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DISCUSSION PAPER SERIES

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# ABSTRACT

## Cognitive Impairment and Prevalence of Memory-Related Diagnoses among U.S. Older Adults

Cognitive impairment creates significant challenges to health and well-being of the fast-growing aging population. Early recognition of cognitive impairment may confer important advantages, allowing for diagnosis and appropriate treatment, education, psychosocial support, and improved decision-making regarding life planning, health care, and financial matters. Yet the prevalence of memory-related diagnoses among older adults with early symptoms of cognitive impairment is unknown. Using 2000-2014 Health and Retirement Survey - Medicare linked data, we leveraged within-individual variation in a longitudinal cohort design to examine the relationship between incident cognitive impairment and receipt of diagnosis among American older adults. Receipt of a memory-related diagnosis was determined by ICD-9-CM codes. Incident cognitive impairment was assessed using the modified Telephone Interview of Cognitive Status (TICS). We found overall low prevalence of early memory-related diagnosis, or high rate of underdiagnosis, among older adults showing symptoms of cognitive impairment, especially among non-whites and socioeconomically disadvantaged subgroups. Our findings call for targeted interventions to improve the rate of early diagnosis, especially among vulnerable populations.

**JEL Classification:** I11, I14, J14, I18, R20

**Keywords:** cognitive impairment, cognitive aging, dementia, Medicare, memory-related diagnosis

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## 1. Introduction

Cognitive impairment of various stages is common among the aging population. The estimated prevalence of cognitive impairment without dementia (CIND) among U.S. population over age 65 has been as high as 35.9%, and increases with age[1,2] . CIND is associated with increased risk for progression to dementia, the prevalence of which was recently estimated at over 10% among people above age 65[3], and incurs substantial care and financial burden on family and society. Timely detection and diagnosis of cognitive impairment before the onset of or at early stages of dementia may confer potential advantages, including the opportunity of early intervention, implementation of coordinated care plans, better management of symptoms, and postponement of institutionalization[4]. On the other hand, research has documented significant barriers to timely diagnosis of cognitive impairment from the perspectives of both patients and providers[5-7]. Further, growing literature has identified racial/ethnic and other disparities in diagnosis of cognitive impairment and treatment of related symptoms and comorbidities[8-11], with Blacks and Hispanics typically receiving dementia diagnosis at a later stage and incurring higher inpatient care expenditure than Whites[12, 13].

Despite the documented barriers and disparities in early diagnosis of cognitive impairment, fundamental questions remain. What fraction of U.S. older adults showing early signs of cognitive impairment received a memory-related diagnosis? How does the probability of receiving early diagnosis among cognitively impaired individuals differ across subpopulations? An improved understanding of these questions is crucial to accurately assess the gaps in cognitive diagnosis, empirically evaluate the role of various factors in preventing or facilitating timely diagnosis to inform targeted interventions. Existing studies in this area almost exclusively focus on patients already diagnosed for cognitive impairment, typically at advanced stages, thereby offering limited evidence on those questions.

We directly addressed these questions by studying a nationwide sample of older adults, who transitioned from cognitively normal to showing initial symptoms of cognitive impairment, with or without a formal memory-related diagnosis. We examined the changes in probability of receiving a memory-related diagnosis associated with the decline in cognitive function, and their heterogeneity by individual demographic, socioeconomic and health characteristics.

## 2. Methods

### 2.1 Data Source and Study Population

We used linked 2000-2014 HRS and 1998-2015 Medicare claims data. HRS is a longitudinal biennial panel study on a representative sample of approximately 20,000 Americans above age 50. Respondents are interviewed on wide-range topics of health, cognition, family, employment, and wealth. Medicare claims data are available from the Centers for Medicare and Medicaid Services (CMS) for HRS respondents who are enrolled in Medicare fee-for-service (FFS) and agreed to link their HRS survey data to Medicare records.

Our study population included all HRS respondents aged 66 and above who were Medicare FFS insured and transitioned from cognitively normal to cognitive impairment between two consecutive HRS waves during 2000-2014. Following an established algorithm, cognitive impairment was defined as having Modified Telephone Interview for Cognitive Status (TICS-M) score below 12[14, 15]. We excluded individuals with no TICS scores in two consecutive HRS waves, whose TICS score never fell below 12 in any HRS wave, whose TICS score was below 12 in their first HRS wave, or whose TICS score reverted back to at least 12 in any wave after the first wave of cognitive impairment. We also excluded individuals with no linkage to FFS Medicare claims data. The final analytical sample included all remaining respondents in HRS waves up to the first wave of cognitive impairment. We did not exclude anyone with previous memory-related diagnosis (during any cognitively normal wave) as our statistical model allowed us to estimate the change in the probability of receiving such a diagnosis upon experiencing symptoms of cognitive impairment, as detailed further below.

### 2.2 Study Design

We used a retrospective, longitudinal cohort design to assess the effect of cognitive decline on receiving a memory-related diagnosis (defined below) among older U.S. adults. For each patient in our study population, we examined the change in probability of receiving a memory-related diagnosis around the time of the HRS interview when the patient was first classified as cognitive impaired, compared to one or more prior HRS interviews when the individual was cognitively normal. This approach exploited within-individual variation in cognitive functioning and

memory-related diagnosis over biennial waves of HRS to identify any changes in probability of memory-related diagnosis attributable to the observed cognitive decline. The study was approved by the Institutional Review Board at Weill Cornell Medical College.

### 2.3 Outcomes

Our outcome was an indicator for whether the respondent had any memory-related diagnosis during the one-year window centered around each HRS interview date. Specifically, for each HRS interview/wave, we examined memory-related diagnoses over one-year, including six months before and six months after the HRS interview date. Individuals were identified as having a memory-related diagnosis during their physician visits if there was at least one Current Procedural Terminology (CPT) reimbursement codes for Evaluation and Management visits (99201-205 and 99211-215) and at least one of the International Classification of Diseases, Ninth Revision (ICD-9) memory-related diagnosis codes in the Medicare Carrier File and Outpatient File (see eTable 1 in the Supplement for ICD-9 memory-related diagnosis codes). Following existing literature[16], we included three types of memory-related diagnosis: Alzheimer's disease and related dementias (ADRD), MCI, and memory loss, other types of dementia or cognitive deficit.

### 2.4 Exposure and Covariates

Our exposure variable, incident cognitive impairment, was defined as the first assessment wherein the subject's TICS-M score was less than 12[14, 15]. For each individual in our study population, the exposed wave was each individual's last HRS wave in our final analytical file.

We controlled for a rich set of time-varying individual characteristics from HRS, including age, marital status, number of living children, total housing wealth, employment status, Medicare-Medicaid dual eligibility, health insurance coverage other than Medicare, region (Northeast, Midwest, South and West), activities of daily living (ADL) difficulties and probable depressive symptoms, flagged if Center for Epidemiologic Studies Depression Scale (CES-D) scores ≥3 on the 8-item CES-D[17, 18]. From Medicare claims, we constructed 11 comorbidity indicators (congestive heart failure, chronic lung disease, cancer, coronary artery disease, renal failure, peripheral vascular disease, diabetes, chronic liver disease, hypertension, stroke, arthritis)

defined using validated algorithms[19, 20], the count of CMS Chronic Conditions Data Warehouse (CCW) conditions, and weighted Charlson Comorbidity Index (CCI). Both the count of CCW conditions and CCI excluded dementia. We constructed these comorbidity measures using claims data for the year prior to the start of the time window for memory-related diagnosis, i.e. 181-545 days preceding the focal HRS interview date for each individual.

**2.5 Statistical Analysis**

We used ordinary least squares (OLS) regressions, i.e. linear probability models, to examine the changes in probability of receiving a memory-related diagnosis as cognitive function of respondents declined from normal to a level classified as cognitive impairment. We controlled for the covariates described above and indicators for persons, years, regions, and year-by-regions. We used OLS instead of logit regressions as the large number of indicator variables in logit regressions may yield inconsistent coefficient estimates[21]. We clustered standard errors at the individual level.

We conducted the analysis on the entire study population and stratified by individual characteristics. Stratifying characteristics included sex (female vs. male), age (below vs. above median age 75), race (non-Hispanic white vs. non-Hispanic black vs. Hispanic vs. other), education (less than high school vs. high school diploma vs. some college or higher), household wealth (below vs. above median household wealth in the cognitive impairment wave), Medicaid eligibility (ineligible vs. eligible for Medicaid), marital status (no partner vs. with partner), number of living children (childless vs. at least one child), number of ADL difficulties (no difficulty in ADL vs. had difficulty in at least one ADL), number of physician visits (below vs. above the median physician visits in the cognitive impairment wave). All stratifying covariates were based on the value during the exposed wave for each individual, i.e. when the individual's TICS score fell below 12. We then performed seemingly unrelated regressions (SUR)[22] to compare the regression coefficients across subgroups. All data analyses were performed using Stata software, version 14 (Stata Corp).

We conducted three sets of sensitivity analyses. First, we repeated the main analysis using memory-related diagnosis received during various time windows as the outcome: 1) one year

before the HRS interview, 2) 9 months before and 3 months after the HRS interview, 3) 3 months before and 9 months after the HRS interview, and 4) one year after the HRS interview. These findings helped mitigate the concern over our estimated effects being driven by memory tests during the HRS survey that prompted memory-related physician visits afterwards. Second, we conducted a placebo test using the wave immediately preceding the cognitive impairment wave as the exposure. This allowed us to assess the likelihood that our estimated changes in diagnosis were simply attributable to respondents getting older. Third, we repeated the analyses including those individuals who experienced any reversion in their TICS-M score after the first wave of cognitive impairment, as prior literature has found reversion to normal or near-normal cognition to be quite common (about 16% to 50%) among those diagnosed with mild cognitive impairment but remained at elevated risk for future cognitive impairment[23-25].

## 3. Results

### 3.1 Unadjusted Analyses

Our final study population included 1,225 persons or 4,714 person waves. Figure 1 illustrates the flow path of sample selection. 1,715 (73.5%) of the respondents received at least high school education, 761 (62.1%) were female, and 1,042 (85.1%) were non-Hispanic white (Table 1). Compared with themselves before cognitive impairment, individuals at cognitive impairment were older (mean [SD] age, 80.0 [6.8] vs. 76.1 [6.5] years), were more likely to be widowed (504 [41.1%] vs. 1,111 [31.8%]), dual-eligible for Medicaid and Medicare (113 [9.2%] vs. 276 [7.9%]), had difficulty in at least one ADL (367 [30.0%] vs. 563 [16.1%]), had depressive symptoms (352 [28.7%] vs. 709 [20.3%]), in the lower two quartiles of household wealth (704 [57.4%] vs. 1,653 [47.4%]), not working for pay (1,152 [94.0%] vs. 3,024 [86.7%]), uncovered by employer-sponsored health insurance (959 [78.3%] vs. 2,551 [73.1%]).

Only 147 (12.0%) of 1,225 individuals experiencing incident cognitive impairment received a related diagnosis, compared to 1.7% before cognitive impairment (Table 2). All subgroups had higher prevalence of memory-related diagnosis after showing early signs of cognitive impairment on TICS assessment. Differences in prevalence of diagnosis exist by demographic and socioeconomic characteristics. For instance, at the wave of cognitive impairment, prevalence of diagnosis was higher among those older than 75 compared to those younger than 75 (13.6%

vs. 7.7%), non-Hispanic whites compared to non-Hispanic blacks (13.2% vs. 1.9%), those with college or higher degree compared to those less than high school (23.4% vs. 3.7%), and those with above-median household wealth compared to below-median (15.0% vs. 9.0%).

### 3.2 Adjusted Analyses

Figure 2 presents regression adjusted results on the full sample and on various sub-samples. Regression using the overall sample showed that, in comparison to the period prior to cognitive impairment, an early sign of cognitive impairment was associated with on average 7.3 percentage points (% hereafter) (95% CI, 5.6% to 9.0%; p<.001) higher adjusted probability of any memory-related diagnosis, with an adjusted prevalence of 9.8% (95% CI, 8.5% to 11.2%; p<.001). eTable 2 presents the full regression results using the whole sample.

We further compared the effects on subgroups stratified by several demographic, socioeconomic, and health characteristics. The change in the probability of diagnosis within a group was always significant at the 5% level except for age≤75 (3.6%; 95% CI, -0.3% to 7.5%; p=.07), non-Hispanic blacks (-0.7%; 95% CI, -3.7% to 2.3%; p=.65), Hispanics (9.0%; 95% CI, -8.8% to 26.7%; p=0.31), less than high school (1.6%, 95% CI, -0.7% to 3.9%; p=.17) and Medicaid eligible (5.3%, 95% CI, -1.9% to 12.5%; p=.15). In comparison, an early sign of cognitive impairment was associated with significantly larger increase in the likelihood of any memory-related diagnosis among those above 75 (8.5%; 95% CI, 6.5% to 10.5%; p<.001) than below (SUR p=.001), among non-Hispanic whites (8.2%; 95% CI, 6.3% to 10.1%; p<.001) than non-Hispanic blacks (SUR p<.001), and among those with at least college education (17.4%; 95% CI, 12.2% to 22.6%; p<.001) than those with high school (6.8%; 95% CI, 4.5% to 9.1%; p<.001) or less than high school education (SUR p<.001). Individual with above-median wealth (10.9%; 95% CI, 8.4% to 13.5%; p<.001), who were partnered (10.2%; 95% CI, 7.4% to 13.0%; p<.001), or those with difficulty in at least one ADL (9.2%; 95% CI, 5.9% to 12.6%; p<.001) also had larger increase in memory-related diagnosis than those with below-median wealth (3.9%; 95% CI, 1.7% to 6.2%; p<.001), non-partnered (4.5%; 95% CI, 2.4% to 6.6%; p<.001) or without ADL difficulty (7.0%; 95% CI, 4.9% to 9.1%; p<.001).

Additionally, the change in diagnosis was statistically indistinguishable between females and males (6.3% vs 9.2%), between those with and without children (7.5% vs. 7.9%), between those with and without Medicaid eligibility (5.3% vs. 7.3%), and between those with above-median and below-median number of physician visits (7.1% vs. 7.4%).

### 3.3 Sensitivity Analyses

Sensitivity analysis results using the whole sample but with alternative time windows were largely consistent with our primary analyses (eTable 3). For instance, when examining one year before the HRS interview, an early sign of cognitive impairment was associated with on average 5.2% (95% CI, 3.6% to 6.8%; p<.001) higher adjusted probability of any memory-related physician visits. Other time windows yielded largely similar results. We also found no association between an early sign of cognitive impairment and probability of memory-related diagnosis (-0.4%; 95% CI, -1.8% to 1.0%; p=0.55) in the placebo test using the HRS wave immediately preceding the cognitive impairment wave as the exposure. Finally, analyses additionally including individuals with reversed TICS-M score yielded lower adjusted prevalence of memory-related diagnoses (5.8%; 95% CI, 5.0% to 6.6%), which is expected as at least some of these additional individuals did not experience permanent cognitive impairment. However, stratified analyses showed similar patterns of disparities across SES and racial/ethnic groups (eFigure 2).

## 4. Conclusions and Discussion

Our study makes three main contributions to the literature. 1) To our knowledge, this is the first study to directly estimate the prevalence of receiving a memory-related diagnosis among a nationwide sample of U.S. older adults showing early signs of cognitive impairment. 2) We are also the first to examine heterogeneity in receiving diagnosis by rich individual characteristics beyond demographics, including SES, family support, functional status and degree of interaction with the healthcare system. 3) Our longitudinal design and fixed effects model leveraged within-person variation to isolate the change in probability of memory-related diagnosis attributable to the change in cognitive functioning.

Only a small proportion (unadjusted prevalence: 12.0%; adjusted prevalence: 9.8%) of U.S. older adults who experienced early symptoms of cognitive impairment received a related diagnosis. This would imply an underdiagnosis rate of 88.0% (unadjusted) or 90.2% (adjusted), suggesting substantial gap in early diagnosis of cognitive impairment. Further, stark variation in the prevalence of diagnosis exists by demographics and SES. Whites were over six times more likely than non-whites to receive a memory-related diagnosis upon developing symptoms of cognitive impairment, and older adults with a college education were eight times as likely as those without a high school degree to receive a diagnosis. These findings were consistent with a recent study finding that racial/ethnic minorities and the less educated were more likely than their counterparts to have been identified as having dementia based on cognitive tests only, with no recorded diagnoses in claims data[26].

Our study is related to but distinct from two recent studies examining concordance in dementia diagnosis between survey-based cognitive test and administrative claims data, also using HRS-Medicare linked data[11, 26]. Both those studies focused on the diagnosis of dementia, whereas we focused on diagnosis of cognitive impairment (including but not limited to both MCI and dementia) at early stage. The latter has received much less attention in the literature, but is crucial in informing early detection of cognitive impairment in light of its many documented advantages, and considering that cognitive impairment symptoms could impact patients' instrumental activities years in advance of a formal diagnosis of dementia[27]. Chen et al. (2019) is more similar to our study as they used the same algorithm based on TICS-M score to identify dementia (using a lower cutoff than ours which is used for identifying cognitive impairment with or without dementia). Gianattasio et al. (2019) used a different algorithm which incorporates a range of demographics and functional characteristics. Their algorithm was specifically designed to determine dementia status and not cognitive impairment in general, and is less conducive to conducting stratified analyses by sociodemographic characteristics, as we did, because their algorithm already incorporates those characteristics. Since dementia is a more severe form of cognitive impairment and is more likely to be picked up by clinicians than cognitive impairment at an earlier stage, it is natural that the estimated underdiagnosis rate in Chen et al. (2019) was lower than ours (about 50% based on their published estimates). Not surprisingly, like our study,

both of those studies found large racial disparities in diagnosis accuracy, particularly between non-Hispanic Whites and non-Hispanic Blacks.

Beyond demographics, we found that other factors, including age and family support also played a role in receiving an early diagnosis of cognitive impairment. People over age 75 and those with partners were more likely than their counterparts to receive an early diagnosis, which may reflect heightened attention to the symptoms of cognitive impairment among such individuals and their providers[28]. Further, the fact that prevalence of early diagnosis was higher among partnered individuals points to the potentially important role of one's spouse in identifying symptoms and facilitating diagnosis and treatment. By contrast, there was no difference in diagnosis between those with and without children, possibly because children, who often live away from their parents, played a lesser role in their parents' daily routines[29].

We found no evidence that those with more frequent interactions (i.e., above median visits, compared to below) with physicians had higher likelihood of early diagnosis. This finding is consistent with systematic barriers reported among providers in making timely diagnosis of cognitive impairment[5], such as lack of specific knowledge or diagnostic skills or uncertainty in guidelines. Moreover, while providers may be more inclined and justified to assign diagnosis of cognitive impairment to patients who were older or had functional difficulties, it is unlikely that clinical judgement alone explained the differential diagnosis by race, education or wealth.

Instead, two groups of factors could explain the racial and socioeconomic disparities in prevalence of early diagnosis of cognitive impairment. First, knowledge and attitudes towards cognitive impairment and dementia differ by both race and SES[30, 31]. Patients and their families (mostly spouses) were likely to be the first ones noticing the early changes in cognitive status, if at all, and those who did and understood its significance would possibly seek diagnosis or mention it to their providers in the next encounter. Those who failed to notice or report any changes or considered them as a normal sign of aging were possibly more likely to be non-white or have less education. Second, implicit biases[32, 33] could impact provider-patient encounters, leading to provider oversight of signs of cognitive impairment among racial and ethnic minority patients or those with lower educational attainment. This finding heightens concerns about the

impact of systemic racism on the disparate quality of healthcare for Black and Hispanic older adults.

Our study highlights the importance of interventions aimed at improving knowledge and changing attitudes regarding cognitive impairment and dementia among patients, providers and families/caregivers. Communities and social organizations may play a more active role in educating older adults and their families/caregivers about the symptoms of cognitive impairment and dementia and the potential benefits of early diagnosis, especially for minorities and socioeconomically disadvantaged groups. They could also help reduce stigma and provide needed support and resources for those receiving a diagnosis. In particular, awareness and usage of self-administered cognitive assessment tools could be an effective way to facilitate the identification of symptoms at an early stage[34, 35]. Clinical and professional education will also be essential in improving diagnosis of cognitive impairment.

Our study has several limitations. First, we assigned cognitive impairment status based on the cutoff of a survey-based cognitive assessment instrument, which may have lower sensitivity or specificity in comparison to a comprehensive clinical assessment[36]. However, given our goal of estimating the population-based prevalence of early memory-related diagnosis, this measure served the purpose of capturing early symptoms of cognitive impairment rather than providing a definitive diagnosis of dementia or MCI. The focus on heterogeneity in diagnosis prevalence also entails using a uniform standard for assigning cognitive impairment status instead of algorithms that already incorporate demographics or SES. Second, we did not examine respondents without Medicare FFS or those for whom Medicare claims could not be linked with HRS data. Third, due to data limitations, we did not compare subsequent outcomes of patients who did or did not receive an early diagnosis of cognitive impairment. Fourth, our results may not be representative of racial or ethnic minority populations in the U.S. given the low number of any particular racial or ethnic minority subgroup in HRS data. Finally, our results may not be generalizable to countries outside of the U.S. due to differences in contexts and healthcare systems.

We found low overall prevalence of memory-related diagnosis among American older adults who experienced early symptoms of cognitive impairment. Moreover, substantial disparities in

diagnosis prevalence exist by race, education, wealth, and family structure. Our findings highlight the importance of interventions aimed at improving knowledge and attitudes about cognitive impairment and dementia among disadvantaged patients and their families. Educational and training efforts towards providers are also needed to improve cognitive assessment when appropriate.

**Contributions:** YQ and XC are joint first authors. JL is the corresponding author. YQ, XC, and JL participated in the study design. YQ and DT analyzed data. YQ, XC, AK, and JL participated in the interpretation of results. YQ, XC, DT, and JL drafted the manuscript. XC, AK, and JL contributed to review the manuscript. All authors read and approved the final manuscript.

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## TABLES & FIGURE LEGENDS

**Table 1. Characteristics of Study Populations**

| | No. (%) | | |
|---|---|---|---|
| | **All** | **Before Cognitive Impairmen[a]** | **At Cognitive Impairment[b]** |
| No. of persons | 1,225 | 1,225 | 1,225 |
| No. of person waves | 4,714 | 3,489 | 1,225 |
| **Time-invariant Characteristic[c]** | | | |
| Sex | | | |
| Female | 761 (62.1) | NA | NA |
| Male | 464 (37.9) | NA | NA |
| Race/Ethnicity | | | |
| Non-Hispanic White | 1,042 (85.1) | NA | NA |
| Non-Hispanic Black | 108 (8.8) | NA | NA |
| Hispanic | 51 (4.2) | NA | NA |
| Other | 24 (2.0) | NA | NA |
| Education level | | | |
| Less than high school | 324 (26.5) | NA | NA |
| High school diploma | 679 (55.4) | NA | NA |
| Some college or higher | 222 (18.1) | NA | NA |
| **Time-varying Characteristic[d]** | | | |
| Age, mean (SD) | 77.1 (6.7) | 76.1 (6.5) | 80.0 (6.8) |
| Marital status | | | |
| Married or partnered | 2,595 (55.1) | 2,005 (57.5) | 590 (48.2) |
| Married, spouse absent | 35 (0.7) | 28 (0.8) | 7 (0.6) |
| Separated/Divorced | 326 (6.9) | 241 (6.9) | 85 (6.9) |
| Widowed | 1,615 (34.3) | 1,111 (31.8) | 504 (41.1) |
| Never married | 143 (3.0) | 104 (3.0) | 39 (3.2) |
| Number of living children, mean (SD) | 3.0 (2.0) | 3.1 (2.0) | 3.0 (2.0) |
| No. of ADL difficulties | | | |
| No difficulty in ADL | 3,784 (80.3) | 2,926 (83.9) | 858 (70.0) |
| Had difficulty in at least one ADL | 930 (19.7) | 563 (16.1) | 367 (30.0) |
| Household wealth | | | |
| 1st quartile | 1,186 (25.2) | 801 (23.0) | 385 (31.4) |
| 2nd quartile | 1,171 (24.8) | 852 (24.4) | 319 (26.0) |
| 3rd quartile | 1,180 (25.0) | 910 (26.1) | 270 (22.0) |
| 4th quartile | 1,177 (25.0) | 926 (26.5) | 251 (20.5) |

| | | | |
|---|---|---|---|
| Medicaid eligibility | | | |
| Not eligible for Medicaid | 4,325 (91.8) | 3,213 (92.1) | 1,112 (90.8) |
| Eligible for Medicaid | 389 (8.3) | 276 (7.9) | 113 (9.2) |
| Work status | | | |
| Working for pay | 538 (11.4) | 465 (13.3) | 73 (6.0) |
| Not working for pay | 4,176 (88.6) | 3,024 (86.7) | 1,152 (94.0) |
| Whether or not covered by employer-sponsored health insurance | | | |
| Yes | 1,204 (25.5) | 938 (26.9) | 266 (21.7) |
| No | 3,510 (74.5) | 2,551 (73.1) | 959 (78.3) |
| Whether or not covered by other health insurance[e] | | | |
| Yes | 2,289 (48.6) | 1,759 (50.4) | 530 (43.3) |
| No | 2,425 (51.4) | 1,730 (49.6) | 695 (56.7) |
| Region | | | |
| Northeast | 760 (16.1) | 569 (16.3) | 191 (15.6) |
| Midwest | 1,428 (30.3) | 1,064 (30.5) | 364 (29.7) |
| South | 1,928 (40.9) | 1,415 (40.6) | 513 (41.9) |
| West | 598 (12.7) | 441 (12.6) | 157 (12.8) |
| Depressive symptoms[f] | | | |
| Yes | 1,061 (22.5) | 709 (20.3) | 352 (28.7) |
| No | 3,653 (77.5) | 2,780 (79.7) | 873 (71.3) |
| Count of CCW conditions[g] (excluding dementia), mean (SD) | 7.8 (3.3) | 8.0 (3.3) | 7.2 (3.4) |
| Weighted Charlson index[g] (excluding dementia), mean (SD) | 1.6 (1.9) | 1.4 (1.7) | 2.1 (2.3) |

Abbreviations: HRS, Health and Retirement Study; CCW, Chronic Conditions Data Warehouse; ADL, Activities of Daily Living; NA, not applicable.

Chi-Square tests and t-tests were used to compare the characteristics of the listed variables between "At Cognitive Impairment" group and "Before Cognitive Impairment" group. All differences were statistically significant at the 5% level, except for the number of living children ($P$=0.45), Medicaid eligibility ($P$=0.15) and region ($P$=0.83).

[a] Before cognitive impairment indicates the waves in which patients were cognitively normal.

[b] At cognitive impairment indicates the wave in which patients experienced cognitive impairment.

[c] Patient level descriptive statistic on time-invariant variables.

[d] Patient-wave level descriptive statistic on time-varying variables.

[e] Other insurance includes government plan - the Civilian Health and Medical Program of the Department of Veteran's Affairs, long-term care and other health insurance.

[f] Center for Epidemiologic Studies Depression Scale (CES-D) scores ≥3 on the 8-item CES-D were interpreted to indicate probable depressive symptoms.

[g] For count of CCW conditions, weighted Charlson index, we are looking back 181-545 days preceding the interview date. This way, we could control for them in our main analysis looking back 6 months from the interview date for the outcome (receipt of a memory-related diagnosis). In our sensitivity analysis, we are looking back 366-730 days preceding the interview date for comorbidity related variables and control for them when looking back a year from the interview date for the outcome.

**Table 2. Unadjusted Prevalence of Memory-related Diagnosis Before and At Cognitive Impairment, All Patients and by Subgroups**

| Study Population | Before Cognitive Impairment[a] | | At Cognitive Impairment[b] | |
|---|---|---|---|---|
| | No. of person waves | Any Memory-related Visits[c], No. (%) | No. of person waves | Any Memory-related Visits[c], No. (%) |
| **All Patients** | 3,489 | 60 (1.7) | 1,225 | 147 (12.0) |
| **Subgroup** | | | | |
| Stratified by sex | | | | |
| Female | 2,171 | 36 (1.7) | 761 | 83 (10.9) |
| Male | 1,318 | 24 (1.8) | 464 | 64 (13.8) |
| Stratified by age | | | | |
| ≤75 | 627 | 7 (1.1) | 325 | 25 (7.7) |
| >75 | 2,862 | 53 (1.9) | 900 | 122 (13.6) |
| Stratified by race/ethnicity | | | | |
| Non-Hispanic White | 3,088 | 56 (1.8) | 1,042 | 138 (13.2) |
| Non-Hispanic Black | 251 | 2 (0.8) | 108 | 2 (1.9) |
| Hispanic | 103 | 1 (1.0) | 51 | 6 (11.8) |
| Other | 47 | 1 (2.1) | 24 | 1 (4.2) |
| Stratified by education level | | | | |
| Less than high school | 735 | 4 (0.5) | 324 | 12 (3.7) |
| High school diploma | 2,038 | 35 (1.7) | 679 | 83 (12.2) |
| Some college or higher | 716 | 21 (2.9) | 222 | 52 (23.4) |
| Stratified by household wealth | | | | |
| Below median | 1,562 | 25 (1.6) | 610 | 55 (9.0) |
| Median and above | 1,927 | 35 (1.8) | 615 | 92 (15.0) |
| Stratified by Medicaid eligibility | | | | |
| Not eligible for Medicaid | 3,213 | 54 (1.7) | 1,112 | 135 (12.1) |
| Eligible for Medicaid | 276 | 6 (2.2) | 113 | 12 (10.6) |
| Stratified by marital status | | | | |
| No partner | 1,867 | 29 (1.6) | 635 | 58 (9.1) |
| With partner | 1,622 | 31 (1.9) | 590 | 89 (15.1) |
| Stratified by No. of living children | | | | |
| No child | 278 | 5 (1.8) | 102 | 9 (8.8) |
| At least one child | 3,211 | 55 (1.7) | 1,123 | 138 (12.3) |

| | | | | |
|---|---|---|---|---|
| Stratified by the No. of ADL difficulties | | | | |
| No difficulty in ADLs | 2,443 | 46 (1.9) | 858 | 105 (12.2) |
| Had difficulty in at least one ADL | 1,046 | 14 (1.3) | 367 | 42 (11.4) |
| Stratified by the number of other physician visits[d] | | | | |
| Below median | 1,600 | 30 (1.9) | 580 | 65 (11.2) |
| Median and above | 1,889 | 30 (1.6) | 645 | 82 (12.7) |

Abbreviations: ADL, Activities of Daily Living; NA, not applicable.

Chi-Square tests were used to compare the proportion of having any physician visits with a memory-related diagnosis between "At Cognitive Impairment" group and "Before Cognitive Impairment" group. All differences were statistically significant at the 5% level, except for the Non-Hispanic Black subgroup ($P$=0.38) and other race group ($P$=0.62).

[a] Before cognitive impairment indicates the waves in which patients were cognitively normal.

[b] At cognitive impairment indicates the wave in which patients experienced cognitive impairment.

[c] Any memory-related visits indicate the frequency of having any physician visits with a memory-related diagnosis at the patient-wave level and the proportions of having any physician visits with a memory-related diagnosis at the patient-wave level.

[d] Other physician visits include any type of E&M visits except for physician visits with a memory related diagnosis and preventive care visits.

**Figure 1. Flowchart of Patients Included for Analysis**

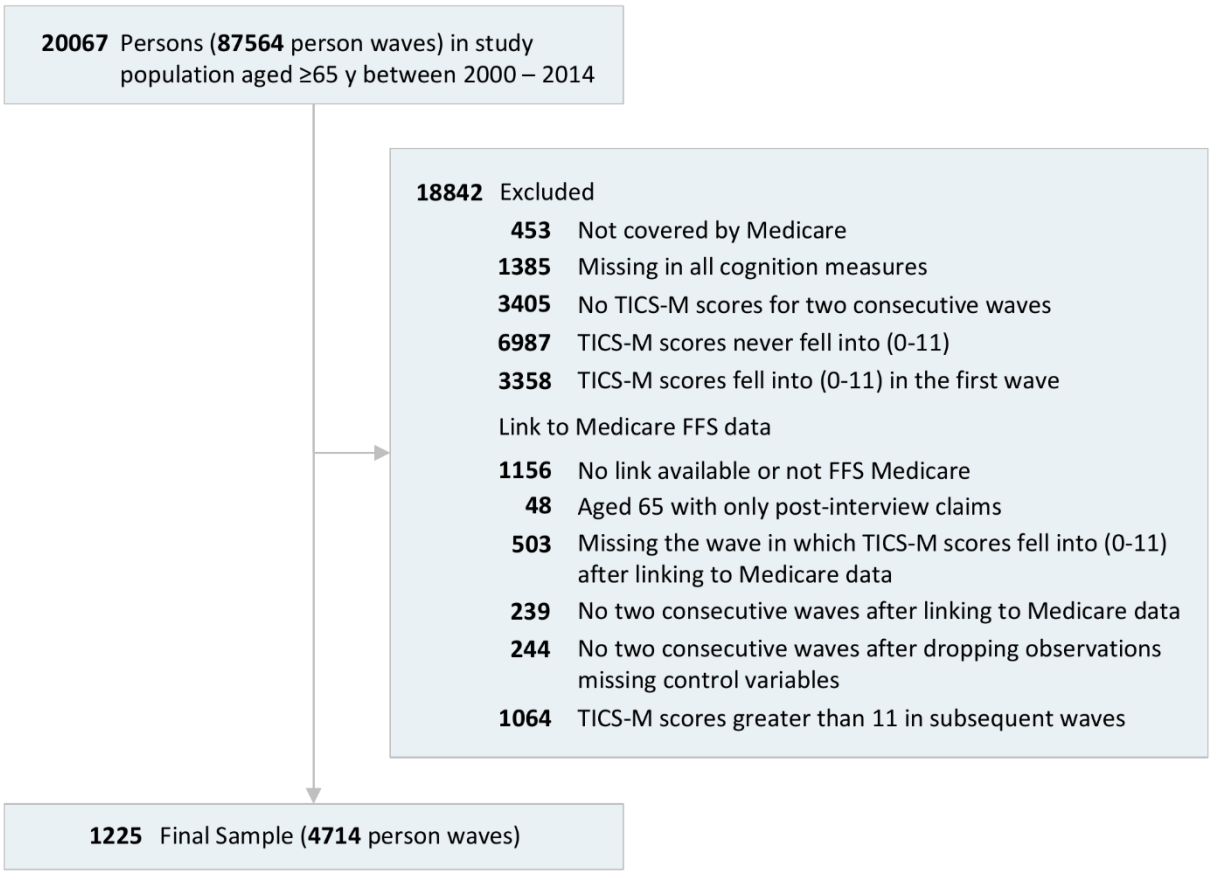
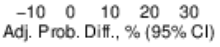


**Figure 2. Associations between Incident Cognitive Impairment and the Probability of Receiving a Memory-related Diagnosis Among All Patients and Subgroups**

| Study Population | No. of Patients, (%) | Adj. Prevalence at Cog. Imp., % (95% CI) | Adj. Prevalence before Cog. Imp., % (95% CI) | Adj. Probability Difference, % (95% CI) | P Value of SG. Diff. |
|---|---|---|---|---|---|
| Overall | 1,225 (100) | 9.80 (8.45, 11.16) | 2.49 (1.81, 3.17) | 7.31 (5.62, 9.00) | |
| Sex | | | | | 0.18 |
| Female | 761 (62.1) | 8.72 (7.09, 10.35) | 2.42 (1.61, 3.24) | 6.30 (4.26, 8.34) | |
| Male | 464 (37.9) | 11.75 (9.30, 14.21) | 2.54 (1.32, 3.76) | 9.21 (6.13, 12.30) | |
| Age | | | | | 0.020 |
| <=75 | 325 (26.5) | 5.73 (3.00, 8.47) | 2.13 (0.47, 3.80) | 3.60 (−0.26, 7.46) | |
| >75 | 900 (73.5) | 11.12 (9.46, 12.77) | 2.62 (1.85, 3.38) | 8.50 (6.46, 10.50) | |
| Race/Ethnicity | | | | | <0.001 |
| Non–Hispanic White | 1,042 (85.1) | 10.80 (9.27, 12.33) | 2.64 (1.89, 3.38) | 8.16 (6.26, 10.10) | |
| Non–Hispanic Black | 108 (8.8) | N/A | N/A | −0.70 (−3.71, 2.32) | |
| Hispanic | 51 (4.2) | 10.53 (−1.12, 22.19) | 1.58 (−4.58, 7.75) | 8.95 (−8.84, 26.70) | |
| Education Level | | | | | <0.001 |
| Less than high School | 324 (26.5) | 2.63 (0.91, 4.35) | 1.02 (0.05, 1.99) | 1.61 (−0.67, 3.89) | |
| High school diploma | 679 (55.4) | 9.44 (7.61, 11.27) | 2.64 (1.77, 3.52) | 6.79 (4.52, 9.07) | |
| Some college or higher | 222 (18.1) | 21.08 (16.88, 25.27) | 3.66 (1.77, 5.55) | 17.40 (12.20, 22.60) | |
| Household Wealth | | | | | <0.001 |
| Below median | 610 (49.8) | 6.51 (4.75, 8.28) | 2.58 (1.64, 3.52) | 3.93 (1.67, 6.20) | |
| Above median | 615 (50.2) | 13.28 (11.22, 15.34) | 2.35 (1.39, 3.31) | 10.90 (8.39, 13.50) | |
| Medicaid Eligibility | | | | | 0.54 |
| Not eligible for Medicaid | 1,112 (90.8) | 9.81 (8.38, 11.25) | 2.49 (1.78, 3.20) | 7.32 (5.53, 9.11) | |
| Eligible for Medicaid | 113 (9.2) | 8.37 (2.99, 13.76) | 3.09 (0.34, 5.85) | 5.28 (−1.92, 12.50) | |
| Marital Status | | | | | 0.006 |
| No partner | 635 (51.8) | 6.81 (5.12, 8.50) | 2.34 (1.52, 3.17) | 4.46 (2.36, 6.57) | |
| With partner | 590 (48.2) | 12.89 (10.70, 15.08) | 2.71 (1.60, 3.82) | 10.20 (7.40, 13.00) | |
| No. of Living Children | | | | | 0.89 |
| No child | 102 (8.3) | 9.48 (4.35, 14.62) | 1.56 (−0.94, 4.05) | 7.93 (1.29, 14.60) | |
| At least one child | 1,123 (91.7) | 10.03 (8.61, 11.45) | 2.50 (1.79, 3.21) | 7.53 (5.75, 9.31) | |
| No. of ADL Difficulties | | | | | 0.33 |
| No difficulty in ADL | 858 (70.0) | 9.76 (8.09, 11.43) | 2.75 (1.92, 3.58) | 7.01 (4.91, 9.11) | |
| At least one ADL difficulty | 367 (30.0) | 10.79 (8.16, 13.43) | 1.57 (0.32, 2.81) | 9.23 (5.88, 12.60) | |
| Number of Physician Visits | | | | | 0.85 |
| Below median | 580 (47.3) | 9.82 (7.90, 11.73) | 2.38 (1.41, 3.35) | 7.44 (5.02, 9.85) | |
| Above median | 645 (52.7) | 9.68 (7.74, 11.62) | 2.62 (1.68, 3.57) | 7.06 (4.64, 9.48) | |




Abbreviations: CI, Confidence Interval; Adj., Adjusted; Cog. Imp., Cognitive Impairment; Prob., Probability; S.G., Subgroup; Diff., Difference.

[a] Adjusted probability differences were obtained from ordinary least squared (OLS) regression of any memory-related diagnosis on cognitive impairment, controlled for all covariates in the Table1 and indicators for individuals, years, regions and year-by-regions. The standard errors in the regressions were clustered at the beneficiary level. Additional details on the specific covariates in the regressions were included in the "Covariates" section of Methods in the manuscript.

[b] Adjusted prevalence at cognitive impairment and before cognitive impairment are the predicted probabilities calculated using the postestimation margins command following multivariable OLS regression analysis.

[c] P-values were obtained from seemingly unrelated regressions (SUR) comparing the regression coefficients across groups.

[d] The change in the probability of diagnosis within a group was always significant at the 5% level except for age≤75 ($P$=0.068), non-Hispanic black ($P$=0.65), Hispanic ($P$=0.31), less than high school ($P$=0.17) and eligible for Medicaid ($P$=0.15).

[e] The other race group was not shown in the figure as the number of individuals in the group was too small to get the coefficient estimates. The adjusted prevalence for Non-Hispanic Black was not estimable.

**ONLINE SUPPLEMENT**

# Prevalence of Memory-Related Diagnoses among U.S. Older Adults with Early Symptoms of Cognitive Impairment

**eTable 1: ICD-9 Codes for Memory-related Diagnoses**

| Type of Memory-related Diagnosis | ICD-9 Codes |
|---|---|
| Alzheimer's disease and related dementias (ADRD) | 331.0, 331.11, 331.19, 331.2, 331.7, 290.0, 290.10, 290.11, 290.12, 290.13, 290.20, 290.21, 290.3, 290.40, 290.41, 290.42, 290.43, 294.0, 294.10, 294.11, 294.20, 294.21, 294.8, 797 |
| Mild cognitive impairment | 331.83 |
| Memory loss, other types of dementia, or cognitive deficit | 290.8, 290.9, 294.9, 331.3–331.6, 331.81–331.83, 331.89, 331.9, 438.0, 780.93 |

**eTable 2: Associations between Cognitive Impairment and the Probability of Receiving a Memory-related Diagnosis Among All Patients and Subgroups: Full Regression Results**

| | Memory-related Diagnosis 6 months before and after the HRS Interview* | |
|---|---|---|
| **Variable** | **Coefficient, % (95% CI)** | **P value** |
| Cognitive Impairment | 7.31 (5.62-9.00) | < 0.001 |
| Marital Status | | |
| Married or partnered (ref) | - | - |
| Married, spouse absent | 5.52 (-2.36-13.4) | 0.17 |
| Separated/Divorced | 1.27 (-5.39-7.93) | 0.71 |
| Widowed | 1.25 (-1.77-4.28) | 0.42 |
| Never married | -10.3 (-26.40-5.78) | 0.21 |
| No. of living children | | |
| 0 (ref) | - | - |
| 1 | 10.70 (-3.41-24.80) | 0.14 |
| 2 | 11.30 (-3.34-25.90) | 0.13 |
| 3 | 9.58 (-5.37-24.50) | 0.21 |
| 4 | 4.65 (-10.30-19.60) | 0.54 |
| 5 | 6.02 (-9.28-21.30) | 0.44 |
| 6 | 3.94 (-12.00-19.90) | 0.63 |
| No. of ADL difficulties | | |
| 0 (ref) | - | - |
| 1 | 0.01 (-2.31-2.33) | 0.99 |
| 2 | -0.17 (-3.82-3.48) | 0.93 |
| 3 | -1.69 (-6.53-3.15) | 0.49 |
| 4 | -2.43 (-8.25-3.40) | 0.42 |
| 5 | -5.15 (-13.80-3.49) | 0.24 |
| Household wealth | | |
| 1st quartile (ref) | - | - |
| 2nd quartile | -1.18 (-3.73-1.36) | 0.36 |
| 3rd quartile | -0.79 (-3.96-2.39) | 0.63 |
| 4th quartile | -3.76 (-7.56-0.04) | 0.05 |
| Medicaid eligibility | | |
| Not eligible for Medicaid (ref) | - | - |
| Eligible for Medicaid | 4.97 (0.46-9.49) | 0.03 |
| Work status | | |
| Not working for pay (ref) | - | - |
| Working for pay | -0.73 (-3.69-2.24) | 0.63 |
| Whether or not covered by employer-sponsored health insurance | | |
| No (ref) | - | - |
| Yes | -2.14 (-4.58-0.30) | 0.09 |
| Whether or not covered by government plan, Champus/VA | | |
| No (ref) | - | - |
| Yes | 0.37 (-3.85-4.58) | 0.86 |

| | | |
|---|---|---|
| Whether or not covered by long-term care insurance | | |
| No (ref) | - | - |
| Yes | 0.91 (-2.60-4.42) | 0.61 |
| Whether or not covered by other health insurance | | |
| No (ref) | - | - |
| Yes | -0.13 (-2.12-1.86) | 0.90 |
| Region | | |
| Northeast (ref) | - | - |
| Midwest | -27.20 (-40.80- -13.60) | < 0.001 |
| South | -21.20 (-31.00- -11.50) | < 0.001 |
| West | -12.20 (-37.90-13.60) | 0.35 |
| Depressive Symptoms | | |
| No (ref) | - | - |
| Yes | 0.64 (-1.26-2.55) | 0.51 |
| Weighted Charlson Index[†] | 0.42 (-0.25-1.09) | 0.22 |

Abbreviations: CI, Confidence Interval; ref, reference group; Champus/VA, the Civilian Health and Medical Program of the Department of Veteran's Affairs; ADL, Activities of Daily Living.

Results were obtained from ordinary least squared (OLS) regression of any memory-related diagnosis on cognitive impairment, controlled for all covariates in Table 1 and indicators for individuals, years, regions and year-by-regions. The standard errors were clustered at the beneficiary level.

[*] The estimates under the column indicates the association between the probability of receiving a cognitive Impairment-related diagnosis and patient characteristics within 6 months before and 6 months after the HRS Interview.

[†] Dementia was excluded from the Weighted Charlson Index.

**eTable 3: Results of Sensitivity Analyses with Alternative Time Windows and Placebo Test**

| Sensitivity Analysis | No. of Patients (%) | Adjusted Prevalence at Cognitive Impairment*, % (95% CI) | Adjusted Prevalence before Cognitive Impairment*, % (95% CI) | Adjusted Probability Difference†, % (95% CI) |
|---|---|---|---|---|
| **Any Physician Visits with a Memory-related Diagnosis within Different Time Windows** | | | | |
| 1 Year before the HRS Interview | 1,225 (100) | 7.64 (6.36-8.92) | 2.45 (1.81-3.09) | 5.19 (3.60-6.79) |
| 9 months before and 3 months after the HRS Interview | 1,225 (100) | 8.12 (6.81-9.43) | 2.39 (1.74-3.05) | 5.73 (4.09-7.36) |
| 3 months before and 9 months after the HRS Interview | 1,225 (100) | 10.68 (9.27-12.08) | 2.61 (1.91-3.32) | 8.06 (6.31-9.81) |
| 1 Year after the HRS Interview | 1,225 (100) | 11.04 (9.61-12.46) | 2.89 (2.18-3.60) | 8.15 (6.37-9.93) |
| **Placebo Test‡** | | | | |
| Any Physician Visits with a Memory-related Diagnosis within 6 months before and after the HRS Interview | 865 (100) | NA | NA | -0.42 (-1.79-0.95) |

Abbreviations: HRS, Health and Retirement Study; CI, Confidence Interval; NA, Not Applicable.

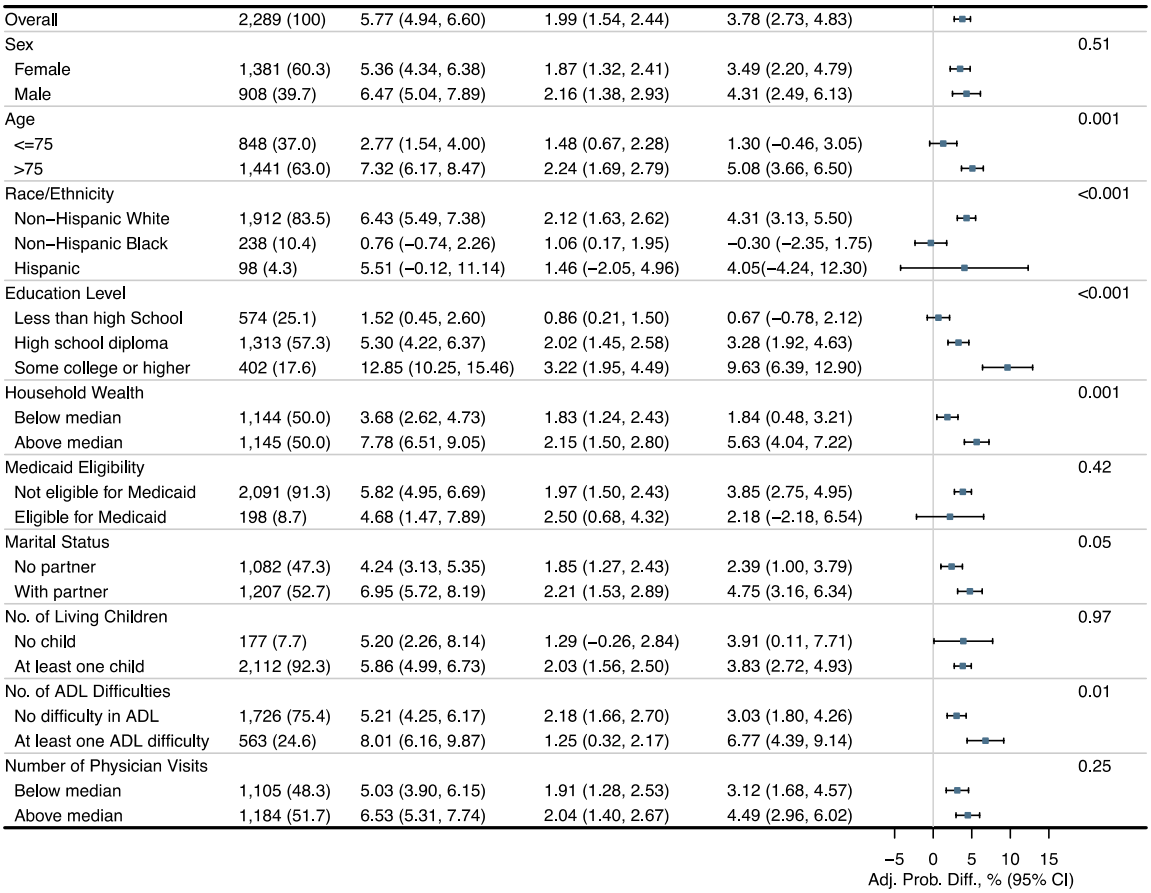
Results were obtained from ordinary least squared (OLS) regression of any memory-related diagnosis on cognitive impairment, controlled for all variables in Table 1 and indicators for individuals, years, regions and year-by-regions. The standard errors were clustered at the beneficiary level.

* Adjusted prevalence values are the predicted probabilities calculated using the postestimation margins command following the multivariable OLS regression analysis.

† All adjusted probability differences were statistically significant at the 5% level, except for the Placebo Test ($P$ =0.55).

‡ Placebo test was conducted using the wave immediately preceding the cognitive impairment wave as the exposure.

**eFigure 1: Associations between Incident Cognitive Impairment and the Probability of Receiving a Memory-related Diagnosis Among All Patients and Subgroups, including Those with Reversion in Cognition**




Abbreviations: CI, Confidence Interval; Adj., Adjusted; Cog. Imp., Cognitive Impairment; Prob., Probability; S.G., Subgroup; Diff., Difference; HRS, Health and Retirement Study.

[a] Adjusted probability differences were obtained from ordinary least squared (OLS) regression of any memory-related diagnosis on cognitive impairment, controlled for all covariates in the Table1 and indicators for individuals, years, regions and year-by-regions. The standard errors in the regressions were clustered at the beneficiary level. Additional details on the specific covariates in the regressions were included in the "Covariates" section of Methods in the manuscript.

[b] Adjusted prevalence at cognitive impairment and before cognitive impairment are the predicted probabilities calculated using the postestimation margins command following multivariable OLS regression analysis.

[c] P-values were obtained from seemingly unrelated regressions (SUR) comparing the regression coefficients across groups.

[d] The change in the probability of diagnosis within a group was always significant at the 5% level except for age≤75 (P=0.15), non-white (P=0.84), less than high school (P=0.37) and eligible for Medicaid (P=0.33).

[e] The other race group was not shown in the figure as the number of individuals in the group was too small to yield the coefficient estimates.