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ORIGINAL ARTICLE

Social Determinants of Health Improve Predictive Accuracy of Clinical Risk Models for Cardiovascular Hospitalization, Annual Cost, and Death

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BACKGROUND: Risk models in the private insurance setting may systematically underpredict in the socially disadvantaged. In this study, we sought to determine whether US minority Medicare beneficiaries had disproportionately low costs compared with their clinical outcomes and whether adding social determinants of health (SDOH) into risk prediction models improves prediction accuracy.

METHODS AND RESULTS: Retrospective observational cohort study of 2016 to 2017 Medicare Current Beneficiary Survey data (n=3614) linked to Medicare fee-for-service claims. Logistic and linear regressions were used to determine the relationship between race/ethnicity and annual costs of care, all-cause hospitalization, cardiovascular hospitalization, and death. We calculated the observed-to-expected (O:E) ratios for all outcomes under 4 risk models: (1) age+sex, (2) model 1+clinical comorbidity adjustment, (3) model 2+SDOH, and (4) SDOH alone. Our sample was 44% male and 11% black or Hispanic. Among minorities, adverse clinical outcomes were inversely related to cost. After multivariable adjustment, blacks/Hispanics had higher rates of cardiovascular hospitalization (incidence rate ratio, 1.78; *P*=0.012) but similar annual costs ($–336, *P*=0.77) compared with whites. Among whites, models 1 to 4 all showed similar O:E ratios, suggesting high accuracy in risk prediction using current models. Among minorities, adjustment for age, sex, and comorbidities underpredicted all-cause hospitalization by 20% (O:E, 1.20) and cardiovascular hospitalization by 70% (O:E, 1.70) and overpredicted death by 21% (O:E, 0.79); adding SDOH brought O:E near 1 for all outcomes. Among both groups, the SDOH risk model alone performed with equal or superior accuracy to the model based on clinical comorbidities.

CONCLUSIONS: A paradoxical relationship was observed between clinical outcomes and costs among racial and ethnic minorities. Because of systematic differences in access to care, cost may not be an appropriate surrogate for predicting clinical risk among vulnerable populations. Adjustment for SDOH improves the accuracy of risk models among racial and ethnic minorities and could guide use of prevention strategies.

Key Words: cohort studies ■ ethnic groups ■ health policy ■ linear models ■ primary prevention

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WHAT IS KNOWN

- Interventions that are directed at high-cost patients may under-target racial and ethnic minorities, who were shown in 1 prior study to have relatively lower costs but worse clinical outcomes.
- Social determinants of health are major drivers of poor health outcomes, and racial and ethnic minorities have a higher burden of these social determinants.

WHAT THE STUDY ADDS

- Adding social determinants data to current risk prediction models improved model accuracy for hospitalization, death, and costs of care among racial and ethnic minorities in a large, nationally representative cohort of older US adults.
- A model based on social determinants of health alone predicted health outcomes and costs as well as one based on clinical comorbidities.
- Including social determinants in prediction models could improve equity in preventive care by more accurately targeting interventions to people at the highest clinical risk.

Hospitals and clinicians are increasingly held accountable for patients' outcomes and costs of care, as Medicare and other payers move from paying for volume to paying for value. As a result, health systems often rely on algorithms and risk prediction models to identify high-risk patients who may benefit from interventions. Many of these models are built with costs as their primary outcome, with the idea that high-cost patients are the group that warrants the most targeted and aggressive intervention to improve outcomes.

One prior study demonstrated that uneven access to health care among racial and ethnic minorities may lead cost prediction models to systematically underpredict costs for high-risk groups, which could lead these groups to receive interventions to improve health outcomes at inappropriately low rates.[1] Similarly, studies on 2 current gold standard clinical risk prediction tools used in cardiovascular medicine, the pooled cohorts equation and the Framingham Risk Score, demonstrate that these models underestimate risk for racial and ethnic minority groups and overestimate risk for whites.[2–4] If costs and clinical risk are systematically mispredicted by current models, the application of such tools to clinical practice could further widen racial and ethnic disparities by failing to match needs to interventions for at-risk groups.

Numerous studies have documented the importance of social determinants of health (SDOH), such as food insecurity, housing instability, and education level, as important drivers of health outcomes.[5–9] This is highly relevant for minorities, who have higher prevalence rates of these social risk factors.[10] This is due, in part, to the negative effects of structural racism and segregation, which have led to disproportionately higher proportions of racial and ethnic minorities living in areas of poor social and economic conditions.[11] However, few studies have examined whether the addition of SDOH into risk prediction models improves risk prediction accuracy and whether these improvements differ by race. Prior studies have incorporated few indicators of social risk or were conducted in small, single-center populations.[2,12] Understanding how adding SDOH to these models impacts risk prediction for racial and ethnic minorities could allow health systems and clinicians to more accurately identify high-risk groups for targeted interventions and avoid exacerbating disparities in care.

Therefore, in this study, we sought to examine whether the addition of SDOH into risk prediction models improves prediction accuracy for minorities. We used a nationally representative sample of US Medicare beneficiaries to determine (1) whether racial and ethnic minority Medicare beneficiaries had disproportionately low predicted costs compared with their clinical outcomes; (2) whether current risk models differ in their accuracy in predicting risk for cardiovascular hospitalization, death, and annual cost between racial and ethnic minorities and whites; and (3) whether the addition of a robust panel of social determinant factors could improve risk prediction accuracy.

METHODS

Data Source and Study Sample

Due to the sensitive nature of the data for this study, the authors are not authorized to share the data. The Centers for Medicare and Medicaid Services (CMS) provides a Medicare Current Beneficiary Survey (MCBS) public use file free for download on their webpage. Requests to access the full MCBS dataset must be requested through the Limited Data Set File Process at cms.gov.

This was a retrospective observational study of 2016 to 2017 MCBS data linked to fee-for-service Medicare claims. The MCBS is a continuous, in-person survey with a 4-year longitudinal design. It is conducted annually and is a nationally representative sample of Medicare participants. Study inclusion was limited to 4703 participants who had 12 consecutive months of enrollment in the MCBS and in fee-for-service Medicare in the baseline year (2016) and 12 months of enrollment or death in the following year (2017). Participants institutionalized in long-term care or without a US ZIP code in the baseline year were excluded (n=561). We further excluded 528 participants for missing data on at least 1 key study variable of interest (problem sleeping, n=527; angina, n=133; overweight, n=133; activities of daily living, n=133; instrumental activities of daily living, n=133), leaving a final study sample of 3614 individuals (Figure I in the Data Supplement).

Definition of Groups

Race was self-reported during survey interview, and participants were classified as white (n=3138), black (n=281), Hispanic (n=61), Asian (n=31), Native American or Pacific Islander (n=26), and unspecified (n=67). We classified their responses into 2 categories: white/other and black/Hispanic (minority). Participants were designated as poor if they were dually enrolled in Medicare and Medicaid. We also identified participants' age, sex, and certain comorbidities including hypertension, dyslipidemia, disordered sleep, overweight, obesity, diabetes mellitus, coronary artery disease, renal insufficiency, chronic obstructive pulmonary disease/asthma, and heart failure. All of the above conditions were identified in the medical claims of participants with *International Classification of Diseases*, Tenth Revision, Clinical Modification diagnosis codes according to the algorithms defined by the Medicare Chronic Condition Warehouse,[13] except for disordered sleep, overweight, and obesity, which were identified using survey questions in the MCBS.

Selection of Social Determinant Variables

Social determinant variables were selected in a 2-step process. First, variables were selected based on variables included in the CMS social determinants assessment.[14] Variables identified as particularly impactful for cardiovascular outcomes by the American Heart Association were also selected.[5] Second, these variables were then assessed according to 3 key factors: feasibility of collection, potential to be actionable, and potential for impact. The final list included the following variables, spanning 7 core SDOH domains: (1) neighborhood and the built environment (rural versus urban residence), (2) behaviors and habits (alcohol abuse), (3) access to care (answers to questions on whether the respondent has trouble getting care, how well the patient speaks English, belief that doctor is concerned with patient's overall health, whether patient has confidence in doctor, whether the patient finds it easy to get to doctor from their home, whether patient reports there is adequate access to specialists), (4) economic status (income, income-to-poverty level), (5) financial strain (answers to questions on whether the respondent has medical bills in collection, ever delayed medical care due to costs, or ever did not seek medical care at all due to costs), (6) social support (marital status), and (7) education: (level of schooling completed). For more detailed information about these variables, please see Table I in the Data Supplement.

Outcomes

Primary outcomes for the study were all-cause hospitalization, cardiovascular hospitalization, death, and annual cost. All primary outcomes were ascertained during the follow-up year, 2017. All-cause hospitalization was defined as all inpatient hospitalizations listed in participants' part A claims. Cardiovascular hospitalization was defined as an inpatient stay (as defined above) with a primary cardiovascular discharge diagnosis *International Classification of Diseases*, Tenth Revision, Clinical Modification code. Annual costs were defined as the total amount reimbursed by Medicare for all part A and part B services. Death was measured using the date of death recorded by the MCBS using Medicare administrative records.

Analysis

First, we computed descriptive statistics for the SDOH predictor variables as well as age, sex, and comorbid conditions (as means or proportions). We also computed descriptive statistics as incidence rates per 100 population on hospitalization outcomes, means on cost outcomes, and proportions on mortality outcomes.

Next, we assessed the unadjusted association between race and the outcome variables, using univariate negative binomial regression (hospitalization outcomes), logistic regression (mortality outcome), and ordinary least squares regression (cost outcome). We reported these results as incidence rate ratios, odds ratios, and cost coefficients.

Finally, we estimated 4 sets of multivariable regression models for each of our 4 outcomes to predict these outcomes under each of the modeling scenarios. We modeled each outcome according to the regression methods appropriate to each outcome as specified above. For model 1, we used age and sex to predict each of our 4 outcomes at the participant level. For model 2, we added the CMS hierarchical condition categories (CMS-HCC) risk-adjustment model to model 1. The CMS-HCC risk-adjustment model assigns points for age, sex, original reason for Medicare eligibility, dual Medicaid enrollment (in some cases), institutionalization in long-term care, and 83 clinical conditions identified by diagnoses in Medicare claims.[15] CMS-HCC ranks diagnoses into categories representative of conditions with similar cost patterns; higher categories correlate with higher predicted costs and result in higher risk scores. For model 3, we added SDOH risk factors to model 2. For model 4, we only used SDOH risk factors to predict outcomes. Each model was run independently of all of the other models in the analysis. For the cost model, we examined the residuals from the CMS-HCC and CMS-HCC plus SDOH models to examine model fit (Figure II in the Data Supplement).

We compared the predicted (ie, expected) to the actual (ie, observed) outcomes, taking the average of these across the entire population and then using observed-to-expected (O:E) event ratios to compare the accuracy of each modeling scenario in our study population. An O:E ratio >1 implies the model underpredicted the actual event, and <1 implies the model overpredicted the actual event. In this way, the O:E ratios tell us which modeling scenario provides the most accurate predictions. We further stratified our O:E ratios by the white/other versus black/Hispanic population to determine which modeling scenario generated the most accurate predictions in these at-risk subpopulations.

Statistical Package Used

Statistical analyses were performed using SAS 9.3 and Stata 14.2. Statistical significance was defined as $P<0.05$. This study was considered to be non-human subjects research due to the deidentified nature of the data. The study was approved by the Human Research Protection Office at the Washington University in St. Louis. All analysis was performed in compliance with the MCBS data use agreement.

RESULTS

Study Population

We included 3614 MCBS participants in our study (Table 1). Our sample was 44% male, 11% black/Hispanic, and 16% poor. The majority of the patients (71%) were between the ages of 65 and 84 years. The prevalence of comorbid conditions was high, with hypertension (61%) and dyslipidemia (54%) being the most prevalent. Other cardiovascular risk factors including diabetes mellitus and obesity were present in about a third of the beneficiaries (27% and 31%, respectively). Coronary artery disease was prevalent in 25% of patients.

Compared with white/other beneficiaries, black and Hispanic beneficiaries were more likely to be dually enrolled in Medicaid and Medicare (45% versus 13%) and had a higher prevalence of comorbidities, such as hypertension (66% versus 61%), heart failure (16% versus 10%), obesity (44% versus 29%), diabetes mellitus (37% versus 25%), renal insufficiency (28% versus 18%), and tobacco use (14% versus 10%).

Prevalence of Social Risk Factors

The burden of social risk was high among beneficiaries (Table 2). Nearly half of participants had low social support (defined as not being married). Financial strain was reported in 11% of participants, 16% were living at <100% below poverty, and 17% had limited access to care. Most beneficiaries had completed high school or some college (57%), while some (15%) had no high school education or lower. Many beneficiaries (41%) were low income, reporting <$25 000/year in income.

Compared with white/other beneficiaries, black/Hispanic beneficiaries were more likely to have income <$25 000 (72% versus 38%), no high school or college education (34% versus 13%), be living at <100% below poverty (41% versus 13%), and report financial strain (27% versus 9%), lack of social support (69% versus 50%), and limited access to care (30% versus 15%).

Relationship Between Clinical Outcomes and Costs of Care

Before risk adjustment, compared with white/others, black/Hispanic beneficiaries had higher rates of all-cause hospitalization (48 versus 29 per 100; *P*=0.004) and cardiovascular hospitalization (16 versus 7.7 per 100; *P*=0.011), similar rates of death (3.4% versus 3.9%; *P*=0.451), and no significant difference in annual costs of care ($11 754 versus $9849; *P*=0.080; Figure).

In fully adjusted models, higher age and clinical comorbidity burden correlated with higher risk for adverse events, and there was directional agreement in groups defined by these features between adverse events and annual cost (Table 3). For example, those in the highest tertile of comorbidity index had the highest rates of adverse outcomes and higher costs compared with those in mid and low tertiles of clinical risk (all-cause hospitalization incidence rate ratio, 3.29; cardiovascular hospitalization incidence rate ratio, 4.37; death odds ratio [OR], 3.35; cost differential, $8641; *P*<0.001 for all).

Table 1. Baseline Characteristics

	Overall	White/ Other	Black/ Hispanic
No. of patient-years with no missing variables	3614	3272	342
Demographics			
Sex			
Female	56.0%	56.0%	56.4%
Male	44.0%	44.0%	43.6%
Age, y			
Mean age	73	73	65
<65	15.3%	12.9%	38.3%
65–75	35.4%	36.3%	26.6%
75–84	35.3%	36.5%	24.6%
≥85	14.0%	14.3%	10.5%
Original reason for Medicare eligibility			
ESRD	1.1%	0.8%	3.5%
Disability	14.1%	12.0%	34.8%
Age ≥65 y	84.8%	87.2%	61.7%
Dual enrollee in Medicaid and Medicare	16.2%	13.2%	44.7%
HCC risk score (mean)	1.08	1.06	1.26
Clinical and cardiovascular risk factors			
Hypertension	61.1%	60.5%	66.4%
Dyslipidemia	53.6%	54.3%	46.8%
Coronary artery disease	24.8%	25.0%	22.8%
Angina	9.2%	9.4%	7.3%
Stroke (CVA, TIA)	3.8%	3.6%	5.6%
Heart failure	10.7%	10.2%	15.8%
Arrhythmia	10.8%	11.3%	5.6%
Obesity (BMI >30)	30.5%	29.1%	43.6%
Diabetes mellitus	26.5%	25.4%	37.4%
Renal insufficiency	19.2%	18.3%	28.1%
COPD/asthma	15.1%	15.2%	14.0%
Disordered sleep	35.3%	35.0%	37.4%
Dementia	4.1%	4.2%	3.5%
Tobacco	9.9%	9.5%	13.5%
Depression	14.0%	14.3%	11.4%

BMI indicates body mass index; COPD, chronic obstructive pulmonary disease; CVA, cerebrovascular accident; ESRD, end-stage renal disease; HCC, hierarchical condition category; and TIA, transient ischemic stroke.

Table 2. Prevalence of Social Determinant Risk Factors

	Overall	White/ Other	Black/ Hispanic
Annual income, $			
≤25 000	41.2%	38.0%	71.9%
>25 000 and <50 000	24.8%	25.9%	14.6%
≥50 000	34.0%	36.2%	13.5%
Education			
No high school or college education	14.7%	12.7%	33.6%
High school/some college	59.4%	59.7%	56.4%
College/graduate school education	25.9%	27.6%	9.9%
Race			
White	87.1%	96.2%	0.0%
Black/Hispanic	9.5%	0.0%	100.0%
Other/unknown	3.4%	3.8%	0.0%
Financial strain			
Yes	11.0%	9.4%	26.6%
No	89.0%	90.6%	73.4%
Income-to-poverty ratio			
≤100%	15.9%	13.3%	41.2%
>100% and ≤200%	24.4%	23.7%	31.0%
>200%	59.7%	63.0%	27.8%
Alcohol problem			
Yes	13.8%	13.2%	19.0%
No	86.2%	86.8%	81.0%
Social support			
Not married	51.6%	49.8%	69.0%
Residential environment			
Urban-rural location			
Metropolitan	67.8%	66.8%	77.8%
Micropolitan	17.2%	17.5%	14.0%
Rural	15.0%	15.7%	8.2%
Access to care			
Yes	83.4%	84.8%	69.9%
No	16.6%	15.2%	30.1%

However, among racial and ethnic minorities, adverse clinical outcomes were inversely related to cost. After multivariable adjustment, blacks/Hispanics had higher rates of cardiovascular hospitalization (incidence rate ratio, 1.78; P=0.012) but similar annual costs (difference in cost, $–336; P=0.77) compared with whites/others. This pattern of similar annual costs, despite higher rates of adverse clinical outcomes, was also observed for those whose income was <25 000/year, those who had less than a college education, and those reporting living at an income-to-poverty ratio of <100% (difference in costs, $–373, $–712, and $–638, respectively; P>0.05).

Accuracy of Risk-Adjustment Models

In whites/others, after age and sex adjustment alone, all-cause hospitalization (O:E, 0.94), death (O:E, 1.00), and costs (O:E, 0.98) all saw good agreement between observed and expected outcomes, whereas cardiovascular hospitalizations were overpredicted by 11% (O:E, 0.89; Table 4). Adding the CMS-HCC model elements showed similar O:E across all outcomes as the age- and sex-adjusted model. The addition of SDOH to the models brought O:E ratios closer to 1 for cardiovascular hospitalization and maintained good agreement across the remaining outcomes. Overall, among whites, the difference in O:E ratios across all 4 models was minimal.

In contrast, among blacks and Hispanics, adjusting for age and sex underpredicted all-cause hospitalization (O:E, 1.54), cardiovascular hospitalization (O:E, 2.18), death (O:E, 1.02), and costs (O:E, 1.21). Including CMS-HCC to adjust for clinical comorbidities reduced O:E ratios near one for total costs but still significantly underpredicted all-cause and cardiovascular hospitalizations, which were underpredicted by 20% (O:E, 1.20) and 70% (O:E, 1.70), respectively. After the inclusion of SDOH in the models, the O:E ratio for all events was brought near to one.

Predictions by Social Risk Alone

Among both groups, the social risk model alone performed as well as the models including demographic, cost, and clinical comorbidity adjustment. For whites/others, the SDOH risk model alone performed most accurately among all models tested with O:E of 1 for all outcomes except for cardiovascular hospitalization where O:E was 0.99. Similarly for blacks/Hispanics, the SDOH risk model showed nearly perfect agreement in O:E events across all outcomes (O:E, 0.98 and 0.96 for all-cause and cardiovascular hospitalization, respectively) and O:E of 1 for death and annual costs. This model showed more accuracy than age- and sex-adjustment or the CMS-HCC–adjustment models and similar agreement to the CMS-HCC+SDOH risk-adjustment models.

DISCUSSION

In this study, we found a paradoxical relationship between adverse outcomes and cost among racial and ethnic minorities. For white/other beneficiaries, risk for all events was predicted with high accuracy in traditional clinical comorbidity-based models. Among minorities, who were considerably more socioeconomically disadvantaged, risk was significantly underpredicted in these models. However, adjusting for social risk improved the predictive accuracy of models for racial and ethnic minorities. Among both groups, SDOH risk alone provided accurate prediction of risk for all outcomes studied.

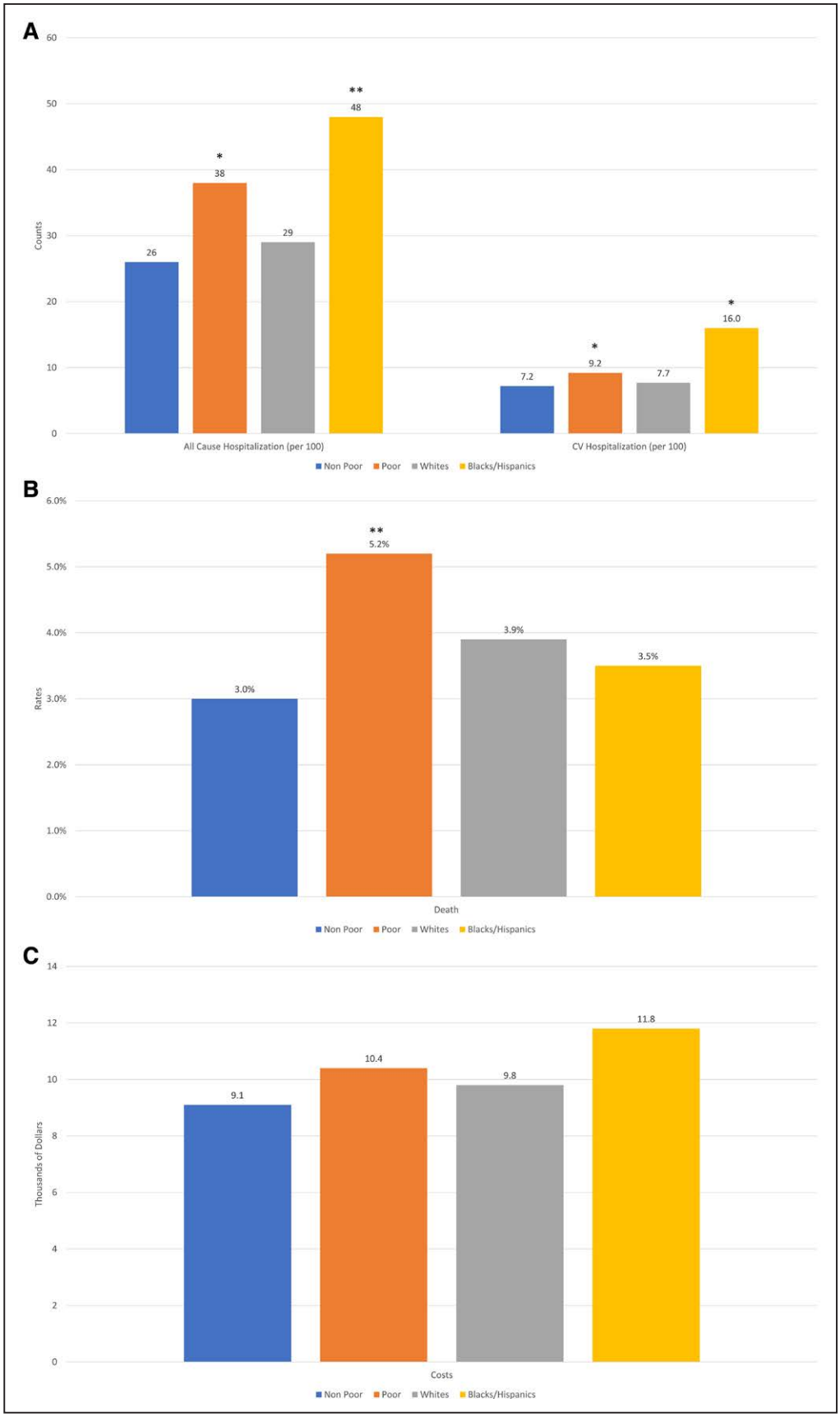

Figure. Relationship between clinical outcomes and costs by race and poverty status. All-cause hospitalization and cardiovascular (CV) hospitalization (A); death (B); costs (C).
*P<0.05, **P<0.001.

Table 3. Unadjusted and Fully Adjusted Differential in Annual Costs of Care; Fully Adjusted Rates for All-Cause Hospitalization, CV Hospitalization, and Odds of Death by Social Risk Factor

	Unadjusted	Fully Adjusted Models			
	Mean Annual Costs ($)	Difference in Cost ($)	All-Cause Hospitalization (IRR)	CV Hospitalization (IRR)	Death (OR)
Charlson Comorbidity Index					
Low tertile	5752	Ref	Ref	Ref	Ref
Middle tertile	8505	2518*	1.63†	2.45†	1.53
High tertile	16460	8641†	3.29†	4.37†	3.35†
Age, y					
<65	9167	Ref	Ref	Ref	Ref
65–75	8677	9970*	1.57	2.98	4.05
75–85	10033	9911*	1.83	3.99	8.41
≥85	13659	12966†	2.80*	6.39*	26.87*
Annual income, $					
≤25000	11132	–373	1.03	1.01	0.83
>25000 and <50000	9348	–330	1.04	1.05	1.28
≥50000	8891	Ref	Ref	Ref	Ref
Education					
No high school or college education	11775	219	1.17	1.62	0.83
High school/some college	9634	–712	1.01	1.10	0.66
College/graduate school education	9549	Ref	Ref	Ref	Ref
Race					
White	9849	Ref	Ref	Ref	Ref
Black/Hispanic	11754	–336	1.24	1.78*	0.77
Other	6876	–2712	0.86	0.42	0.66
Financial strain					
Yes	11055	167	1.18	1.36	0.92
No	9787	Ref	Ref	Ref	Ref
Income-to-poverty ratio					
≤100%	10380	–638	0.98	1.28	2.05
>100% and ≤200%	11754	1900	1.17	1.37	1.86
>200%	9060	Ref	Ref	Ref	Ref
Behavioral factors					
Alcohol problem					
Yes	12501	2720*	1.09	1.06	1.41
No	9516	Ref	Ref	Ref	Ref
Social support					
Not married	10844	1285	1.04	0.89	1.10
Residential environment					
Rurality					
Metropolitan	10622	Ref	Ref	Ref	Ref
Micropolitan	7983	–2420*	0.82	0.99	1.01
Rural	9007	–1121	0.86	0.85	1.48
Access to care					
Yes	9594	Ref	Ref	Ref	Ref
No	11606	2001*	1.17	1.09	1.01

CV indicates cardiovascular; IRR, incidence rate ratio; OR, odds ratio; and ref, reference group.
*P<0.05.
†P<0.001.

Table 4. Summary O:E Ratios in Sequentially Adjusted Models

	White/Other					Black/Hispanic				
	Unadjusted	Model 1: Age and Sex	Model 2: CMS-HCC Model	Model 3: CMS-HCC+SDOH Risk Model	Model 4: SDOH Risk Model Alone	Unadjusted	Model 1: Age and Sex	Model 2: CMS-HCC Model	Model 3: CMS-HCC+SDOH Risk Model	Model 4: SDOH Risk Model Alone
Annual incidence* of all-cause hospitalization	29.2	31.0	30.7	29.8	29.2	48.0	31.1	39.9	47.4	49.0
Annual incidence* of hospitalizations for CVD	7.5	8.4	8.4	7.6	7.6	16.1	7.4	9.5	15.6	16.5
Death	3.9%	3.9%	3.8%	3.9%	3.9%	3.5%	3.4%	4.4%	3.5%	3.5%
Total annual cost	9736	9951	9718	9736	9736	11 754	9699	11 928	11 754	11 754
	O:E ratios					O:E ratios				
Any cause hospitalization	…	0.94	0.95	0.98	1.00	…	1.54	1.20	1.01	0.98
Hospitalizations for CVD	…	0.89	0.90	0.98	0.99	…	2.18	1.70	1.03	0.96
Death	…	1.00	1.03	1.00	1.00	…	1.02	0.79	1.00	1.00
Total annual cost	…	0.98	1.00	1.00	1.00	…	1.21	0.99	1.00	1.00

An O:E ratio >1 implies that the model underpredicted actual event rates or costs in the population of interest. An O:E ratio <1 implies that the model overpredicted actual event rates of costs in the population of interest. CMS indicates Center for Medicare and Medicaid Services; CVD, cardiovascular disease; HCC, hierarchical condition category; O:E, observed to expected; and SDOH, social determinants of health.

*Annual incidence per 100 population.

Our first finding was to confirm the paradoxical relationship between clinical outcomes and costs among racial and ethnic minorities, using a nationally representative population of older adults. This is important to consider when using cost-based prediction models and suggests that cost may be an inadequate to identify high-risk patients in need of interventions. As we shift from fee-for-service to value-based payment models, healthcare systems and hospitals are becoming increasingly interested in ways to mitigate the impact of social risk on the bottom line[16]; if models fail to account for the potential distortion in cost models related to unequal access to care, interventions based on high-cost status may be inappropriately targeted for optimal effect and may systematically under-enroll racial and ethnic minorities.

Our second finding was that current risk prediction models perform better for whites than for racial and ethnic minorities across a range of cost and clinical outcomes. Further, these data suggest that the addition of SDOH to risk models may provide an opportunity to improve the performance of these models for everyone. Our findings are consistent with previous literature on clinical comorbidity-focused risk prediction tools (such as the pooled cohorts equation and Framingham Risk Score), which have been shown to overestimate risk in the affluent and underestimate risk in the socially high risk.[2,3] One prior study demonstrated improvement in primary risk prediction models for atherosclerotic cardiovascular disease after including neighborhood-level social risk.[12] However, to our knowledge, our study is the first to examine the influence of SDOH on risk prediction outside of primary risk prediction.

Our study supports the importance of social risk for accurate risk assessment, particularly among minorities. Race-based differences in the importance of social risk for accurate risk prediction may be, in part, due to unmeasured differences between black and white patients that are related to the differential lived experiences of blacks versus whites in the United States. For example,[17] structural racism and the impact of discrimination and racism unique to minorities[18] are associated with both a higher burden of social risk factors and also independently associated with stress,[19,20] inflammation, and negative health outcomes.[21] This supports arguments to push for integration of SDOH into risk prediction and clinical assessment where feasible because it would allow us to better and more equitably identify at-risk patients and intervene on that risk accordingly.[22]

Perhaps the most striking finding in this analysis was that the SDOH risk model alone performed with near 100% precision among both minorities and nonminority patients independent of adjustment for clinical comorbidities or costs. This underscores the importance of these factors as important determinants of outcomes, as well as the need to continue to develop effective strategies to collect and utilize these data if our aim is accuracy in risk prediction. Currently, there is ongoing debate as to whether it is feasible or useful to include social risk in clinical management.[23,24] Physicians have been reluctant to screen for these factors,[25] due to the sheer volume of social risk factors, lack of standardization of methods to collect them, and unclear direction as to how to address them.[23] It will be important to conduct systematic study and identification of key barriers and enablers to the col-

lection and use of these data across use cases and contexts. However, health systems and insurers have begun to think about and pilot interventions to directly impact SDOH. Some examples include providing housing, transportation, and other key services. Whether these interventions are best positioned in the healthcare delivery system or whether they should be addressed by broader strategies to improve economic opportunity remains to be seen but represents important areas for future work for both researchers and policymakers.

Limitations

There are several limitations. First, predictor variables were collected via survey, which makes the data vulnerable to certain biases (recall bias, response bias, question order bias). Second, socially disadvantaged patients may have lower health literacy, which may limit the accuracy of reporting of comorbid conditions or other variables for these groups. Third, although we chose variables based on previous studies on SDOH, this specific panel of social determinants has not been validated previously. Finally, our cost model was poorly predictive for the small number of individuals with extremely high costs, which is a problem with cost modeling using ordinary least squares regression more broadly; we elected that method because we aimed to evaluate the relationship between race, social risk factors, and costs under the models that CMS currently uses to measure costs in a number of national quality and pay-for-performance programs. Improving upon the methods of the model itself is beyond the scope of this article but may be an important area for future work.

Conclusions

A paradoxical relationship was observed between adverse outcomes and cost among racial and ethnic minorities and those from low socioeconomic groups. Because of systematic differences in access to care, cost may not be an appropriate surrogate for predicting clinical risk among the poor or other vulnerable populations, and algorithms that are based on cost alone may lead to inadequate risk prediction. We found that including social risk in models predicting costs and clinical outcomes improves model accuracy among racial and ethnic minorities. Outcome studies will be required to assess the efficacy of modifying treatment based on reclassification of risk using social determinants data. Further exploration of these models may improve risk prediction for overall and cardiovascular events among vulnerable populations and guide more optimal use of prevention strategies.

ARTICLE INFORMATION

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