Multilevel Associations of Individual- and Neighborhood-Level Factors With Racial and Ethnic Disparities in Timely Dementia Diagnosis

Yuting Qian[1], Fan Li[2], Xi Chen[1,3]

1. Department of Health Policy and Management, Yale University, New Haven, CT
2. Department of Biostatistics, Yale University, New Haven, CT
3. Department of Economics, Yale University, New Haven, CT

Corresponding Author:

Xi Chen, PhD
Department of Health Policy and Management
Department of Economics
Yale University
60 College Street, Ste 301
New Haven, CT 06520
E-mail: xi.chen@yale.edu

KEY POINTS

Question: What factors are associated with racial and ethnic differences in the timely diagnosis of dementia among US older adults?

Findings: In this population-based study of 3,424 US older adults, non-Hispanic Black and Hispanic individuals with dementia were less likely than non-Hispanic White individuals to receive a timely diagnosis. Mediation analysis revealed that individual- and neighborhood-level factors, including education, neighborhood affluence, health care practitioner density, and physician density, explained most racial and ethnic disparities in the timely diagnosis of dementia.

Meaning: These findings suggest that efforts to reduce racial and ethnic disparities in dementia diagnosis should target enhancing dementia education for racial and ethnic minority groups and supporting health care professionals in less affluent communities.

ABSTRACT

Importance: Underdiagnosis of dementia disproportionately affects racial and ethnic minority groups. As disease-modifying treatments become available, it is critical to ensure equitable detection of dementia among older adults.

Objective: To examine racial and ethnic disparities in the timely diagnosis of dementia and determine what individual- and neighborhood-level factors explain most of these disparities among older US adults with dementia.

Design: Retrospective observational study using Medicare-linked survey data from 1998-2020.

Setting: Medicare fee-for-service.

Participants: U.S. adults aged 65 and older with incident dementia in the Health and Retirement Study, linked to Medicare claims.

Exposures: Race and ethnicity of older adults.

Main Outcomes: Timely diagnosis of dementia, defined as a clinical diagnosis of dementia recorded in any Medicare claim within 3 years before or 1 year after the month of the HRS interview when dementia was first observed, compared with delayed or missed dementia diagnosis.

Results: There were significant racial and ethnic disparities in the likelihood of receiving a timely dementia diagnosis after adjusting for demographics and health conditions, with Hispanic individuals having the lowest likelihood (OR, 0.67; 95% CI, 0.51-0.88; $P < .01$), followed by non-Hispanic Black (OR, 0.73; 95% CI, 0.60-0.88; $P < .01$), relative to non-Hispanic White. However, these disparities were substantially attenuated after further adjustment for individual-level and neighborhood-level factors. Education and neighborhood affluence explained the largest proportion of the observed racial and ethnic disparities in timely diagnosis, ranging from 45.4% and 33.6% for non-Hispanic Black individuals to 58.8% and 23.4% for Hispanic individuals, compared with non-Hispanic White individuals. The density of health practitioner offices/clinics and physician offices/clinics also accounted for a significant share of the disparity in timely diagnosis for non-Hispanic Black individuals (17.9% and 14.3%) and Hispanic individuals (19.5% and 13.3%) compared with non-Hispanic White individuals.

Conclusions and Relevance: This retrospective cohort study found that a large proportion of racial and ethnic disparities in timely diagnosis among older adults with dementia was explained by educational attainment and neighborhood affluence, followed by health care practitioner and physician densities, and receiving a dementia specialist evaluation. Targeted interventions addressing these key drivers may improve early dementia detection and reduce disparities in dementia care.

Introduction

Alzheimer's disease and related dementias (ADRD), neurodegenerative conditions characterized by progressive cognitive decline, are a leading cause of disability and dependency among older adults and are the most expensive diseases in the U.S[1-3]. As life expectancy increases, the prevalence and burden of dementia are growing exponentially[4]. High-quality care for individuals with dementia begins with a timely diagnosis, a crucial first step that allows providers to identify reversible causes, optimize treatment, coordinate medical care, and help individuals and families plan for the future[5, 6]. However, dementia often goes undetected, with up to 60% of cases going undiagnosed in the U.S. primary care[7]. Although underdiagnosis is a critical public health concern across all populations, it disproportionately affects racial and ethnic minority groups. For instance, Black and Hispanic individuals are about 1.5 to 2 times more likely than White individuals to develop dementia, yet they are far less likely to receive a timely diagnosis[8-11]. The delays in diagnosis may further exacerbate racial and ethnic health disparities.

Recent advancements in dementia care, such as the FDA's approval of a new class of disease-modifying treatments for early-stage Alzheimer's disease and the Centers for Medicare & Medicaid Services' (CMS) adoption of an alternative payment model for comprehensive dementia care, represent a turning point in transforming the landscape of dementia care[12, 13]. However, racial and ethnic disparities in the timely diagnosis of dementia may hinder equitable access to these novel treatments and strategies. Ensuring equitable, timely detection of dementia is therefore critical for optimizing patient outcomes across all communities.

Prior studies have evaluated the association between individual demographic and socioeconomic factors and delayed or missed dementia diagnoses[8, 9]. Additionally, neighborhood-level factors, such as neighborhood disadvantage and rurality, have also been suggested to be associated with the timeliness of dementia diagnoses[14]. However, it remains unclear which factors drive racial and ethnic differences in receiving a timely diagnosis and the relative contributions of individual- and neighborhood-level factors to these disparities. A deeper understanding of these underlying mechanisms is essential for developing targeted interventions that address key drivers of dementia diagnostic disparities and help advance health equity. In this study, we sought to identify racial and ethnic disparities in the timely diagnosis of dementia and determine which individual- and neighborhood-level factors, including socioeconomic factors and access to health care services, explain most of these disparities among older US adults with dementia.

Methods

Data Source

We used data from the 1998-2020 Health and Retirement Study (HRS) linked with Medicare claims. The HRS is a nationally representative biennial survey of older adults in the U.S. that collects detailed information on demographics, socioeconomic status, and cognitive and physical functioning. By linking HRS data to Medicare claims, we could track the timing of diagnoses, allowing us to assess both cognitive status and diagnostic information over the years. Additionally, we merged the HRS-Medicare linked data with the National Neighborhood Data Archive (NaNDA) for the years 1998 to 2020 to extract neighborhood-level characteristics. The NaNDA is a public archival resource containing composite index measures of socioeconomic disadvantage, affluence, and health care service availability at the local level across the U.S., and

has been increasingly used in recent studies since its establishment in 2019[15-17]. Census tract identifiers from the Cross-Wave Geographic Information File in the restricted-use version of the HRS were used to link these datasets.

Study Population

We included HRS respondents from 1998 to 2020 with incident dementia who consented to Medicare records linkage and were enrolled in Medicare fee-for-service during the three years preceding and one year following the month of their HRS interview in which dementia was first observed. This three-year pre-interview and one-year post-interview window was used to define our outcomes, as described in the *Outcomes* section.

We assigned dementia status to all person-wave observations using the predicted cognition and dementia measures developed by Hudomiet et al[18]. This algorithm increases the precision of dementia classification by leveraging the longitudinal dimension of the data and is designed to produce more accurate estimates of dementia prevalence by race and ethnicity than do existing HRS-based methods[18, 19]. The dementia measures developed by Hudomiet et al. are available for the years 2000 – 2016. In our study, we built upon their methodology to include additional years by replicating their algorithms using the codes and methods they published[20]. This allowed us to supplement the original measures with replicated estimates for 1998 and from 2018 to 2020. Our replicated measures closely align with the original estimates. A detailed description of our replication methods and comparisons between our measures and those of Hudomiet et al. are provided in the Online Supplement (**eMethods** in the Supplement). Additionally, in sensitivity

analyses, we restricted our data to the 2000–2016 period, during which the original measures are fully available.

We excluded beneficiaries enrolled in Medicare Advantage (MA) plans at any point during the three-year pre-interview and one-year post-interview window, as Medicare claims are only consistently available for those covered by traditional fee-for-service (FFS) Medicare. Additionally, individuals who did not receive a diagnosis during this period but had a documented dementia diagnosis more than three years prior were excluded to avoid cases of potential overdiagnosis. Those with missing covariate data were also excluded (**eFigure 1** presents a flowchart of the sample selection process).

Measures

Our primary outcome was whether a patient with dementia received a timely diagnosis or a delayed/missed diagnosis. A timely diagnosis was defined as a clinical diagnosis of dementia recorded in any Medicare claim within 3 years before or 1 year after the month of the HRS interview when dementia was first observed. A delayed or missed diagnosis was defined as receiving the first dementia diagnosis more than 1 year after that HRS interview or never receiving a diagnosis. The diagnoses of dementia were determined based on the *International Classification of Diseases, Ninth or Tenth Revision, Clinical Modification* diagnosis codes widely used in prior studies[21-23] (**eTable 1** in the Supplement).

We evaluated individual- and neighborhood-level factors associated with differences in receiving a timely diagnosis of dementia among racial and ethnic groups. Patient race and ethnicity were

self-reported by the respondents and classified as non-Hispanic White, non-Hispanic Black, Hispanic, and non-Hispanic other. Due to the limited sample size in the non-Hispanic other category, our analysis focuses on the non-Hispanic Black, Hispanic, and White groups. Other individual-level variables included patients' demographic characteristics (age, sex), comorbid medical conditions, cognitive status (estimated using predicted latent cognition from the measures developed by Hudomiet et al.), socioeconomic status (income, education), and whether they were evaluated by a dementia specialist before diagnosis. The specialties classified as dementia specialties included neurology, psychiatry, neuropsychiatry, geriatrics, and geriatric psychiatry, as they have in previous studies[24].

Neighborhood-level socioeconomic factors and access to care were captured at the census tract level using index variables representing neighborhood disadvantage, neighborhood affluence, and density of physician and health practitioner offices/clinics. The neighborhood disadvantage index was calculated as the average of four census indicators (proportion of female-headed families with children, proportion of households receiving public assistance income or food stamps, proportion of families with income below the federal poverty level, and proportion of the population aged 16 years or older who were unemployed) ranging from 0 to 1.0. The neighborhood affluence index was derived from the average of three census indicators (proportion of households with income exceeding $75,000, proportion of the population aged 16 years or older employed in professional or managerial occupations, and proportion of adults with a bachelor's degree or higher) ranging from 0 to 1.0. The density of physician and health practitioner offices/clinics was measured as the number of physician and health practitioner

offices/clinics per 1,000 people. All individual and neighborhood factors were obtained for the year of the HRS interview in which dementia was first observed.

Statistical Analysis

We first examined racial and ethnic differences in the likelihood of receiving a timely diagnosis of dementia using multivariable logistic regression. Following the Institute of Medicine (IOM) definition of a disparity (a health service disparity between racial and ethnic groups that is not justified by the differences in health status or preferences)[25], widely used in prior research[26, 27], we adjusted for patients' unmodifiable demographic characteristics (age, sex), comorbid medical conditions, and cognitive status (estimated using predicted latent cognition from the measures developed by Hudomiet et al.) in the model (Model A) to measure racial and ethnic disparities in timely diagnosis. We then sequentially adjusted for individual-level socioeconomic status (Model B), neighborhood-level socioeconomic status (Model C), and health care access (Model D) to identify factors associated with an increased odds ratio (OR) of receiving a timely diagnosis.

To examine whether and to what extent individual- and neighborhood-level factors explain racial and ethnic disparities in timely dementia diagnosis in Model A, we used the general causal mediation approach by Imai et al[28]. Specifically, we estimated the association between race and ethnicity and timely dementia diagnosis, as well as the association between race and ethnicity and each potential mediator described in the *Measures* section (income, education, neighborhood disadvantage, neighborhood affluence, density of physician offices, density of health care practitioner offices, and whether the patient was seen by a dementia specialist before diagnosis)

using logistic regression, adjusting for age, sex, comorbid medical conditions, and cognitive status. Average causal mediation effects (ACME) were then calculated as the average difference in the probability of receiving a timely diagnosis from fixing race/ethnicity but changing the level of each mediator between the level predicted under the condition of being non-Hispanic White versus non-Hispanic Black or Hispanic. Confidence intervals were estimated via bootstrapping with 1000 resampling. The proportion mediated by each factor was then computed as the percentage of the total effect associated with corresponding indirect effects (ACME) from the mediation analyses.

We performed two sensitivity analyses. First, to assess the robustness of our findings to the choice of methods, we conducted a regression-based mediation analysis using the product-of-coefficients method described by Cheng et al[29]. Second, we repeated our analysis estimating racial and ethnic disparities in timely diagnosis while adjusting for HRS sampling weights. Sampling weights were not included in the primary analysis because their large variability can increase uncertainty and may cause convergence issues in logistic regression models used for mediation analysis. Additionally, we performed supplementary analyses comparing our primary findings with results from an analysis using the calibrated cutoff method for dementia classification, described by Crimmins et al.[30], which has been widely used in prior studies[9, 31].

All analyses were conducted using Stata, version 18 (StataCorp LLC) and R, version 4.3.0 (R Project for Statistical Computing). $P < .05$ (2-sided) was considered statistically significant. The institutional review board of Yale University reviewed and approved this study.

Results

Sample Characteristics

Of the 3,424 HRS respondents aged 65 and above with incident dementia who had Medicare linkage and FFS coverage during the three years preceding and one year following the month of their HRS interview in which dementia was first observed (**eFigure 1** in the Supplement), just over half of the respondents (53.3%) received a timely diagnosis (**Table 1**). Compared with those who received a delayed or missed diagnosis, respondents with a timely diagnosis were more likely to be older (87.7% aged ≥75 years vs 79.4%), have at least a high school education (60.5% vs 51.5%), and received a specialist evaluation (41.4% vs 33.0%). They were less likely to reside in neighborhoods with a low density of physician offices/clinics (28.6% vs 35.9%) or a low density of health practitioner offices/clinics (32.4% vs 42.5%). Additionally, a higher proportion lived in the least disadvantaged neighborhoods (23.5% vs 18.9%) and the most affluent neighborhoods (34.8% vs 25.5%).

With regard to racial and ethnic composition, 74.1% of the individuals identified as non-Hispanic White, 16.3% as non-Hispanic Black, and 7.3% as Hispanic (**Table 2**). Compared with non-Hispanic White individuals, non-Hispanic Black and Hispanic individuals were less likely to receive a timely diagnosis (55.7% vs 49.0% and 45.4%), younger (72.0% aged ≥80 years vs 56.7% and 55.8%), more likely to have income below the poverty threshold (11.7% vs 33.9% and 42.6%), and more likely to live in areas with lower physician density (29.3% vs 41.5% and 39.4%) and lower health practitioner density (31.3% vs 56.4% and 52.2%). Additionally, they were more likely to reside in highly disadvantaged neighborhoods (15.2% vs 63.0% and 64.5%) and least affluent neighborhoods (11.6% vs 41.8% and 47.0%).

Furthermore, among those who received a dementia diagnosis in our sample, the average time from dementia onset, defined as the midpoint between the interview wave in which dementia was first observed and the prior wave, to the date of the first recorded dementia diagnosis was 9 months overall (SD: 42) (**Figure 1**). In particular, the average time to dementia diagnosis was 8 months (SD: 40) among non-Hispanic White, 11 months (SD: 44) among non-Hispanic Black, and 15 months (51) among Hispanic. In addition, more than 20% of individuals with incident dementia never received a diagnosis, with a higher proportion among non-Hispanic Black (25.0%) and Hispanic (26.7%) compared with non-Hispanic White (19.5%).

Racial/Ethnic Differences in Timeliness of Diagnosis

The results of adjusted logistic regression models are presented in **Table 3**. After adjusting for demographic and health conditions, there were significant racial and ethnic disparities in the likelihood of receiving a timely dementia diagnosis, with Hispanic individuals having the lowest likelihood (OR, 0.67; 95% CI, 0.51-0.88; $P < .01$), followed by non-Hispanic Black (OR, 0.73; 95% CI, 0.60-0.88; $P < .01$). However, these disparities were substantially attenuated after further adjustment for individual-level and neighborhood-level factors. The adjusted OR for receiving a timely dementia diagnosis increased from 0.73 (95% CI, 0.60-0.88) to 0.93 (95% CI, 0.76-1.14) for non-Hispanic Black older adults and from 0.67 (95% CI, 0.51-0.88) to 0.94 (95% CI, 0.70-1.26) for Hispanic older adults, compared with their White counterparts.

Mediators of Timely Diagnosis

In the mediation analysis, we found that education and neighborhood affluence were the most significant mediators, explaining the largest proportion of the observed racial and ethnic disparities in timely diagnosis, ranging from 45.4% and 33.6% for non-Hispanic Black individuals to 58.8% and 23.4% for Hispanic individuals, compared with non-Hispanic White individuals (Figure 2). Additional mediators included the density of health practitioner offices/clinics, which accounted for 17.9% and 19.5% of the differences in timely diagnosis for non-Hispanic Black and Hispanic individuals, respectively, compared with non-Hispanic White, followed by density of physician offices/clinics (14.3% for non-Hispanic Black and 13.3% for Hispanic). A specialist evaluation also accounted for a significant share of racial and ethnic disparities in timely diagnosis, although the effect size was relatively modest (7.4% for non-Hispanic Black and 7.0% for Hispanic).

Sensitivity and Supplementary Analyses

Sensitivity analyses applying HRS sampling weights and restricting the sample to 2000–2016 (when dementia measures by Hodomiet et al. were fully available) revealed consistent racial/ethnic differences in timeliness of diagnosis (**eTable 2** and **eTable3**). The mediation analysis using the product method by Cheng et al. and the restricted sample also yields results similar to those of the main analysis (**eFigure 2** and **eTable 4**).

Our supplementary analysis shows that racial/ethnic disparities in timely dementia diagnosis were less pronounced using predicted cognition and dementia measures versus the calibrated cutoff method. Using the cutoff methods, the odds ratios (adjusted for demographics and health conditions) for receiving a timely diagnosis were 0.54 (95% CI, 0.45–0.65) for non-Hispanic

Black and 0.45 (95% CI, 0.34–0.58) for Hispanic individuals, compared with non-Hispanic White (**eTable 5**).

Discussion

Our study confirmed previous findings that, compared with non-Hispanic White patients with dementia, non-Hispanic Black and Hispanic patients were less likely to receive a timely diagnosis of dementia[8, 9, 21]. Although previous studies have documented racial and ethnic disparities in timely diagnosis, we evaluated factors that might explain these disparities and quantified the relative contributions of potential mediators. We found that, after adding individual- and neighborhood-level factors to the models, the association between race/ethnicity and the timely diagnosis was substantially attenuated. In particular, educational attainment explained about half of the observed disparity, while neighborhood factors, including neighborhood affluence, health care practitioner density, and physician density, accounted for a meaningful share of the observed disparities.

These findings are important in the context of previous studies investigating the association of educational attainment and neighborhood factors with dementia incidence among racial and ethnic groups. Several studies have found that lower educational attainment and neighborhood socioeconomic status were associated with a higher risk of dementia among racial/ethnic minorities compared with White populations[32-34]. In the context of our findings, if the adverse impacts of low education and under-resourced neighborhoods could be mitigated, far fewer patients from racial and ethnic minority groups would receive a delayed dementia diagnosis, and health disparities would be further narrowed.

This is the first study, to our knowledge, to examine the multidimensional mechanisms underlying the observed disparities in the timely diagnosis of dementia. Our findings have important implications for informing policy interventions to improve equity in early dementia detection. Specifically, our finding that educational attainment explains the largest proportion of diagnostic disparities underscores the need to strengthen education and awareness about dementia and its early symptoms among racial and ethnic minority groups. In addition, our population-based results indicate that only 37.5% of patients with dementia have received a specialist evaluation, an estimate that is consistent with previous findings on dementia diagnostic practices in California[21]. Although a specialist visit was a significant mediator of the association between race/ethnicity and timely diagnosis, the much greater proportion explained by neighborhood affluence and the density of practitioner/physician offices suggests the critical role of primary care clinicians in diagnosing dementia. It also highlights the need to expand and support health care professionals serving patients in less affluent communities.

In addition, the results from our supplementary analysis indicate that the uniform cutoff method used in prior HRS studies on racial and ethnic differences in dementia diagnosis may have overestimated these disparities, even though both the predicted dementia measures by Hudomiet et al. and the cutoff method revealed significant racial and ethnic differences in timely diagnosis. This discrepancy likely arises because the former accounts for differences in how dementia status is related to HRS cognitive measures across population subgroups, while the latter may overpredict dementia prevalence in racial and ethnic minority individuals[10].

Limitations

This study had several limitations. First, we used a prediction algorithm to identify individuals with incident dementia due to the lack of clinical ascertainment in HRS surveys across the years. However, this validated prediction model provides more accurate estimates of dementia prevalence in population subgroups than methods previously used with the HRS and is, therefore, well-equipped for the study of disparities in dementia and its diagnosis. Second, the use of the dementia prediction algorithm for 2018 and 2020 may have underestimated dementia in those years, as there might be bias in the web-based mode of data collection (web respondents tend to score higher on cognitive measures during web interviews) beginning in 2018[35]. However, results from our sensitivity analysis restricting the sample to 2000–2016 were very consistent with our main findings. Third, our sample was limited to Medicare fee-for-service beneficiaries, and therefore, the observed diagnostic delays and disparities may not be generalizable to those enrolled in Medicare Advantage plans, where risk adjustment in capitated payment models may affect the dementia detection rate. Finally, our measures of access to health services were derived at the census tract level, which may differ from county-level estimates given that counties have larger healthcare market sizes. However, since the measure is density-based, it can be less sensitive to differences in geographic scale.

Conclusion

This study found that individual- and neighborhood-level socioeconomic factors, including educational attainment, neighborhood affluence, physician and health care practitioner density, and specialist evaluation, explained a significant share of the racial and ethnic disparities in timely dementia diagnosis among non-Hispanic Black and Hispanic older adults compared with

non-Hispanic White individuals. These findings highlight specific factors that could be targeted in intervention strategies to improve early dementia detection and reduce disparities in dementia care.

Funding: This work was supported by a research grant [R01AG077529] funded by research grant R01AG077529 from the National Institute on Aging (NIA) and grant P30AG021342 from the NIA to the Yale Claude D. Pepper Older Americans Independence Center.

Conflict of interest: The authors have no conflict of interest to declare.

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Table 1. Characteristics of Patients with a Timely and Delayed/Missed Dementia Diagnosis

Characteristic	Patients, No (%)		
	Timely diagnosis[a]	Delayed/Missed diagnosis[b]	Full sample
All observations, No.	1,825 (53.3)	1,599 (46.7)	3,424
Individual level			
Age, y			
65-69	87 (4.8)	169 (10.6)	256 (7.5)
70-74	136 (7.5)	160 (10.0)	296 (8.6)
75-79	291 (15.9)	253 (15.8)	544 (15.9)
80-84	422 (23.1)	360 (22.5)	782 (22.8)
>=85	889 (48.7)	657 (41.1)	1546 (45.2)
Race/Ethnicity			
Non-Hispanic White	1,413 (77.4)	1,124 (70.3)	2537 (74.1)
Non-Hispanic Black	273 (15.0)	284 (17.8)	557 (16.3)
Hispanic	114 (6.2)	137 (8.6)	251 (7.3)
Non-Hispanic Other	25 (1.4)	54 (3.4)	79 (2.3)
Male	588 (32.2)	625 (39.1)	1213 (35.4)
Married or partnered	660 (36.2)	631 (39.5)	1291 (37.7)
High school education or higher	1,104 (60.5)	824 (51.5)	1928 (56.3)
Ratio of family income to poverty threshold			
Less than 1	309 (16.9)	318 (19.9)	627 (18.3)
Between 1 and 4	1,099 (60.2)	960 (60.0)	2059 (60.1)
Greater than or equal to 4	417 (22.8)	321 (20.1)	738 (21.6)
Number of chronic conditions[c], mean (SD)	2.77 (1.58)	2.53 (1.62)	2.65 (0.1)
Number of activities of daily living (ADL)	2.32 (2.3)	1.82 (2.05)	2.09 (0.1)
Number of instrumental activities of daily living (IADL)	2.66 (1.88)	1.81 (1.67)	2.26 (0.1)
Predicted latent cognition	-0.59 (0.61)	-0.34 (0.39)	-0.47 (0)
Was seen by a dementia specialist[d]	755 (41.4)	528 (33.0)	1283 (37.5)
Neighborhood level[e]			
Density of physician offices/clinics[f]			
Low density (deciles 1-2)	522 (28.6)	574 (35.9)	1096 (32)
Medium density (deciles 3-8)	655 (35.9)	578 (36.1)	1233 (36)
High density (deciles 9-10)	648 (35.5)	447 (28.0)	1095 (32)

Density of health practitioner offices/clinics[g]			
Low density (deciles 1-2)	592 (32.4)	679 (42.5)	1271 (37.1)
Medium density (deciles 3-8)	584 (32.0)	489 (30.6)	1073 (31.3)
High density (deciles 9-10)	649 (35.6)	431 (27.0)	1080 (31.5)
Neighborhood disadvantage[h]			
Least disadvantage (deciles 1-2)	429 (23.5)	303 (18.9)	732 (21.4)
Intermediate disadvantage (deciles 3-8)	930 (51.0)	824 (51.5)	1754 (51.2)
Most disadvantage (deciles 9-10)	466 (25.5)	472 (29.5)	938 (27.4)
Neighborhood affluence[i]			
Least affluent (deciles 1-2)	288 (15.8)	386 (24.1)	674 (19.7)
Intermediate affluent (deciles 3-8)	902 (49.4)	806 (50.4)	1708 (49.9)
Most affluent (deciles 9-10)	635 (34.8)	407 (25.5)	1042 (30.4)

[a] Timely diagnosis was defined as the presence of a clinical diagnosis of dementia, identified by an ICD-9-CM or ICD-10-CM code in any Medicare claim, recorded up to 3 years prior to or 1 year following the month of the HRS interview in which dementia was first observed.

[b] Delayed/Missed diagnosis was defined as the presence of a clinical diagnosis of dementia, based on an ICD-9-CM or ICD-10-CM code in any Medicare claims, recorded more than 1 year after the month of the HRS interview in which dementia was first observed or as having never been diagnosed.

[c] Chronic conditions data were obtained from the Chronic Condition Warehouse (CCW) linked to the Health and Retirement Study (HRS) survey year when dementia was first observed. Conditions were categorized in alignment with the HRS survey and included eight categories: high blood pressure, diabetes, cancer, lung disease, heart disease, stroke, psychiatric disorder, and arthritis.

[d] Specialties classified as dementia specialties were neurology, psychiatry, neuropsychiatry, geriatrics, and geriatric psychiatry.

[e] Neighborhood level characteristics, defined at the census tract level, were extracted from the National Neighborhood Data Archive (NaNDA) and linked to the Health and Retirement Study (HRS) survey year when dementia was first observed.

[f] Density of physician offices/clinics and density of health practitioner offices/clinics Physician offices/clinics were defined as establishments of licensed practitioners with an MD or DO degree, engaged in the practice of general or specialized medicine and surgery.

[g] Health practitioner offices/clinics included the establishment of general health practitioners such as physical therapists, occupational therapists, speech pathologists, clinical psychologists, psychotherapists, registered nurses, chiropractors, podiatrists, acupuncturists, massage therapists, and other non-physician health partitioners.

[h] The neighborhood disadvantage index is defined as the mean of the following proportions: people with income below federal poverty level, households receiving public assistance income, population age 16+ unemployed, and female headed families with children.

[i] The neighborhood affluence index is an average of three census indicators: the proportion of households with income greater than $75K, the proportion of population age 16+ employed in professional or managerial occupations, and the proportion of adults with a Bachelor's Degree or higher.

Table 2. Characteristics of Patients with Incident Dementia by Race/Ethnicity

Characteristic	Patients, No (%)		
	Non-Hispanic White	Non-Hispanic Black	Hispanic
All observations, No.	2,537 (74.1)	557 (16.3)	251 (7.3)
Timely diagnosis[a]	1,413 (55.7)	273 (49.0)	114 (45.4)
Individual level			
Age, y			
65-69	136 (5.4)	74 (13.3)	36 (14.3)
70-74	201 (7.9)	59 (10.6)	24 (9.6)
75-79	373 (14.7)	108 (19.4)	51 (20.3)
80-84	599 (23.6)	115 (20.6)	49 (19.5)
>=85	1,228 (48.4)	201 (36.1)	91 (36.3)
Male	886 (34.9)	210 (37.7)	83 (33.1)
Married or partnered	984 (38.8)	178 (32.0)	100 (39.8)
High school education or higher	1,666 (65.7)	190 (34.1)	37 (14.7)
Ratio of family income to poverty threshold			
Less than 1	298 (11.7)	189 (33.9)	107 (42.6)
Between 1 and 4	1,601 (63.1)	300 (53.9)	123 (49.0)
Greater than or equal to 4	638 (25.1)	68 (12.2)	21 (8.4)
Number of Chronic Conditions[b], mean (SD)	2.59 (1.59)	2.77 (1.64)	3.07 (1.60)
Number of activities of daily living (ADL)	2.00 (2.17)	2.19 (2.27)	2.78 (2.35)
Number of instrumental activities of daily living (IADL)	2.21 (1.84)	2.29 (1.85)	2.73 (1.76)
Predicted latent cognition	-0.46 (0.51)	-0.55 (0.60)	-0.44 (0.53)
Was seen by a dementia specialist[c]	975 (38.4)	192 (34.5)	88 (35.1)
Neighborhood level[d]			
Density of physician offices/clinics[e]			
Low density (deciles 1-2)	744 (29.3)	231 (41.5)	99 (39.4)
Medium density (deciles 3-8)	897 (35.4)	196 (35.2)	104 (41.4)
High density (deciles 9-10)	896 (35.3)	130 (23.3)	48 (19.1)
Density of health practitioner offices/clinics[f]			
Low density (deciles 1-2)	793 (31.3)	314 (56.4)	131 (52.2)

Medium density (deciles 3-8)	820 (32.3)	144 (25.9)	83 (33.1)
High density (deciles 9-10)	924 (36.4)	99 (17.8)	37 (14.7)
Neighborhood disadvantage[g]			
Least disadvantage (deciles 1-2)	690 (27.2)	22 (3.9)	13 (5.2)
Intermediate disadvantage (deciles 3-8)	1,462 (57.6)	184 (33.0)	76 (30.3)
Most disadvantage (deciles 9-10)	385 (15.2)	351 (63.0)	162 (64.5)
Neighborhood affluence[h]			
Least affluent (deciles 1-2)	295 (11.6)	233 (41.8)	118 (47.0)
Intermediate affluent (deciles 3-8)	1,309 (51.6)	262 (47.0)	103 (41.0)
Most affluent (deciles 9-10)	933 (36.8)	62 (11.1)	30 (12.0)

[a] Timely diagnosis was defined as the presence of a clinical diagnosis of dementia, identified by an ICD-9-CM or ICD-10-CM code in any Medicare claim, recorded up to 3 years prior to or 1 year following the month of the HRS interview in which dementia was first observed.

[b] Chronic conditions data were obtained from the Chronic Condition Warehouse (CCW) linked to the Health and Retirement Study (HRS) survey year when dementia was first observed. Conditions were categorized in alignment with the HRS survey and included eight categories: high blood pressure, diabetes, cancer, lung disease, heart disease, stroke, psychiatric disorder, and arthritis.

[c] Specialties classified as dementia specialties were neurology, psychiatry, neuropsychiatry, geriatrics, and geriatric psychiatry.

[d] Neighborhood level characteristics, defined at the census tract level, were obtained from the National Neighborhood Data Archive (NaNDA) and linked to the Health and Retirement Study (HRS) survey year when dementia was first observed.

[e] Density of physician offices/clinics and density of health practitioner offices/clinics Physician offices/clinics were defined as establishments of licensed practitioners with an MD or DO degree, engaged in the practice of general or specialized medicine and surgery.

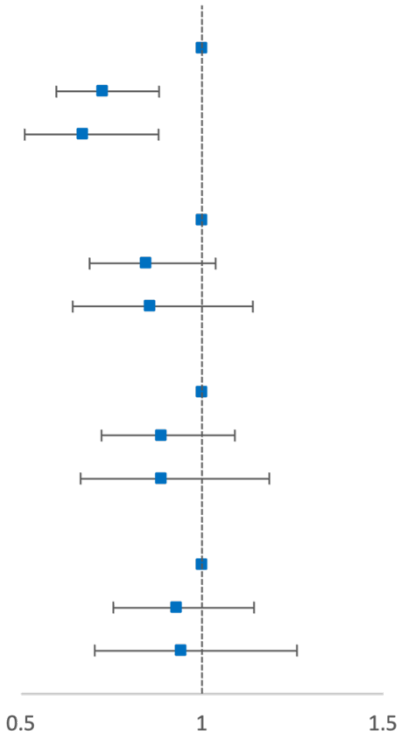
[f] Health practitioner offices/clinics included the establishment of general health practitioners such as physical therapists, occupational therapists, speech pathologists, clinical psychologists, psychotherapists, registered nurses, chiropractors, podiatrists, acupuncturists, massage therapists, and other non-physician health partitioners.

[g] The neighborhood disadvantage index is defined as the mean of the following proportions: people with income below federal poverty level, households receiving public assistance income, population age 16+ unemployed, and female headed families with children.

[h] The neighborhood affluence index is an average of three census indicators: the proportion of households with income greater than $75K, the proportion of population age 16+ employed in professional or managerial occupations, and the proportion of adults with a Bachelor's Degree or higher.

Table 3. Association between Race/Ethnicity and the Timely Diagnosis of Dementia

Model	The timely diagnosis of dementia, OR (95% CI)
Model A	
White	1 [Reference]
Black	0.725** (0.598 - 0.881)
Hispanic	0.670** (0.510 - 0.879)
Model B	
White	1 [Reference]
Black	0.846 (0.690 - 1.037)
Hispanic	0.856 (0.643 - 1.140)
Model C	
White	1 [Reference]
Black	0.888 (0.722 - 1.091)
Hispanic	0.888 (0.665 - 1.186)
Model D	
White	1 [Reference]
Black	0.930 (0.755 - 1.144)
Hispanic	0.942 (0.703 - 1.262)



** p<0.01, * p<0.05

Model A: Adjusted for unmodifiable demographics and health conditions

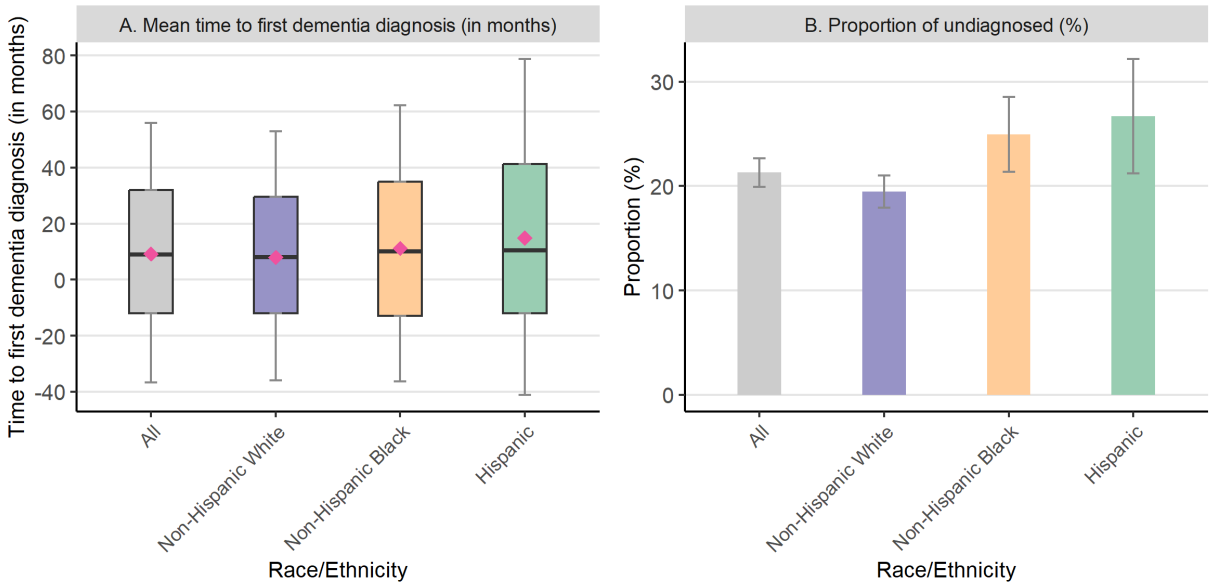
Model B: Individual level SES

Model C: Neighborhood level SES

Model D: Health care access

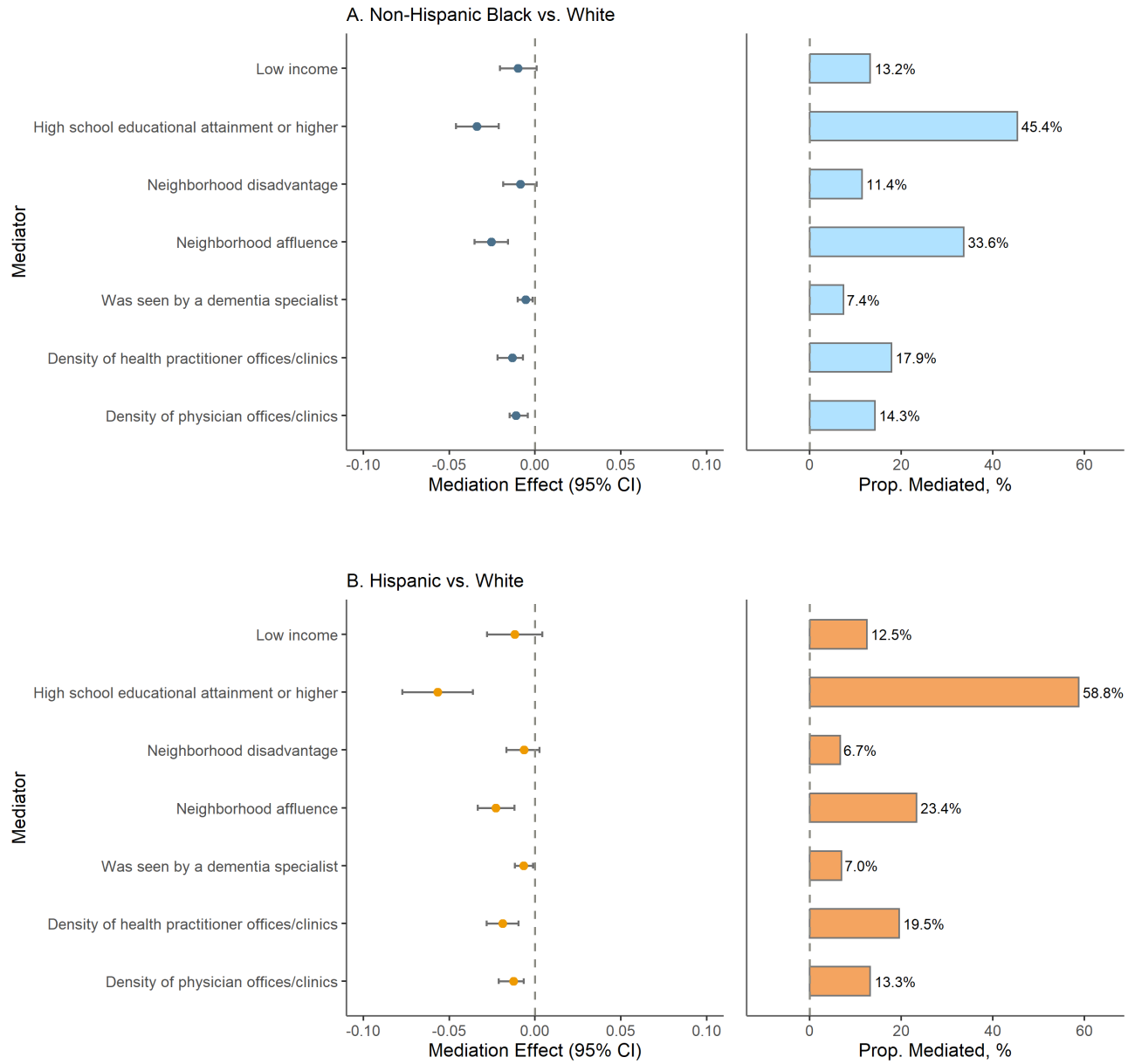
Notes: The multivariable logistic regression was used to identify racial and ethnic disparities in the timely diagnosis of dementia, adjusting for 1) unmodifiable demographic characteristics and underlying health conditions (Model A), 2) additional modifiable individual-level factors (Model B), 3) additional modifiable neighborhood-level socioeconomic factors (Model C), and 4) additional modifiable variables indicating access to care (Model D).

Figure 1. Time from Dementia Onset to First Diagnosis and the Proportion of Undiagnosed Individuals by Race/Ethnicity



Notes: Panel A presents the unadjusted time from dementia onset, defined as the midpoint between the interview wave in which dementia was first observed and the prior wave, to the date of the first recorded dementia diagnosis among individuals who received a dementia diagnosis, stratified by race/ethnicity. The upper and lower boundaries of boxes indicate 25th and 75th percentiles; whiskers, 10th and 90th percentiles; horizontal lines within the boxes, 50% percentile (median); and diamonds, mean. Panel B presents the proportion of individuals with incident dementia who never received a diagnosis, stratified by race/ethnicity. In Panel B, whiskers represent 95% confidence intervals.

Figure 2. Relative Effects From Mediation Analysis for the Timely Diagnosis of Dementia



Notes: All mediator variables were included as binary indicators in the mediation analysis. The low-income indicator was defined as a family income-to-poverty threshold ratio of less than 1. The neighborhood disadvantage indicator was coded as 1 if the individual resided in the least disadvantaged neighborhood (disadvantage index deciles 1-2). The neighborhood affluence indicator was coded as 1 if the individual resided in the most affluent neighborhood (affluence index deciles 9-10). The indicator "was seen by a dementia specialist" is coded as 1 if the individual had any office visits to a dementia specialist before the diagnosis. The health practitioner office/clinic density and the physician office/clinic density indicators were coded as 1 if the individual resided in a neighborhood with a density index in deciles 9-10.

ONLINE SUPPLEMENT

Multilevel Associations of Individual- and Neighborhood-Level Factors With Racial and Ethnic Disparities in Timely Dementia Diagnosis

PP2: eFigure 1: Generation of the Analytic Sample

PP3: eFigure 2: Relative Effects From Mediation Analysis for the Timely Diagnosis of Dementia Using the 2000-2016 Sample

PP5: eTable 1: ICD-9-CM and ICD-10-CM Codes Utilized for Identifying Dementia Diagnoses

PP7: eTable 2: Association between Race/Ethnicity and the Timely Diagnosis of Dementia: Weighted Analysis

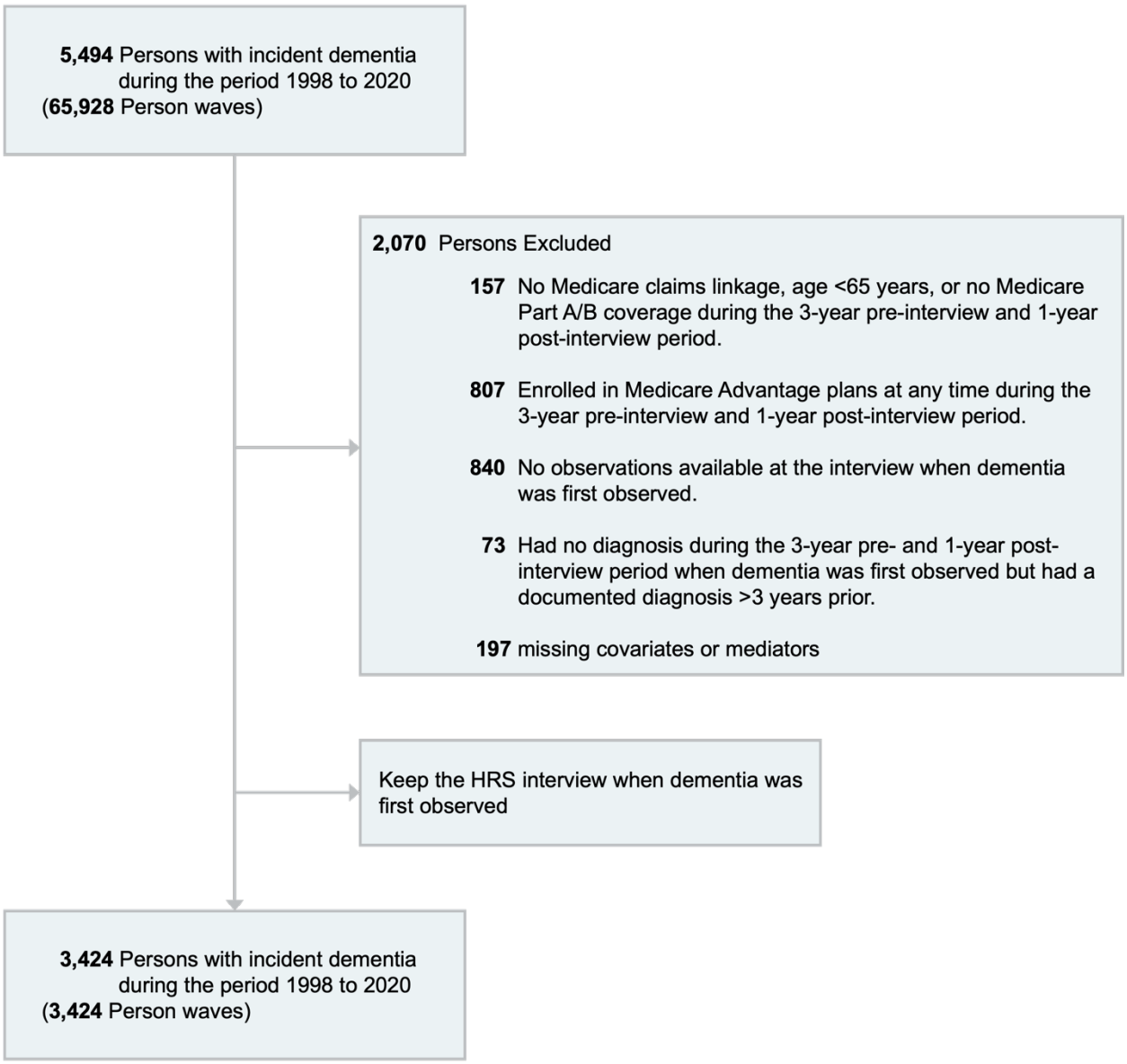
PP8: eTable 3: Association between Race/Ethnicity and the Timely Diagnosis of Dementia Using the 2000-2016 Sample

PP10: eTable 4: Mediation Analysis Using Product Methods With Main Analysis Sample

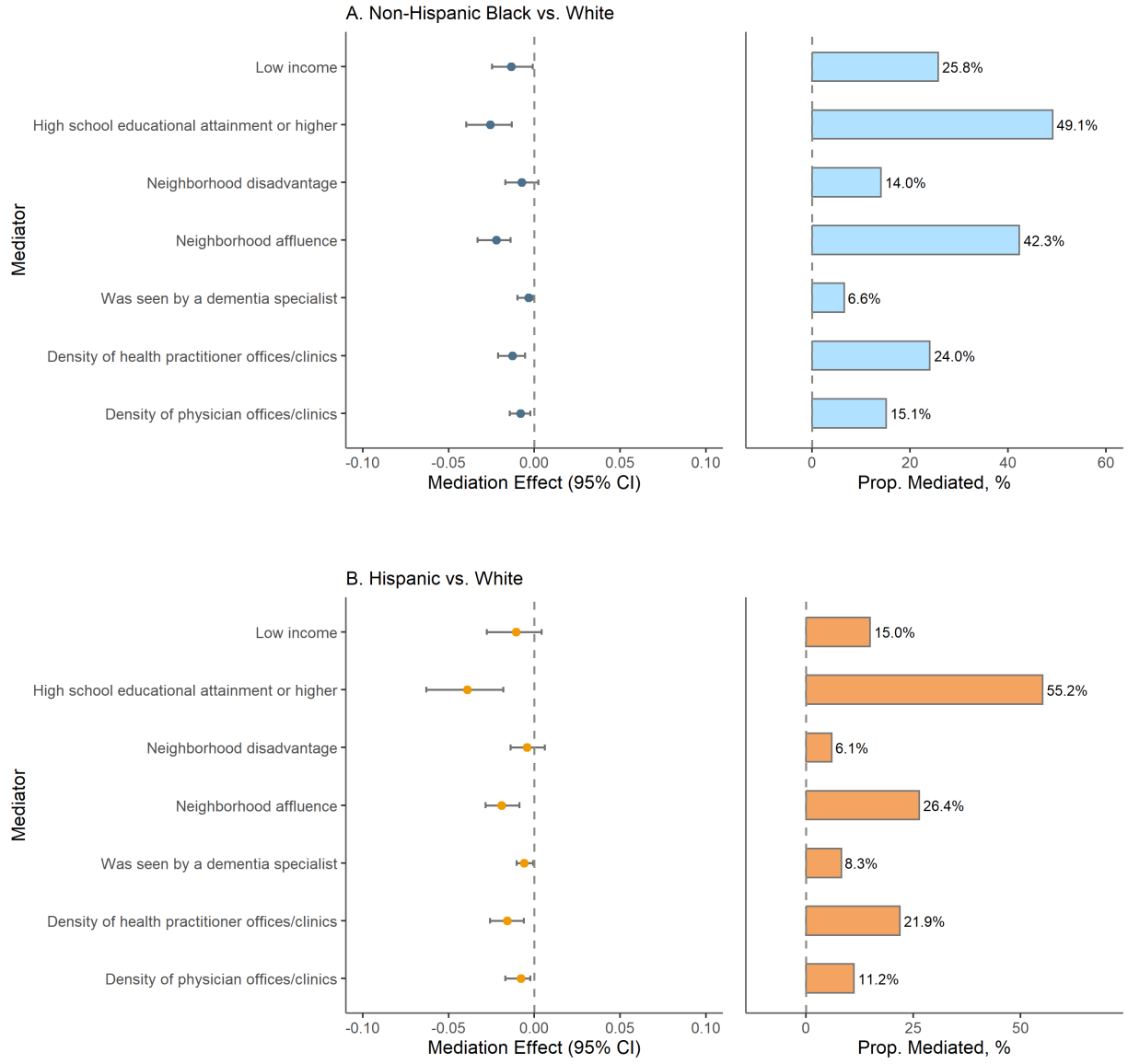
PP11: eTable 5: Association between Race/Ethnicity and the Timely Diagnosis of Dementia Using the Calibrated Cutoff Methods for Dementia Classification, 1998-2020

PP13: eMethods: Replication of Predicted Cognition and Dementia Measures and Application to 1998–2020

eFigure 1: Generation of the Analytic Sample



eFigure 2. Relative Effects From Mediation Analysis for the Timely Diagnosis of Dementia Using the 2000-2016 Sample



Notes: The estimates were derived from the analysis by restricting the Health and Retirement Study (HRS) sample to the 2000-2016 period, during which the dementia probability measures developed by *Hudomiet et al*. were available and HRS cognition tests were not subject to potential biases introduced by the web-based mode of data collection in 2018 and 2020. All mediator variables were included as binary indicators in the mediation analysis. The low-income indicator was defined as a family income-to-poverty threshold ratio of less than 1. The neighborhood disadvantage indicator was coded as 1 if the individual resided in the least disadvantaged neighborhood (disadvantage index deciles 1-2). The neighborhood affluence indicator was coded as 1 if the individual resided in the most affluent neighborhood (affluence index deciles 9-10). The indicator "was seen by a dementia specialist" is coded as 1 if the

individual had any office visits to a dementia specialist before the diagnosis. The health practitioner office/clinic density and the physician office/clinic density indicators were coded as 1 if the individual resided in a neighborhood with a density index in deciles 9-10.

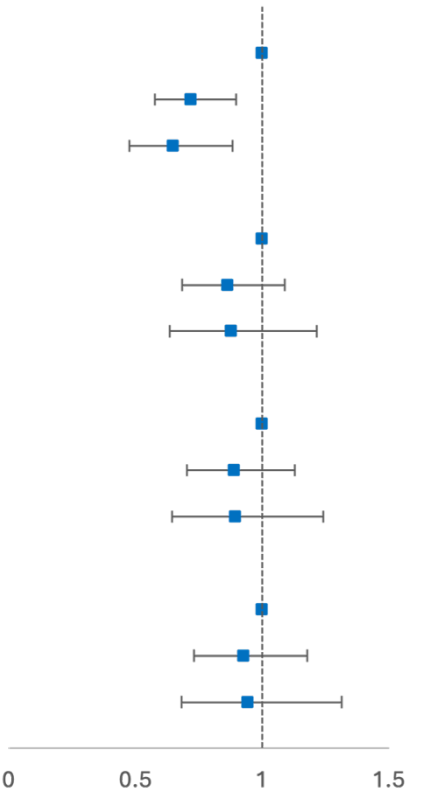
eTable 1: ICD-9-CM and ICD-10-CM Codes Utilized for Identifying Dementia Diagnoses

Dementia			
ICD-9-CM Code	**Description**	**ICD-10-CM Code**	**Description**
290.0	Senile dementia, uncomplicated	F01.50	Vascular dementia without behavioral disturbance
290.10	Presenile dementia, uncomplicated	F01.51	Vascular dementia with behavioral disturbance
290.11	Presenile dementia with delirium	F02.80	Dementia in other diseases classified elsewhere without behavioral disturbance
290.12	Presenile dementia with delusional features	F02.81	Dementia in other diseases classified elsewhere with behavioral disturbance
290.13	Presenile dementia with depressive features	F03.90	Unspecified dementia without behavioral disturbance
290.20	Senile dementia with delusional features	F03.91	Unspecified dementia with behavioral disturbance
290.21	Senile dementia with depressive features	F04	Amnestic disorder due to known physiological condition
290.3	Senile dementia with delirium	F05	Delirium due to known physiological condition
290.40	Vascular dementia, uncomplicated	F06.1	Catatonic disorder due to known physiological condition
290.41	Vascular dementia with delirium	F06.8	Other specified mental disorders due to known physiological condition
290.42	Vascular dementia with delusions	G13.8	Other systemic atrophies primarily affecting the central nervous system
290.43	Vascular dementia with depressed mood	G30.0	Alzheimer's disease with early onset
294.0	Amnestic disorder in conditions classified elsewhere	G30.1	Alzheimer's disease with late onset
294.10	Dementia in conditions classified elsewhere without behavioral disturbance	G30.8	Other Alzheimer's disease
294.11	Dementia in conditions classified elsewhere with behavioral disturbance	G30.9	Alzheimer's disease, unspecified
294.20	Dementia, unspecified, without behavioral disturbance	G31.01	Pick's disease
294.21	Dementia, unspecified, with behavioral disturbance	G31.09	Other frontotemporal dementia
294.8	Other persistent mental disorders due to conditions classified elsewhere	G31.1	Senile degeneration of the brain, not elsewhere classified
331.0	Alzheimer’s disease	G31.2	Degeneration of nervous system due to alcohol
331.11	Pick’s disease	G94	Other disorders of brain in diseases classified elsewhere
331.19	Other frontotemporal dementia	R41.81	Age-related cognitive decline
331.2	Senile degeneration of brain	R54	Senility without mention of psychosis

331.7	Cerebral degeneration in diseases classified elsewhere		
797	Senility without mention of psychosis		

eTable 2. Association between Race/Ethnicity and the Timely Diagnosis of Dementia: Weighted Analysis

Model	The timely diagnosis of dementia, OR (95% CI)
Model A	
White	1 [Reference]
Black	0.720** (0.577 - 0.898)
Hispanic	0.650** (0.477 - 0.884)
Model B	
White	1 [Reference]
Black	0.864 (0.685 - 1.090)
Hispanic	0.878 (0.634 - 1.215)
Model C	
White	1 [Reference]
Black	0.891 (0.704 - 1.129)
Hispanic	0.894 (0.645 - 1.240)
Model D	
White	1 [Reference]
Black	0.928 (0.732 - 1.177)
Hispanic	0.945 (0.681 - 1.313)



** p<0.01, * p<0.05

Model A: Adjusted for unmodifiable demographics and health conditions

Model B: Individual level SES

Model C: Neighborhood level SES

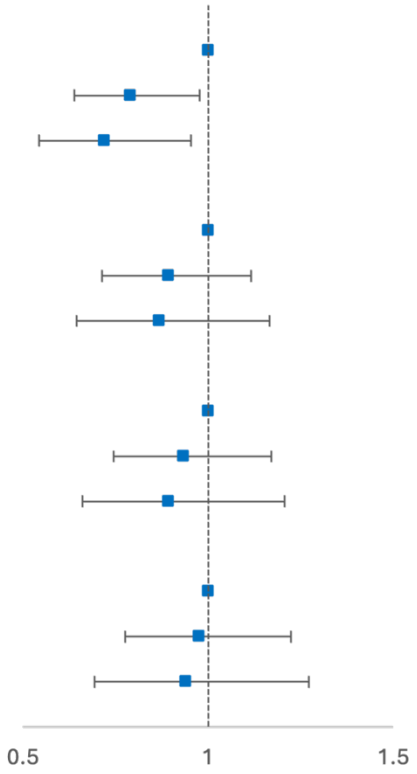
Model D: Health care access

Notes: The multivariable logistic regression was used to identify racial and ethnic disparities in the timely diagnosis of dementia, adjusting for 1) unmodifiable demographic characteristics and underlying health conditions (Model A), 2) additional modifiable individual-level factors (Model B), 3) additional modifiable neighborhood-level socioeconomic factors (Model C), and 4) additional modifiable variables indicating access to care (Model D). The estimates were weighted using Health and Retirement Study (HRS) sampling weights from the year of dementia onset.

eTable 3. Association between Race/Ethnicity and the Timely Diagnosis of Dementia Using the 2000-2016 Sample

Panel A: Proportion of individuals receiving timely diagnosis of dementia[a]		
Race/Ethnicity	**Unadjusted, N (%)**	**Adjusted[b], N (%)**
Total sample	3,003	3,003
White	1,257 (56.8)	1,257 (57.0)
Black	257 (52.9)	257 (51.8)
Hispanic	117 (50.2)	117 (49.7)

Panel B: Adjusted association of race/ethnicity with the timely diagnosis of dementia	
Adjusted Model	**OR (95% CI)**
Model A	
White	1 [Reference]
Black	0.790* (0.639 - 0.977)
Hispanic	0.720* (0.543 - 0.953)
Model B	
White	1 [Reference]
Black	0.892 (0.713 - 1.116)
Hispanic	0.867 (0.644 - 1.166)
Model C	
White	1 [Reference]
Black	0.933 (0.744 - 1.170)
Hispanic	0.893 (0.661 - 1.207)
Model D	
White	1 [Reference]
Black	0.975 (0.776 - 1.223)
Hispanic	0.939 (0.693 - 1.272)



The timely diagnosis of dementia, OR (95% CI)

** p<0.01, * p<0.05

Model A: Adjusted for unmodifiable demographics and health conditions
Model B: Individual level SES
Model C: Neighborhood level SES
Model D: Health care access

Notes: The estimates were derived from the analysis by restricting the Health and Retirement Study (HRS) sample to the 2000-2016 period, during which the dementia probability measures developed by *Hudomiet et al*. were available and HRS cognition tests were not subject to potential biases introduced by the web-based mode of data collection in 2018 and 2020. The multivariable logistic regression was used to identify racial and ethnic disparities in the timely diagnosis of dementia, adjusting for 1) unmodifiable demographic characteristics and underlying health conditions (Model A), 2) additional modifiable individual-level factors (Model B), 3) additional modifiable neighborhood-level socioeconomic factors (Model C), and 4) additional modifiable variables indicating access to care (Model D).

eTable 4. Mediation Analysis Using Product Methods With Main Analysis Sample

	Black vs White		Hispanic vs White	
Mediators	**Natural indirect effect, (95% CI)**	**Mediation proportion (%)**	**Natural indirect effect, (95% CI)**	**Mediation proportion (%)**
Low income	-0.04 (-0.08, 0)	12.73	-0.02 (-0.09, 0.05)	4.58
High school educational attainment or higher	-0.15 (-0.2, -0.1)	45.30	-0.23 (-0.33, -0.15)	44.37
Neighborhood disadvantage	-0.04 (-0.09, 0)	12.32	-0.05 (-0.09, -0.01)	9.57
Neighborhood affluence	-0.13 (-0.18, -0.08)	36.75	-0.09 (-0.15, -0.04)	17.89
Was seen by a dementia specialist	-0.01 (-0.03, 0)	4.64	-0.01 (-0.03, 0.01)	1.74
Density of health practitioner offices/clinics	-0.07 (-0.1, -0.04)	20.93	-0.08 (-0.13, -0.04)	15.39
Density of physician offices/clinics	-0.04 (-0.07, -0.02)	13.40	-0.05 (-0.09, -0.02)	10.64

Notes: The table presents the mediation analysis results using the *Product Method* by Cheng, Spiegelman, and Li, based on our main analysis sample. All mediator variables were included as binary indicators in the mediation analysis. The low-income indicator was defined as a family income-to-poverty threshold ratio of less than 1. The neighborhood disadvantage indicator was coded as 1 if the individual resided in the least disadvantaged neighborhood (disadvantage index deciles 1-2). The neighborhood affluence indicator was coded as 1 if the individual resided in the most affluent neighborhood (affluence index deciles 9-10). The indicator "was seen by a dementia specialist" is coded as 1 if the individual had any office visits to a dementia specialist before the diagnosis. The health practitioner office/clinic density and the physician office/clinic density indicators were coded as 1 if the individual resided in a neighborhood with a density index in deciles 9-10.

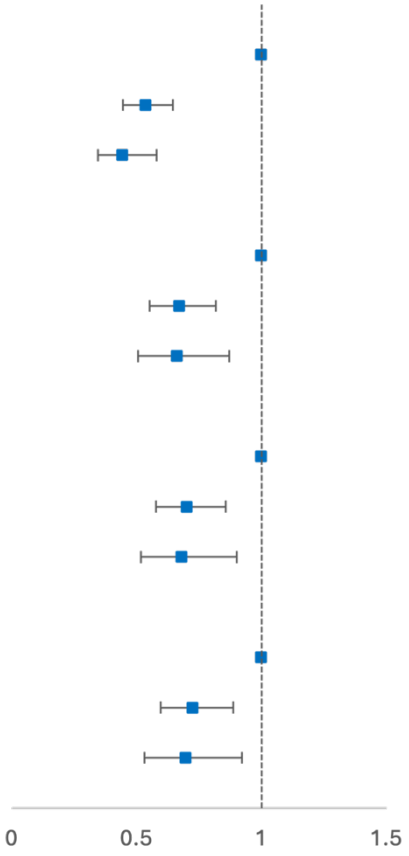
eTable 5. Association between Race/Ethnicity and the Timely Diagnosis of Dementia Using the Calibrated Cutoff Methods for Dementia Classification, 1998-2020

Panel A: Proportion of individuals receiving timely diagnosis of dementia[a]

Race/Ethnicity	Unadjusted, N (%)	Adjusted[b], N (%)
Total sample	3,882	3,882
White	1,462 (54.7)	1,462 (51.5)
Black	246 (32.3)	246 (39. 2)
Hispanic	108 (29.3)	108 (35.7)

Panel B: Adjusted association of race/ethnicity with the timely diagnosis of dementia

Adjusted Model	OR (95% CI)
Model A	
White	1 [Reference]
Black	0.537*** (0.446 - 0.646)
Hispanic	0.446*** (0.344 - 0.579)
Model B	
White	1 [Reference]
Black	0.672*** (0.553 - 0.817)
Hispanic	0.663*** (0.505 - 0.870)
Model C	
White	1 [Reference]
Black	0.703*** (0.577 - 0.856)
Hispanic	0.683*** (0.518 - 0.900)
Model D	
White	1 [Reference]
Black	0.727*** (0.595 - 0.887)
Hispanic	0.698** (0.530 - 0.921)



Notes: The estimates were derived from the analysis using the dementia sample from 1998 to 2020, based on the Calibrated Cutoff Methods for Dementia Classification**,** *described by Crimmins et al.*.

[a] Timely diagnosis was defined as the presence of a clinical diagnosis of dementia, identified by an ICD-9-CM or ICD-10-CM code in any Medicare claim, recorded up to 3 years prior to or 1 year following the month of the HRS interview.
[b] In Panel A, the adjusted estimates were derived from the logistic regression model, adjusted for non-modifiable demographics (age, gender) and health conditions (number of chronic conditions, number of instrumental activities of daily living).
[c] In Panel B, The multivariable logistic regression was used to identify racial and ethnic disparities in the timely diagnosis of dementia, adjusting for 1) unmodifiable demographic characteristics and underlying health conditions (Model A), 2) additional modifiable individual-level factors (Model B), 3) additional modifiable neighborhood-level socioeconomic factors (Model C), and 4) additional modifiable variables indicating access to care (Model D).

eMethods: Replication of Predicted Cognition and Dementia Measures and Application to 1998–2020

We replicated the methodology developed by Hudomiet et al. for creating predicted cognition and dementia measures, closely following their statistical approach and implementing their replication package. This allowed us to extend these measures to 1998–2020, as the original study only covered 2000–2016.

Specifically, the algorithm developed a longitudinal, latent-variable model of cognitive status, which was estimated using the Markov Chain Monte Carlo method using 2,000,000 simulation draws, and the first 10% burn-in draws were discarded. The data and methodological details are described in their original paper, *Cognitive Impairment in the United States: Racial Disparities and Modifiable Risk Factors* (Hudomiet et al., 2023).

All variables required for replication were available from 1998 to 2020, except for interviewers' assessments of cognitive limitations in proxy interviews, which were not collected in 1998. To address this, we used the 2000 assessment as a proxy measure for 1998. In addition, beginning in 2018, the HRS introduced web-based cognitive interviews, with 2016 respondents randomly assigned to phone or web-based modes. Some cognitive measures collected through web interviews differed in implementation, measurement, or elicitation. This change in data collection methods may have introduced bias in dementia prevalence estimates for 2018 and 2020. As a sensitivity analysis, we restricted the sample to 2000–2016, when the original measures were fully available, and repeated our primary analysis.

Below, we present our re-created dementia prevalence estimates in comparison with the original released estimates for the comparable years 2000–2016. Overall, our re-created estimates closely tracked the original estimates.

Age-adjusted prevalence of dementia from 1998 to 2020 for total population, Age 65+

	Estimates by Hudomiet et al.		Re-created Estimates	
	Mean	95% CI	Mean	95% CI
1998	NA	NA	0.100	0.1 [0.094, 0.105]
2000	0.122	[0.117, 0.127]	0.117	0.117 [0.112, 0.122]
2002	0.109	[0.104, 0.114]	0.106	0.106 [0.101, 0.111]
2004	0.102	[0.097, 0.106]	0.101	0.101 [0.096, 0.106]
2006	0.098	[0.093, 0.103]	0.098	0.098 [0.093, 0.103]
2008	0.095	[0.09, 0.1]	0.094	0.094 [0.09, 0.099]
2010	0.093	[0.087, 0.098]	0.091	0.091 [0.086, 0.096]
2012	0.091	[0.086, 0.096]	0.089	0.089 [0.083, 0.094]
2014	0.087	[0.082, 0.093]	0.086	0.086 [0.08, 0.091]
2016	0.085	[0.079, 0.091]	0.084	0.084 [0.078, 0.089]
2018	NA	NA	0.077	0.077 [0.072, 0.082]
2020	NA	NA	0.070	0.07 [0.065, 0.075]

* Sample: Health and Retirement Study, Age 65+. The estimates by Hudomiet et al. (2000–2016) included 97,629 person-year observations; the replicated estimates (1998–2020) included 126,428 person-year observations.