4.4.2 Conceptual Model Rationale for the Stroke Mortality Measure

The goal of risk adjustment is to adjust for case-mix differences between hospitals. Risk adjustment supports fair and accurate comparison of outcomes across measured entities by including an adjustment for patient-level factors such as age, comorbid diseases, and indicators of patient frailty, which are clinically relevant and have relationships with the outcome.

In pursuing an approach that best leverages the data and analytical advancements since initial measure development, we developed and evaluated a framework to use individual ICD-10 codes for risk adjustment. The main advantage of leveraging ICD-10 codes in place of the prior method (that used an ICD-10 grouper, CMS's Condition Categories, or CCs) is the ability to address the clinical heterogeneity found in the broadly defined CCs. Our previous research indicates that the model performance of the mortality measures is significantly improved by using individual codes instead of CCs.

Selection of Clinical Risk Variables

For candidate risk variables, we included all secondary ICD-10 codes documented as present-on-admission (POA) during the index admission (except for the palliative care code of Z51.5, which, effective October 1, 2021, was considered POA-exempt), and both principal and secondary ICD-10 codes in the 12 months prior to admission from any inpatient, outpatient, and professional provider claims. We also considered age, frailty, sex, an indicator for whether the admission was MA vs. FFS and other non-individual-ICD variables in the existing publicly reported CMS mortality measures. The variable selection of individual ICD codes mainly relied on data-driven methodologies involving three key steps: 1) pre-processing, 2) evaluating association with outcome, and 3) consideration of associations between other non-individual-code variables, including frailty, with the outcome.

In pre-processing, we screened and included index and history (pre-index) codes if their prevalence exceeded 0.5% and 2.5%, respectively. Further, pairs of index and pre-index codes that correlated larger than 0.8 were combined into one risk variable. Specific ICD-10 codes for social risk factors were removed from the candidate list to be consistent with how the measures currently address social risk. Finally, pairs of the index and pre-index ICD-10 codes where the difference in association with the outcome, measured by Odds Ratio (OR), was less than 0.2 were merged. We additionally excluded ICD-10 codes that begin with R297 since they are components of the National Institutes of Health Stroke Scale (NIHSS) variable included in the risk adjustment model for the measure as a numeric variable in a later stage.

In the second step, we included the remaining candidate variables with age in a multivariable logistic regression model and underwent variable selection through 1,000 iterations of bootstrapping. We selected variables that were statistically significantly associated with outcomes ($p<0.05$) greater than a certain cutoff value of frequency over the bootstrapped samples. The cutoff value was chosen for each measure based on empirical evaluation of the model performance. We forced age into the model if it was not selected into the model through the bootstrapping process.

Lastly, based on literature evidence, specific suggestions, and guidance from the consensus-based entity for measure endorsement, the Assistant Secretary for Planning and Evaluation [ASPE. 2020], other stakeholders, as well as prior testing results, we included a claims-based indicator of frailty that was developed for CMS's Multiple Chronic Conditions measure in the final model for all measures. We generally did not include sex as a variable since sex can be considered a socio-demographic variable.

We also added into the model for all measures the history of coronavirus disease 2019 (COVID-19) variable to be consistent with current CMS policy. For the stroke mortality measure only, we added into the model the NIHSS score variable derived from ICD-10 codes R29701–R29742 corresponding to NIHSS score 1–42. For patients with no R297 codes, we imputed the NIHSS score as 0.

For the combined MA and FFS cohort, the risk adjustment model was updated to include an MA indicator (versus FFS) as a main effect. This was to adjust for the generally higher prevalence of comorbidities in the MA cohort, especially among the pre-index variables that were derived from services in the outpatient setting (e.g., physician visits). For the stroke mortality measure, the NIHSS variable was also included in the final model as specified in the current measure; the related ICD-10 diagnosis codes for the NIH stroke scale variable are removed from the candidate variable for this measure.

Social Risk Factors

To inform our conceptual framework regarding the impact of social risk factors on stroke outcomes, we reviewed the existing literature. Our search was centered on articles that included key terms related to stroke mortality, disparities in socioeconomic and sociodemographic factors, and access to healthcare.

Our findings highlighted several demographic and socioeconomic variables that significantly influence stroke outcomes. Age, for instance, was an example of a determinant of stroke outcomes, with older adults experiencing higher mortality rates and poorer recovery outcomes post-stroke. Smithard (2017) noted that individuals aged 80 and above are more prone to increased frailty and multiple health conditions, which increases their risk of mortality and complicated recovery. Kelly and Rothwell (2021) further supported this by showing that frail older adults have a six-fold increase in mortality compared to those who are not frail, largely due to the compounded effects of frailty and pre-existing health conditions such as cardiovascular disease and diabetes.

Socioeconomic status (SES) is another factor influencing stroke outcomes. A systematic review and meta-analysis by Wang et al. (2020) revealed that individuals with the lowest SES had a 39% higher risk of stroke-related mortality compared to those with the highest SES. The study highlighted that lower SES populations often have reduced access to high-quality acute care and rehabilitation services which results in delayed treatment and poorer recovery after a stroke.

Disparities in stroke outcomes and care by race are also well documented and have been identified at the geographic and hospital level. A recent analysis by the CDC confirmed the well-known race disparity: at the county level, median stroke mortality rates were higher for Black vs. white Medicare beneficiaries over age 65 (1,214 vs 1,115 deaths per 100,000, respectively, or an absolute disparity of 61.5 deaths per 100,000 individuals. While there are racial disparities in the underlying risk factors for stroke, and in the incidence of stroke, there is also evidence for disparities in treatment within the healthcare system. A 2022 systematic review analyzed 30 studies that examined racial differences in hospital-based care and found disparities in rates of evidence-based treatment of ischemic stroke, lower use of emergency services, longer waiting times (emergency department, and time-to-treat), and lower referral rates to higher-level facilities among Hispanic and Black patients compared with white patients.

Social Risk Factor Conceptual Model

Our social risk factor conceptual model described below builds on the literature cited above and envisions several different pathways, including:

1. **Patients with social risk factors may have worse health at the time of hospital admission**. Patients who have lower income/education/literacy or unstable housing may have a worse general health status and may present for their hospitalization or procedure with a greater severity of underlying illness. These social risk factors, which are characterized by patient-level or neighborhood/community-level (as proxy for patient-level) variables, may contribute to worse health status at admission due to competing priorities (restrictions based on job, lack of childcare, etc.), lack of access to care

(geographic, cultural, or financial), or lack of health insurance. Given that these risk factors all lead to worse general health status, this causal pathway should be largely accounted for by current clinical risk-adjustment**.**

2. **Patients with social risk factors may receive care at lower quality hospitals**. Patients of lower income, lower education, or unstable housing may have inequitable access to high quality facilities, in part, because such facilities may be less likely to be found in geographic areas with large populations of patients with social risk factors. Thus, patients with low income may be more likely to be seen in lower quality hospitals, which can contribute to an increased risk of stroke mortality.
3. **Patients with social risk factors may receive differential care within a hospital.** The third major pathway by which social risk factors may contribute to readmission risk is that patients may not receive equivalent care within a facility. Alternatively, patients with social risk factors such as lower education may require differentiated care – e.g., provision of lower literacy information – that they do not receive.
4. **Patients with social risk factors may experience worse health outcomes beyond the control of the healthcare system.** Some social risk factors, such as income or wealth, may affect the likelihood of readmission without directly affecting health status at admission or the quality of care received during the hospital stay. For instance, while a hospital may make appropriate care decisions and provide tailored care and education, a lower-income patient may have a worse outcome post-discharge due to competing economic priorities or a lack of access to care outside of the hospital.

These proposed pathways are complex to distinguish analytically. They also have different implications on the decision to risk adjust or not. We, therefore, first assessed if there was evidence of a meaningful effect on the risk model to warrant efforts to distinguish among these pathways. Based on this model, the following social risk variables were considered:

Dual-eligible (DE) Status

Dual eligibility for Medicare and Medicaid is available at the patient level in the Medicare Master Beneficiary Summary File. The eligibility threshold for aged 65 or older Medicare patients considers both income and assets. For the dual-eligible (DE) indicator, there is a body of literature demonstrating differential health care and health outcomes among beneficiaries (ASPE, 2020).

Area Deprivation Index (ADI)

While we previously used the AHRQ social risk variable in these types of analyses, we now use the validated ADI (Forefront Group, 2023). We made this change to align with other CMS work on social risk factors that now use the ADI. We describe the ADI variable below.

The ADI, initially developed by the Health Resources & Services Administration, is based on 17 measures across four domains: income, education, employment, and housing quality (Kind et al., 2018; Singh, 2003).

The 17 components are listed below:

- Population aged ≥ 25 y with < 9 y of education, %
- Population aged ≥ 25 y with at least a high school diploma, %
- Employed persons aged ≥ 16 y in white-collar occupations, %
- Median family income, $
- Income disparity

- Median home value, $
- Median gross rent, $
- Median monthly mortgage, $
- Owner-occupied housing units, % (homeownership rate)
- Civilian labor force population aged ≥16 y unemployed, % (unemployment rate)
- Families below poverty level, %
- Population below 150% of the poverty threshold, %
- Single-parent households with children aged < 18 y, %
- Households without a motor vehicle, %
- Households without a telephone, %
- Occupied housing units without complete plumbing, % (log)
- Households with more than one person per room, % (crowding)

ADI scores were derived using the beneficiary's 9-digit ZIP Code of residence, which is obtained from the Master Beneficiary Summary File and is linked to 2017-2021 US Census/ACS data. In accordance with the ADI developers' methodology, an ADI score is calculated for the census block group corresponding to the beneficiary's 9-digit ZIP Code using 17 weighted Census indicators. Raw ADI scores were then transformed into a national percentile ranking ranging from 1 to 100, with lower scores indicating lower levels of disadvantage and higher scores indicating higher levels of disadvantage. Percentile thresholds established by the ADI developers were then applied to the ADI percentile to dichotomize neighborhoods into more disadvantaged (high ADI areas=ranking equal to or greater than 85) or less disadvantaged areas (low ADI areas=ranking of less than 85).

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