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Identifying High-Cost Medicare Beneficiaries: Impact of Neighborhood Socioeconomic Disadvantage

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Abstract

The objective of this observational longitudinal study of Maryland fee-for-service Medicare beneficiaries (2015–2016) was to investigate whether using data on neighborhood socioeconomic disadvantage in addition to individual clinical risk data improves identification of high-cost Medicare beneficiaries. Neighborhood socioeconomic disadvantage is measured using the Area Deprivation Index (ADI), a validated composite measure based on publically-available US census data (2011–2015) for Maryland census block groups. Hierarchical Condition Categories (HCC) score, health care utilization, and spending were obtained from Centers for Medicare & Medicaid Services Chronic Condition Warehouse beneficiary file and Part A and Part B claims data (2015). Total cost of care (TCOC) was calculated for 2016. Descriptive and multivariate analyses were performed to examine the relationship of residency in neighborhoods with high ADI and subsequent year health care spending. Among 615,637 Maryland Medicare fee-for-service beneficiaries, those living in neighborhoods with the greatest disadvantage vs. the least disadvantage incur significantly greater costs in the subsequent year (ADI Quintile 5 \$12,439 versus Quintile 1 \$8920, $P < .001$). Clinical risk exacerbates this disparity. Among beneficiaries in the highest HCC score quintile, costs are 27% (\$5458, $P < .001$) higher among beneficiaries in the highest compared with the lowest ADI quintiles without risk adjustment and 24% (\$4599, $P < .001$) higher with risk adjustment. Several sensitivity analyses found the relationship between ADI and TCOC robust. Association between neighborhood socioeconomic disadvantage and health care cost is most pronounced among the most clinically complex Maryland Medicare beneficiaries. Using ADI in combination with HCC score may facilitate more precise targeting of care management resources.

Keywords: socioeconomic disadvantage, social determinants of health, Area Deprivation Index, Maryland, Medicare, total cost of care

Introduction

The social conditions in which individuals live, work, and play have complex and multifactorial relationships with health,[1–4] precipitating or exacerbating organic conditions while driving key behavioral health risk factors such as tobacco use,[5,6] poor diet,[7] attitudes toward physical activity,[8] and other risk behaviors.[9–11] In some ways, such contextual disadvantage may be more important than individual disadvantage in affecting health.[12,13] As Medicare shifts from paying for volume to paying for value, increasing attention is paid to the financial risks providers may face caring for socially at-risk beneficiaries, particularly without additional program investments or technical assistance for these providers.[14]

Identifying high-cost, high-complexity individual patients who can benefit from intensive care management is a critical first step in managing the quality and cost of care for a population.[15] Yet, clinical risk stratification alone is not sufficient as social factors also are powerful influencers of health outcomes.[1–4] Identifying socially at-risk patients may facilitate more efficient targeting of care management and

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other health care resources.[16] However, collecting individual-level socioeconomic data is often impractical in the clinical setting, and administrative claims data do not capture robust measures of social risk, such as income or education.[17]

A neighborhood-level measure of socioeconomic disadvantage, based on readily-available zip code information of patients' addresses, may present a more practical method of identifying high-cost, high-complexity patients when combined with clinical risk information. Area Deprivation Index (ADI) is one such measure. ADI is a validated composite measure of neighborhood socioeconomic deprivation that can be calculated for geographies as small as Census blocks and can be scaled for subnational regions, such as states.[18,19]

Previous studies demonstrate strong relationships between the ADI and mortality, hospital readmissions, and other health outcomes,[18–22] yet the relationship between ADI and health care costs has not been described in the United States. This study investigates whether using ADI as a measure of neighborhood socioeconomic disadvantage improves identification of high-cost Medicare beneficiaries when combined with a measure of clinical risk, the Hierarchical Condition Categories (HCC) risk score. This study is an observational longitudinal analysis of the association of ADI and health care spending among fee-for-service Medicare beneficiaries residing in Maryland in 2015 and 2016.

Methods

Study population

The Centers for Medicare & Medicaid Services (CMS) Chronic Condition Warehouse (CCW) Master Beneficiary File[23] was used to identify 690,317 fee-for-service Medicare beneficiaries who were continuously enrolled in both Part A and Part B plans for 12 months and had Maryland listed as the primary state of residence in 2015. Beneficiaries were excluded who did not have a valid Maryland 9-digit zip code or those with non-residential zip codes that cannot be matched to a Census block group from the US Census Bureau's American Community Survey (ACS) data (n = 14,709). A total of 4659 beneficiaries eligible for Medicare were excluded because of end-stage renal disease (ESRD) as these patients exhibit very different utilization patterns and are often included in separate risk adjustment models for CMS payments.[24] Finally, 531 beneficiaries with missing HCC score were excluded. Among the remaining 670,418 beneficiaries, 615,637 continue to reside in Maryland and were continuously enrolled in Medicare Part A and Part B in 2016.

Exposure

The research team created a Maryland-specific ADI to measure socioeconomic conditions in Maryland at the Census block group level. The Maryland ADI was calculated from a principal component analysis (PCA) as outlined by Singh[18] and using the 2011–2015 ACS 5-year Summary File data. Singh's original ADI analysis included 17 variables related to poverty, housing, employment, and education; however, one particular variable related to indoor plumbing did not load well in the PCA and was excluded, leaving 16 variables in the Maryland ADI. Supplementary Table A1 in the Technical Appendix shows the final variables used to construct the Maryland ADI and the ACS source files from which data were collected.

A final ADI base score for each block group was computed as the sum of the 16 variables weighted by their factor score coefficients obtained from the PCA. Next, a standardized z-score for each base score was calculated following Singh's approach by setting the mean to 100 and the standard deviation to 20. Factor score coefficients estimated for the Maryland ADI, validation results, and the distribution of 16 predictor variables of ADI by ADI quintile are included in Supplementary Tables A2 to A4. The resulting standardized block group-level ADI values were ranked. The research team examined the continuous distribution of ADI in relationship to the primary outcome variable (health care spending) and observed natural breaks in the data at the fourth and fifth ADI quintiles. Thus, the ADI was divided into quintiles with the lowest quintile representing the lowest socioeconomic disadvantage.

Beneficiaries were assigned to Census block groups on the basis of the 9-digit zip code of their address in 2015 using a proprietary crosswalk file.[25] Individuals reporting multiple 9-digit zip codes were assigned to a block group based on the 9-digit zip code with the longest period of residence in the year. ADI quintile indicators associated with each block group were then attached to each beneficiary.

Covariates

The key covariate variable is the HCC risk score in 2015, a standardized measure of clinical complexity and demographic information based on beneficiary age, sex, Medicare eligibility reason (ie, aged, disabled, ESRD, ESRD & disabled), Medicare–Medicaid dual eligibility status, 79 select HCC disease indicators, and interactions between disease and disability indicators.[26] HCC risk score is a validated risk-adjustment tool used by CMS.[27] For these analyses, HCC risk score was divided into quintiles with the lowest quintile representing the lowest clinical risk. Other covariates used for risk adjustment include race/ethnicity (Non-Hispanic white, Non-Hispanic black, Asian/Pacific Islander, Hispanic, Other, and Unknown), and a variable measuring the percentage of individual health care spending at a teaching hospital at the Census block group level to address the potential role of proximity and patient preference in the selection of high-cost providers.

Outcomes

The main outcome of interest is total cost of care (TCOC) – Medicare spending calculated at the individual beneficiary level as the sum total of Medicare fee-for-service Part A and Part B institutional and noninstitutional final action claims in 2016 from the CCW.[23] Additionally, the research team examined health care utilization patterns, including inpatient length of stay in number of days, inpatient admission, emergency department (ED) visit, physician office visit, and number of outpatient and ancillary claims (eg, outpatient visits, lab, procedures), for 3 prevention quality indicators (PQIs), including diabetes long-term complications and heart failure (among the adult population), and chronic obstructive pulmonary disease (COPD) or asthma (among the population aged 40 years and older). Developed by the Agency for Healthcare Research and Quality (AHRQ), PQI measures can be used to identify quality of care for ambulatory care sensitive conditions (ACSCs).[28] For this analysis, measures of diabetes long-term complications, COPD/asthma, and heart failure were selected as these conditions are chronic, costly, and sensitive to longitudinal care management in the outpatient setting. Using the comprehensive list of *International Classification of Diseases* (9^{th} or 10^{th}) diagnosis codes included for all PQI measures related to diabetes, heart failure, COPD/asthma, the team also created a flag variable for each condition, to allow examination of disease prevalence across ADI quintiles. PQI technical specifications are available on the AHRQ website.[29,30]

Statistical analysis

Descriptive statistics for beneficiary baseline characteristics included age, sex, race/ethnicity, Medicare–Medicaid dual benefit eligibility. Also reported are summary statistics of PQI disease prevalence and health utilization per 1000 beneficiaries in 2015, stratified by ADI quintiles. An ordinary least squares regression (OLS) was used to assess the relationship between ADI and individual TCOC in the subsequent year while controlling for baseline race/ethnicity, percentage of spending by teaching hospitals, and beneficiary clinical risk measured by HCC score. Logistic regressions were used to risk adjust for ACSC disease prevalence by ADI quintile, and generalized linear models (GLMs) with negative binomial distribution and log link were used to assess relationships for ADI and health utilization measures. To account for potential interactions between individual clinical risk and neighborhood socioeconomic disadvantage, interaction terms were included for each combination of HCC quintile and ADI quintile. OLS regression results are included in Supplementary Table A5. A sensitivity analysis among the subgroup of beneficiaries in the highest HCC quintile (n = 116,493) examining the impact of variation in HCC scores on the ADI and TCOC relationship within this unhealthy population (Supplementary Table A8), along with other sensitivity analyses of the impact of outliers (Supplementary Tables A6 and A7), are included in the Appendix. Differences in risk-adjusted linear mean TCOC were compared across ADI quintiles using z-tests for statistical significance; differences in percentages of baseline characteristics were compared across ADI quintiles using chi-square tests. All analyses were performed using SAS Enterprise Guide V7.1 (SAS Institute Inc., Cary NC).

Results

Figure 1 shows the geographic variation in ADI quintile across Census block groups in Maryland. Both rural and

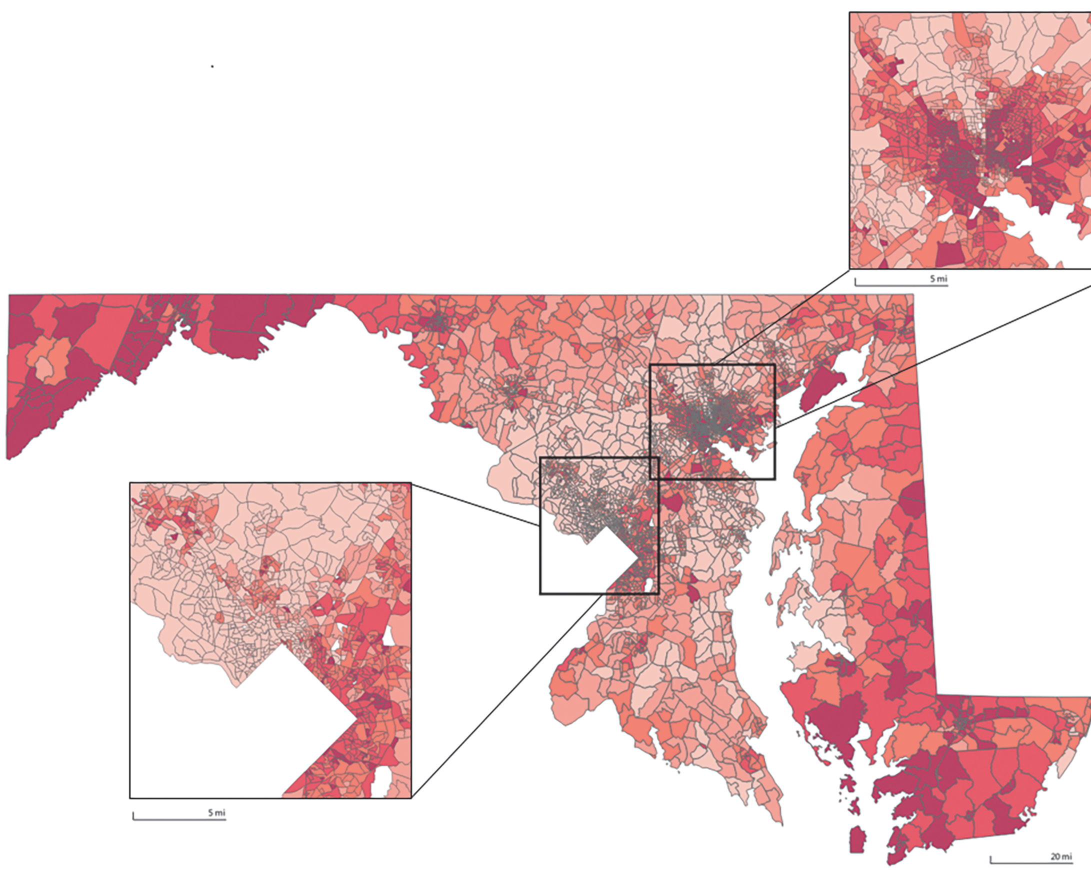

FIG. 1. Variation in Area Deprivation Index across Maryland Census block group.
ADI – least socioeconomically disadvantaged areas are depicted in *light pink* and most socioeconomically disadvantaged areas in *dark red*.
ADI, Area Deprivation Index; TCOC, total cost of care (Medicare Parts A and B); HCC, Hierarchical Condition Category.

urban areas of the state have greater socioeconomic disadvantage. Average HCC score increases from 0.92 in the lowest to 1.19 in the highest ADI quintile.

Average TCOC also significantly increases with ADI quintile.

Beneficiary characteristics display a pronounced, systematic association with level of neighborhood social risk (Table 1). Beneficiaries aged <65 years old, who are partially or fully eligible for both Medicare and Medicaid coverage, non-Hispanic black, and those with the greatest clinical complexity are more likely to live in the most socioeconomically disadvantaged neighborhoods.

For the selected ACSCs, the prevalence of diabetes, COPD/asthma, and heart failure significantly and consistently increase with ADI (Table 2). In addition to the significant positive correlation between ADI and hospital inpatient care and ED visits, higher ADI also is significantly associated with an increase in physician office visits. Utilization rates are 1.4 to 6.3 times greater in the highest versus the lowest ADI quintile, depending on the disease and the measure.

Figure 2 summarizes the impact of ADI on the subsequent year's TCOC among beneficiaries after adjusting for race/ethnicity, percentage of spending by teaching hospitals in block group of residence, and quintiles of HCC risk score (that intrinsically factored in the effects of other covariates such as age, sex, disability status, and Medicare–Medicaid dual status) in an OLS regression. After adjustment, 2016 TCOC continues to be significantly associated with ADI quintile in the overall study population (n = 615,637). However, the impact of ADI on TCOC is most pronounced within the highest HCC quintile (n = 116,493). Among the most clinically complex beneficiaries, a 24% ($4599) increase in spending is observed for beneficiaries residing in the most compared with the least socioeconomically disadvantaged areas. Notably, beneficiaries in the highest HCC quintile account for 41% of all health care expenditures, and those in both the highest HCC and ADI quintiles account for near 10% of all health care expenditures.

Discussion

Identification of the highest cost Medicare beneficiaries can be improved by using measures of both neighborhood socioeconomic disadvantage and individual clinical risk. The HCC score alone was able to identify a large segment of the high-cost, high-complexity beneficiary population; however, the addition of ADI to HCC score improved identification of these beneficiaries. Among beneficiaries in the highest HCC quintile, a 24% relative ($4599 absolute)

Table 1. Study Population (N = 615,637) Beneficiary Attributes by Quintiles of Area Deprivation Index

	ADI 1st quintile (least disadvantaged)	*ADI 2nd quintile*	*ADI 3rd quintile*	*ADI 4th quintile*	*ADI 5th quintile (most disadvantaged)*	*Overall*
N	137,889	138,422	130,922	111,633	96,771	615,637
Age Group						
<65 years	6.0%	9.7%	12.9%	17.9%	25.6%	13.5%
65–74 years	49.5%	49.2%	45.7%	44.1%	40.1%	46.2%
75–84 years	31.3%	29.3%	28.8%	26.6%	24.5%	28.4%
85 years & older	13.2%	11.8%	12.5%	11.3%	9.9%	11.9%
Sex						
Male	44.0%	43.3%	41.8%	41.3%	41.4%	42.5%
Female	56.0%	56.7%	58.2%	58.7%	58.6%	57.5%
Dual Eligibility						
Non-dual	91.2%	89.0%	86.4%	81.2%	69.7%	84.5%
Partial dual	2.6%	4.0%	5.4%	8.4%	13.8%	6.3%
Full dual	6.2%	7.0%	8.2%	10.4%	16.5%	9.2%
Race/Ethnicity						
Unknown	2.0%	1.4%	1.0%	0.8%	0.5%	1.2%
Non-Hispanic white	78.2%	76.1%	70.4%	62.4%	51.9%	69.1%
Non-Hispanic black	9.7%	15.4%	22.7%	32.1%	44.9%	23.3%
Asian/Pacific Islander	6.2%	3.6%	2.7%	1.8%	1.1%	3.3%
Hispanic	2.4%	2.5%	2.4%	2.3%	1.2%	2.2%
Other	1.5%	1.0%	0.9%	0.7%	0.5%	0.9%
HCC Quintile (Q)						
Q1 (<0.43)	23.9%	22.4%	20.0%	19.2%	16.9%	20.8%
Q2 (0.43-<0.60)	22.6%	21.3%	20.2%	19.0%	17.3%	20.3%
Q3 (0.60-<0.89)	20.3%	19.9%	19.9%	19.8%	19.3%	19.9%
Q4 (0.89-<1.45)	18.0%	19.2%	20.4%	21.1%	22.8%	20.1%
Q5 (>= 1.45)	15.2%	17.2%	19.6%	20.8%	23.7%	18.9%
Select Chronic Condition Indicator In						
Diabetes	23.4%	28.4%	30.6%	33.0%	35.2%	29.6%
COPD/Asthma	9.0%	11.3%	12.6%	14.6%	17.1%	12.6%
Heart Failure	6.6%	7.7%	8.7%	9.4%	10.5%	8.4%

All measures are significantly different ($P < 0.01$) from ADI Q1 using chi-square tests.
ADI, Area Deprivation Index; COPD, chronic obstructive pulmonary disease; HCC, Hierarchical Condition Categories.

Table 2. Prevalence and Health Care Utilization of Key Ambulatory Care Sensitive Conditions by Quintiles of Area Deprivation Index (N = 615,637)

	ADI 1st quintile (least disadvantaged)	*ADI 2nd quintile*	*ADI 3rd quintile*	*ADI 4th quintile*	*ADI 5th quintile (most disadvantaged)*	*Overall*
Diabetes						
Prevalence	23%	28%	31%	33%	35%	30%
Inpatient length of stay (days)	5.9	9.4	13.7	16.8	23.1	13.0
Inpatient admissions	1.1	1.6	2.5	3.0	4.4	2.4
ED visits	0.9	1.4	2.0	2.8	4.0	2.1
Physician office visits	64.7	81.6	91.5	103.3	110.5	88.4
Outpatient & ancillary claims	8.2	13.1	18.9	27.3	48.8	21.4
COPD/Asthma						
Prevalence	9%	11%	13%	15%	17%	13%
Inpatient length of stay (days)	14.4	25.0	30.6	45.1	53.9	32.0
Inpatient admissions	3.5	6.0	7.7	11.3	14.0	8.0
ED visits	3.4	5.9	8.2	12.1	19.9	9.1
Physician office visits	105.8	128.5	141.6	152.1	151.5	134.1
Outpatient & ancillary claims	7.5	11.2	14.3	18.9	24.3	14.5
Heart Failure						
Prevalence	7%	8%	9%	9%	10%	8%
Inpatient length of stay (days)	25.5	34.6	43.6	60.4	72.7	45.2
Inpatient admissions	5.9	7.6	10.1	12.9	15.8	10.0
ED visits	1.2	2.1	2.4	3.6	4.4	2.6
Physician office visits	32.2	34.3	41.9	44.9	49.7	39.8
Outpatient & ancillary claims	4.5	5.9	7.5	14.6	28.0	10.9

Prevalence is in percentages and utilization measures are per 1000 population. All measures are significantly different ($P < 0.01$) from ADI Q1 using chi-square tests. Risk adjusting prevalence and utilization comparison across ADI quintiles by age, sex, race/ethnicity, dual status, the percentage of cost by a teaching hospital (ranging from 0–100%) did not change the overall association between ADI and these measures. HCC score is endogenous to health utilization and so was not included in the risk adjustment.

ADI, Area Deprivation Index; ED, emergency department; COPD, chronic obstructive pulmonary disease; HCC, Hierarchical Condition Categories.

increase in TCOC is observed in beneficiaries residing in the most compared with the least socioeconomically disadvantaged areas.

Several sensitivity analyses confirm that the significant and positive relationship found between ADI and TCOC among the least healthy beneficiaries is robust. To examine the extent to which the association between ADI and TCOC may have been affected by potential outliers, the research team examined the risk-adjusted TCOC by ADI quintile excluding 2 potential sources of outliers: (1) TCOC in the 95^{th} percentile and (2) HCC scores in the 95^{th} percentile. The findings of these analyses are consistent with the main findings of the strong positive association between ADI and TCOC among the least healthy beneficiary subgroup (ie, HCC Q5 group). Within this subgroup, the first regression excluding TCOC outliers decreased the risk-adjusted TCOC difference between ADI Q5 and Q1 from $4599 to $3317 and the second regression excluding the HCC outliers decreased the cost difference to $3785. In both cases, TCOCs in ADI Q2-Q5 are statistically significantly ($P < 0.001$) higher than ADI Q1. Another subgroup analysis for the HCC Q5 group examined if the large variation in HCC scores across different ADI quintiles within this least healthy group would change the conclusion about the ADI and TCOC relationship. In this analysis, in addition to adjusting for the same covariates included in the main regressions, the team further adjusted for the continuous HCC scores, and found that the highest ADI (most disadvantaged) is still associated with a $1451 higher TCOC than the lowest ADI (least disadvantaged). This shows that ADI, independent of HCC score, has a significant relationship with TCOC. These additional findings are included in Supplementary Tables A6–A8.

Additionally, an analysis of those who remained in the same ADI quintile for an observation period of ≥2 years (91% of the total sample) found that, within the HCC Q5 group, the risk-adjusted cost differences between ADI Q5 and Q1 increased from $4599 to $4760. This indicates an even stronger relationship between ADI and TCOC among Maryland Medicare beneficiaries who remained in the same ADI quintile for longer periods. It is plausible that longer term exposure to social deprivation might affect chronic disease burden more significantly, although this conclusion is beyond the scope of this study.

The present study found a higher concentration of beneficiaries with higher HCC scores and a higher prevalence of diabetes, COPD/asthma, and heart failure among the more disadvantaged communities. Additionally, health care utilization by types of service for these ACSCs shows that ADI is positively associated with health utilization across the board, not only the potentially avoidable health care service categories (ie, inpatient stay, ED visits). Risk adjusting the prevalence and utilization measures with age, sex, race/ethnicity, and dual status using logistic regression or GLMs attenuated the relationship but did not change the overall pattern or the overall relationship between ADI and chronic disease burden (results not shown). These findings suggest opportunities for targeted prevention interventions, screening for health-related social needs, and improved care management and coordination for beneficiaries living in disadvantaged neighborhoods.

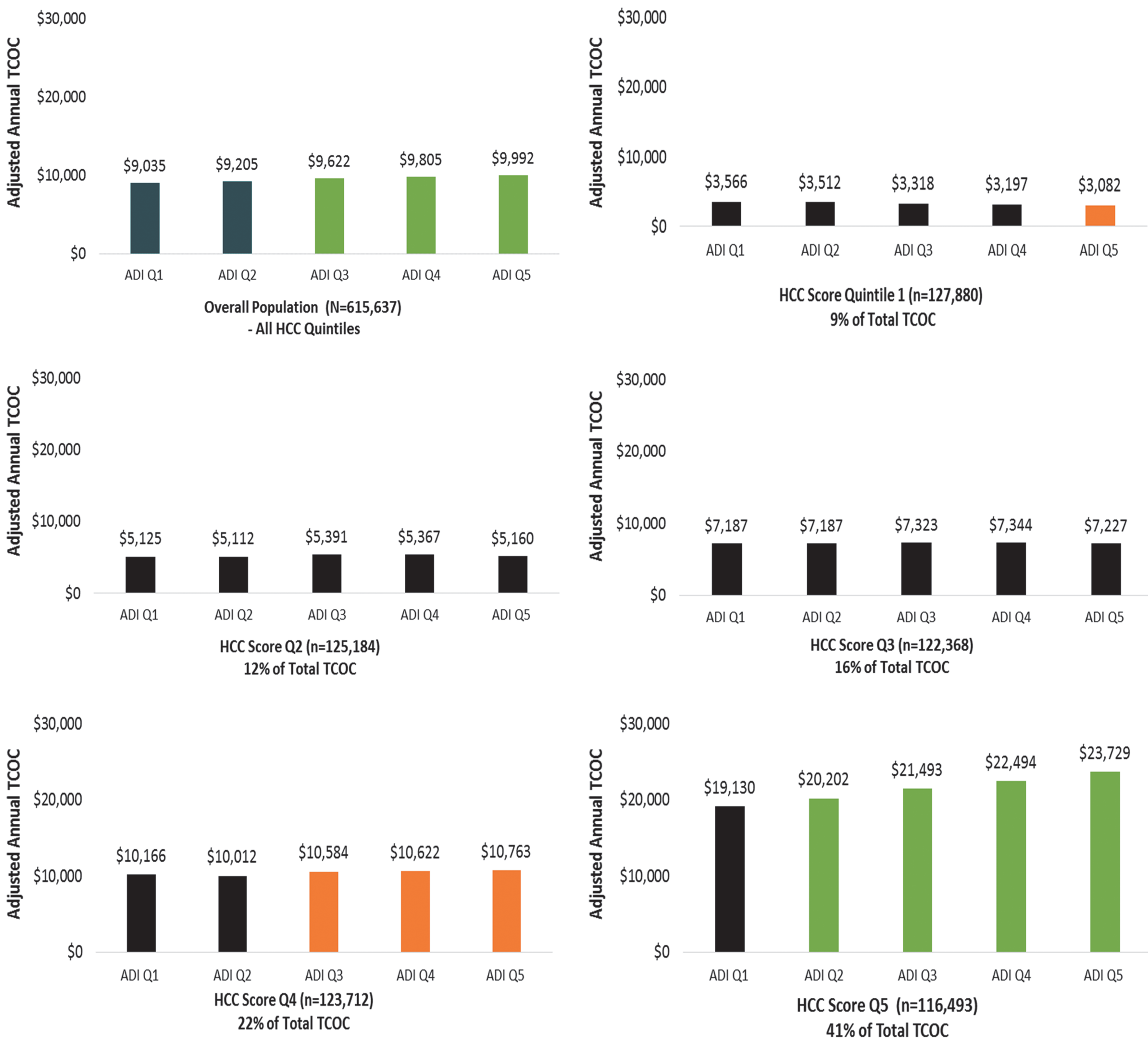

FIG. 2. Risk Adjusted 2016 Total Cost of Care (TCOC) by 2015 Hierarchical Condition Category (HCC) and Area Deprivation Index (ADI) Quintiles (N = 615,637).
Note: ADI Q1 (least socioeconomically disadvantaged), ADI Q5 (most socioeconomically disadvantaged); HCC score Q1 (healthiest), HCC score Q5 (least healthy); adjusted for race/ethnicity and percentage of spending by teaching hospitals. The *orange bars* are statistically significantly different from ADI Q1 at $p < 0.05$ and the *green bars* are significantly different from ADI Q1 at $P < 0.0001$.

These results are consistent with evidence in the existing literature that neighborhood-level social conditions influence health care utilization and spending.[31,32] It also adds new insight into the interaction between individual clinical risk and neighborhood-level social conditions. Prior work among patients receiving care at 2 hospital systems in North Carolina found no additional benefit to adding neighborhood social context to clinical risk information obtained from electronic medical records for predicting outcomes such as utilization or cost.[33] The study sample in that analysis are the residents of Durham county in North Carolina who were age 18 or older with any types of insurance coverage or were uninsured. The present study based on the Maryland Medicare beneficiary population finds that although the relationships between ADI and cost are modest overall, pronounced relationships are observed among the least healthy Medicare beneficiaries. This relationship persists when controlling for the wide variation in HCC score in the subgroup of the least healthy beneficiaries (HCC Q5). Neighborhood social context has the greatest impact on health care cost for Maryland Medicare beneficiaries who are experiencing poor health.

Present study results indicate that ADI may be an appropriate tool for prioritizing health care investments in Maryland. ADI can be used in combination with clinical risk indices to identify Medicare beneficiaries with the potential for the highest cost and who may benefit from additional interventions. One such application of ADI may be for providers who participate in alternative payment models aimed at reducing TCOC, such as accountable care organizations or hospitals on global budgets, as a method to prioritize care coordination services to the highest complexity and highest cost beneficiaries even within high clinical risk strata. For programs aimed at improving the health of geographically-defined populations, ADI also may be useful as it identifies areas with a high burden of chronic conditions amenable to both prevention and longitudinal care management. This study found that ADI is associated with clinical risk and that on its own, ADI is significantly associated with TCOC. Therefore, if no individual-level clinical risk information is available, ADI may help to identify populations within Maryland who may most benefit from intervention; however, the intersection of both HCC score and ADI remains the most closely associated with high TCOC.

This study has several strengths, including its longitudinal design. It is the first US study using state empirical data to examine the association between neighborhood socioeconomic disadvantage and future health care spending. With a large sample of more than 600,000 Maryland Medicare beneficiaries, the research team was able to provide more precise and robust estimates of the impact of ADI on TCOC, even in stratified analyses of population subgroups. The findings indicate that neighborhood disadvantage is significantly associated with health care spending in Maryland, even after accounting for population demographic characteristics, clinical risk, race/ethnicity, and percent of spending in teaching hospitals at the Census block group level. A sensitivity analysis revealed that this key finding did not change after excluding disabled beneficiaries, who are more likely to live in disadvantaged neighborhoods than aged beneficiaries, from the analysis (results not shown).

One limitation of this study is that the analysis focuses on the Maryland Medicare population only and may not be applicable to the national Medicare beneficiary population or to populations insured by other payers. To explore the implications of these findings beyond the state of Maryland, the research team performed an exploratory descriptive analysis of the national Medicare 2015 claims data linked with the latest ADI ranking (scaled around the state average) published by the University of Wisconsin's Health Innovation Program.[19] This analysis found that although many states show correlation between ADI and contemporaneous TCOC, other states showed no such relationship. These results suggest that the impact of neighborhood disadvantage on TCOC may differ depending on the underlying health and health care spending patterns of the state population. Future research could probe more deeply into the impact of state context on neighborhood disadvantage and health care spending.

Conclusions

Neighborhood socioeconomic disadvantage, as measured by ADI, is significantly associated with future health care spending among Maryland Medicare beneficiaries. Subsequent year TCOC significantly increases with residence in communities with high social disadvantage as measured by ADI quintile; this relationship persists after accounting for HCC risk score, race/ethnicity, and the percentage of health care spending in teaching hospitals in each Census block group. Living in disadvantaged neighborhoods has the most profound effect on future Medicare spending among the least healthy beneficiaries. This highlights the opportunity for refined risk identification and resource prioritization and the potential benefit for targeted care management among the most clinically complex population.

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Author Disclosure Statement

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Supplementary Material

Supplementary Data
Supplementary Table A1
Supplementary Table A2
Supplementary Table A3
Supplementary Table A4
Supplementary Table A5
Supplementary Table A6
Supplementary Table A7
Supplementary Table A8

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