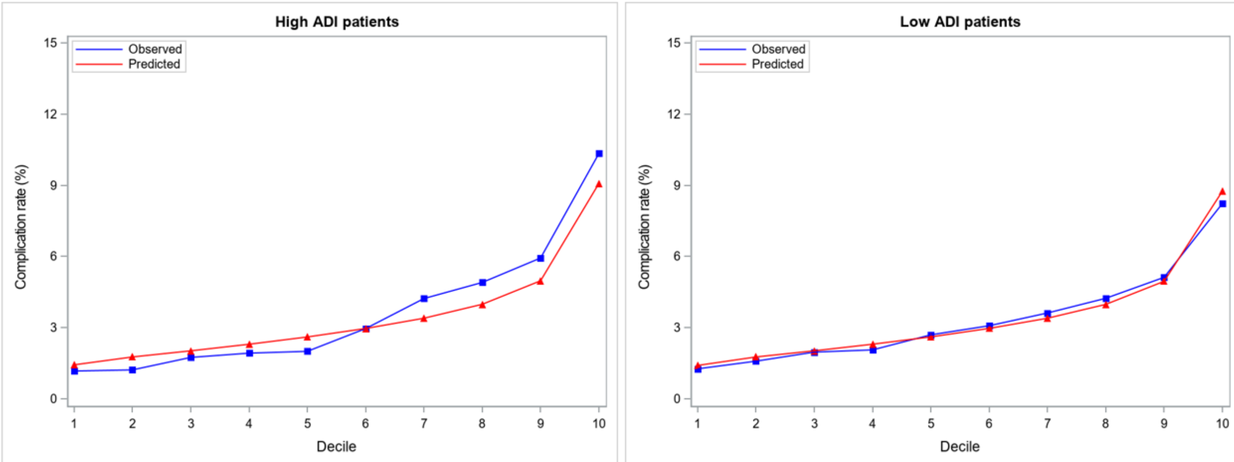

Figure 6. Calibration plot of THA/TKA Complication measure between high/low ADI patients

Incremental effects of SRF variables in a multivariable model

Table 3 shows the estimated odds ratio with the corresponding 95% confidence interval of each SRF variable within the hierarchical logistic model when the two SRFs were added one at a time and both at the same time, to the original risk-adjustment model with the clinical risk factors included.

Table 3. Estimated odds ratio and 95% confidence interval of SRF variables

Measure	SRF	Adding Either SRF Individually	Adding Both SRFs Simultaneously
Stroke Mortality	DE	0.79 (0.75, 0.82)	0.78 (0.74, 0.81)
	High ADI	1.20 (1.15, 1.25)	1.21 (1.16, 1.27)
THA/TKA Complication	DE	1.02 (0.93, 1.13)	1.00 (0.90, 1.11)
	High ADI	1.08 (0.99, 1.18)	1.08 (0.99, 1.18)

For Stroke Mortality measure, the association between death and high ADI was positive. The odds ratio of DE, however, was consistently negative whether added to the model individually or simultaneously with high ADI. Given this association and the observation that the model without DE overpredicted for DE patients, it suggests that the model without SRFs have sufficiently adjusted for DE patients for stroke mortality. For THA/TKA Complication measure, both the effect of DE and high ADI were insignificant in the multivariate model.

We also found that the c-statistics for the logistic model were almost unchanged with the addition of either or both SRFs into the model (Table 4).

Table 4. C-statistic for models with and without SRFs

Measure	Model			
	Base (without SRFs)	Base plus DE	Base plus high ADI	Base plus DE and high ADI
Stroke Mortality	0.91	0.91	0.91	0.91
THA/TKA Complication	0.67	0.67	0.67	0.67

Impact on measure score

We then examined the impact of adding each SRF separately on measure scores, i.e., the national average mortality/complication rate multiplied by the ratio of predicted and expected mortality/complication rate at each hospital. We found that the addition of either SRF to the model had little to no effect on hospital performance, as measured by the distribution of absolute difference in measure scores and by the correlation coefficients between measure scores, with and without the SRFs (Table 5).

Table 5. Differences in measure score and correlation coefficients comparing the measure model with and without each SRF

Measure	Metric	Absolute difference in measure scores (%)		Measure Score Correlation
	SRF	Median	IQR	Pearson Correlation Coefficient
Stroke Mortality	DE	-0.0002	-0.0005 - 0.0003	0.9990
	High ADI	0.0006	-0.0006 - 0.0014	0.9847
THA/TKA Complication	DE	0.0000	-0.0000 - 0.0000	1.0000
	High ADI	0.0002	0.0000 - 0.0004	0.9893

Relationship between measure score and proportion of patients with SRF

As we observed an underprediction for high ADI patients, we aimed to test the impact of such underprediction on hospitals with various proportions of high ADI patients. Therefore, we investigated the relationship between measure score and quartile of proportion of high ADI patients.

Figure 7 presents the relationship between measure score (i.e., RSMR) and quartile of proportion of high ADI patients for the Stroke Mortality measure. A great overlap of measure scores was observed across different quartiles of proportion of high ADI patients, suggesting that hospitals with more high ADI patients did not inherently have a significantly higher measure score.

Additionally, the boxplot of THA/TKA Complication measure (Figure 8) indicated similar conclusions.

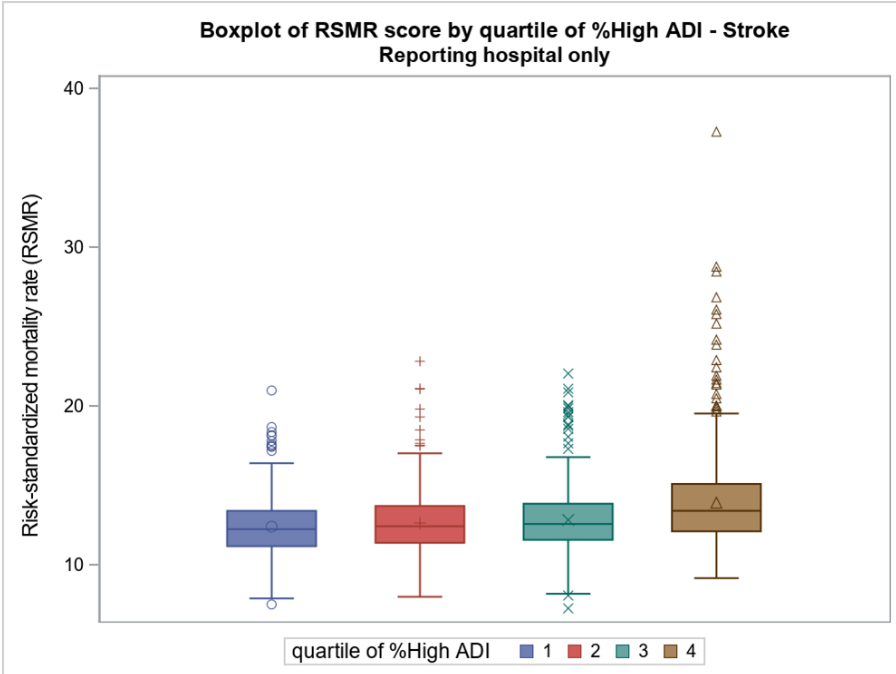

Figure 7. Boxplot of RSMR score by quartile of proportion of high ADI patients – Stroke Mortality

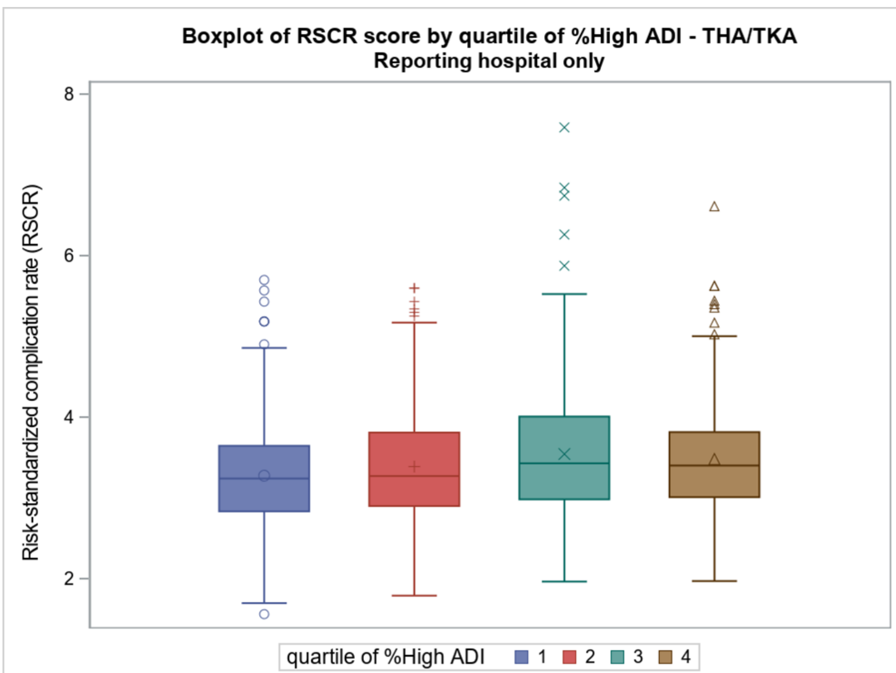

Figure 8. Boxplot of RSCR score by quartile of proportion of high ADI patients – THA/TKA Complication

Summary

The analyses above showed that the observed outcome rate for patients with SRFs is higher. For THA/TKA Complication measure, neither SRFs was significantly associated with complications. For Stroke Mortality measure after adjusting for other clinical risk factors, patients who are dually eligible were at decreased risk of mortality, while high ADI status was associated with a higher risk of mortality. We believe that the clinical risk factors account sufficiently for patients with SRFs and the overall effect of these SRFs on the measure score was deemed minimal. First, the models calibrated well in subgroups stratified by SRFs without adding the SRFs. Second, the estimated risk-standardized measure scores for hospitals with and without adjusting for either social risk factor were highly correlated. Third, the differences in measure scores between the social-risk-factor unadjusted and adjusted measures were minimal. Finally, a substantial overlap of measure score was observed across different quartiles of proportion of high ADI patients, suggesting that hospitals with more high ADI patients did not inherently have a higher risk of mortality/complication. Given these findings and the complex pathways that could explain any relationship between social risk and mortality/complications, we did not incorporate social risk variables into the measures.

References

Adler NE, Newman K. Socioeconomic disparities in health: pathways and policies. *Health affairs* (Project Hope). 2002; 21(2):60-76.

Blum AB, Egorova NN, Sosunov EA, et al. Impact of socioeconomic status measures on hospital profiling in New York City. *Circulation Cardiovascular quality and outcomes.* 2014; 7:391-7.

Buntin MB, Ayanian JZ. Social Risk Factors and Equity in Medicare Payment. *New England Journal of Medicine.* 2017;376(6):507-510.

Calvillo-King L, Arnold D, Eubank KJ, et al. Impact of social factors on risk of readmission or mortality in pneumonia and heart failure: systematic review. *J Gen Intern Med*. 2013 Feb; 28(2):269-82. doi: 10.1007/s11606-012-2235-x. Epub.

Chang W-C, Kaul P, Westerhout CM, Graham MM, Armstrong Paul W. Effects of Socioeconomic Status on Mortality after Acute Myocardial Infarction. *The American Journal of Medicine.* 2007; 120(1): 33-39.

Chen HF, Nevola A, Bird TM, et al. Understanding factors associated with readmission disparities among Delta region, Delta state, and other hospitals. *Am J Manag Care.* May 2018.24(5): e150-156.

Committee on Accounting for Socioeconomic Status in Medicare Payment Programs; Board on Population Health and Public Health Practice; Board on Health Care Services; Institute of Medicine; National Academies of Sciences, Engineering, and Medicine. Accounting for Social Risk Factors in Medicare Payment: Identifying Social Risk Factors. *National Academies Press (US)*. 2016 Jan 12. https://www.ncbi.nlm.nih.gov/books/NBK338754/doi:10.17226/21858.

Department of Health and Human Services, Office of the Assistant Secretary of Planning and Evaluation. Report to Congress: Social Risk Factors and Performance under Medicare's Value-based Payment Programs. *U.S. Department of Health and Human Services.* December 21, 2016. https://aspe.hhs.gov/pdf-report/report-congress-social-risk-factors-and-performance-under-medicares-value-based-purchasing-programs.

Department of Health and Human Services, Office of the Assistant Secretary of Planning and Evaluation (ASPE). Second Report to Congress: Social Risk Factors and Performance in Medicare's Value-based Purchasing Programs. *Department of Health and Human Services*. 2020. https://aspe.hhs.gov/pdf-report/second-impact-report-to-congress.

Eapen ZJ, McCoy LA, Fonarow GC, Yancy CW, Miranda ML, Peterson ED, Califf RM, Hernandez AF. Utility of socioeconomic status in predicting 30-day outcomes after heart failure hospitalization. *Circ Heart Fail.* May 2015; 8(3):473-80.

Howard VJ, Kleindorfer DO, Judd SE, et al. Disparities in stroke incidence contributing to disparities in stroke mortality. *Ann Neurol*. 2011; 69:619–627.

Hu J, Gonsahn MD, Nerenz DR. Socioeconomic status and readmissions: evidence from an urban teaching hospital. *Health affairs* (Project Hope). 2014; 33(5):778-785.

Kind AJH, Buckingham W. Making Neighborhood Disadvantage Metrics Accessible: The Neighborhood Atlas. *New England Journal of Medicine*, 2018. 378: 2456-2458. DOI: 10.1056/NEJMp1802313. PMCID: PMC6051533. AND University of Wisconsin School of Medicine Public Health. 2021 Area Deprivation Index v4. Downloaded from https://www.neighborhoodatlas.medicine.wisc.edu/ July 14, 2023.

Krumholz HM, Brindis RG, Brush JE, et al. Standards for statistical models used for public reporting of health outcomes. *Circulation.* 2006; 113: 456-462. http://circ.ahajournals.org/content/113/3/456.full.pdf+html.

Lindenauer PK, Lagu T, Rothberg MB, et al. Income inequality and 30 day outcomes after acute myocardial infarction, heart failure, and pneumonia: retrospective cohort study. *BMJ*. 2013 Feb 14; 346:f521. doi: 10.1136/bmj.f521.

Mackenbach JP, Cavelaars AE, Kunst AE, Groenhof F. Socioeconomic inequalities in cardiovascular disease mortality; an international study. *European heart journal.* 2000; 21(14):1141-1151.

Normand S-LT, Shahian DM. Statistical and Clinical Aspects of Hospital Outcomes Profiling. *Statist. Sci.* 2007; 22(2): 206-226 . DOI: 10.1214/088342307000000096.

Pedigo A, Seaver W, Odoi A. Identifying unique neighborhood characteristics to guide health planning for stroke and heart attack: fuzzy cluster and discriminant analyses approaches. *PloS one*. 2011;6(7):e22693.

Reames BN, Birkmeyer NJ, Dimick JB, et al. Socioeconomic disparities in mortality after cancer surgery: failure to rescue. *JAMA surgery.* 2014; 149:475-81.

Spatz ES, Beckman AL, Wang Y, Desai NR, Krumholz HM. Geographic Variation in Trends and Disparities in Acute Myocardial Infarction Hospitalization and Mortality by Income Levels, 1999-2013. *JAMA Cardiol*. 2016;1(3):255-265. doi:10.1001/jamacardio.2016.0382.

Tonne C, Schwartz J, Mittleman M, Melly S, Suh H, Goldberg R. Long-term survival after acute myocardial infarction is lower in more deprived neighborhoods. *Circulation*. Jun 14, 2005; 111(23):3063-3070.