

## **Supplementary Data**

Referral of patients with cognitive impairment to specialty memory care: associations with patient-centered outcomes and specificity of diagnoses

Erin L Ferguson, Silvia Miramontes, Justin S White, Katherine L Possin, Anna Chodos, Fan Xia, Eva Raphael, Alexander K Smith, M Maria Glymour

### **List of Included Materials**

**Appendix S1.** Completed STROBE checklist for present manuscript.

**Appendix S2.** Observed models of the association between referral to specialty memory care and binary outcomes at 1-, 2-, and 5-years.

**Appendix S3.** Instrumental variable models of the association between referral to specialty memory care and binary outcomes at 1-, 2-, and 5-years.

**Table S1.** International Classification of Diseases (ICD) codes used for measuring cognitive impairment, quality-of-care outcomes, dementia diagnosis specificity outcome, model covariates, and descriptive covariates.

**Table S2.** Departments included as specialty memory care centers.

**Table S3.** Descriptive characteristics of primary care providers represented in this cohort.

**Table S4.** Incidence of quality-of-care outcomes and diagnosis specificity over varying lengths of follow-up time after diagnosis with cognitive impairment.

**Table S5.** Proportion of cohort who were lost to follow-up by referral group and time.

**Table S6.** Proportion of cohort who died by referral group and time.

**Table S7.** Coefficients from Aalen additive hazards models for the association between referral, 13 quality-of-care outcomes, and diagnosis specificity using both observed and instrumental variable (physician preference) approaches.

**Table S8.** Proportion of cohort with confirmed visits to specialty memory care by referral group and time.

**Table S9.** Patient and provider-level predictors (odds ratios) of referral from clinical and social covariates available in EHRs.

**Table S10.** Proportion of cohort with referrals from their primary care provider at baseline to other clinical departments by group and time.

**Table S11.** P-values for the interaction between referral (exposure) and physician preference (instrumental variable) for each outcome from Aalen additive hazard models.

**Table S12.** Association between referral to specialty memory care and measured weight (pounds) using both traditional and IV approaches.

**Table S13.** Cumulative coefficients from Aalen additive hazards models for the association between referral, 13 quality-of-care outcomes, and diagnosis specificity when excluding diagnoses made by geriatricians (n=578).

**Table S14.** Cumulative coefficients from Aalen additive hazards models for the association between referral, 13 quality-of-care outcomes, and diagnosis specificity when extending the measurement period of referral to two years.

**Figure S1.** Empirical cumulative distribution function of time between encounters during the 5 years of follow-up.

**Figure S2.** Linear observational and biprobit IV associations between referral to care, 13 quality-of-care outcomes, and diagnostic specificity at year 5 among survivors.

**Figure S3.** Linear observational and biprobit IV associations between referral to care, 13 quality-of-care outcomes, and diagnostic specificity at year 1 among survivors.

**Figure S4.** Linear observational and biprobit IV associations between referral to care, 13 quality-of-care outcomes, and diagnostic specificity at year 2 among survivors.

**Figure S5.** Observational and biprobit IV associations between referral to care and composite outcomes (outcome of interest, death, or loss to follow-up) at year 1.

**Figure S6.** Observational and biprobit IV associations between referral to care and composite outcomes (outcome of interest, death, or loss to follow-up) at year 2.

**Figure S7.** Observational and biprobit IV associations between referral to care and composite outcomes (outcome of interest, death, or loss to follow-up) at year 5.

## **Appendix S2. Observed models of the association between referral to specialty memory care and binary outcomes at 1-, 2-, and 5-years.**

This section reports the results from observational analyses using linear regression models.

We first calculated the association between referral, quality-of-care, and diagnosis specificity among survivors at each endpoint. At each endpoint, referral was associated an elevated absolute difference in risk of getting a more specific dementia diagnosis (risk difference at year 5: 0.065, 95% CI: 0.024-0.105; **Figure S2**). Referrals were also associated with increased risk of hospitalization and ED visits at years 1 (**Figure S3**) and 2 (**Figure S4**). Referral was associated with increased risk of depression at all timepoints (year 5: 0.081, 95% CI: 0.023-0.140).

In analyses retaining all individuals, referral was associated with decreased risk of all composite outcomes except for hospitalization, ED visits, inappropriate prescriptions and diagnosis specificity at year 1 (**Figure S5**). Referral was also associated with decreased risk of composite outcomes including weight loss, preventable hospitalizations, and hip fractures at 2 years (**Figure S6**). Referral was also associated with a composite outcome including weight loss at 5 years (**Figure S7**).

### **Appendix S3. Instrumental variable models of the association between referral to specialty memory care and binary outcomes at 1-, 2-, and 5-years.**

This section reports the results from IV analyses using bivariate probit models.

In survivors, referral was associated with decreased risk of weight loss at year 1 (RD: -0.150, 95% CI: -0.253, -0.048; **Figure S4**) and 5 (-0.196, 95% CI: -0.343, -0.048). At year 5, referral was also associated with increased risk of urinary incontinence (0.208, 95% CI: 0.027-0.389) and antipsychotics use (0.221, 95% CI: 0.076-0.367; **Figure S2**).

In analyses retaining all individuals in the IV models, referral was not associated with any composite outcome (outcome or death) at years 2 (**Figure S6**) or 5 (**Figure S7**). At year 1, referral was associated with decreased risk of weight loss (-0.165, 95% CI: -0.294, -0.037; **Figure S5**).

**Table S1.** International Classification of Diseases (ICD) codes used for measuring cognitive impairment, quality-of-care outcomes, dementia diagnosis specificity outcome, model covariates, and descriptive covariates.

| Variable  | ICD-9 Code  | ICD-10 Code  |
|---|---|--|
| <b>Cognitive Impairment Diagnoses in Primary Care</b>       |   |  |
| Alzheimer's disease and related dementias                   |   |  |
| Alzheimer's Disease   | 331.0   | G30.x  |
| Vascular Dementia   | 290.4x  | F01.5x   |
| Non-specific Dementia                                       | 290.0, 290.1x, 290.2x, 290.3, 294.2x, 294.8;  | F03.9x   |
| Mild Cognitive Impairment                                   | 331.83  | G31.83   |
| Memory loss   | 780.93  | R41.1, R41.2, R41.3  |
| <b>Quality-of-care Outcomes</b>                             |   |  |
| Hospitalization due to ambulatory care sensitive conditions |   |  |
| Short-term complications from diabetes                      | 250.10, 250.11, 250.12, 250.13, 250.20, 250.21, 250.22, 250.23, 250.30, 250.31, 250.32, 250.33  | E10.10, E10.11, E10.641, E10.65, E11.00, E11.01, E11.641, E11.65   |
| Long-term complications from diabetes                       | 250.40, 250.41, 250.42, 250.43, 250.50, 250.51, 250.52, 250.53, 250.60, 250.61, 250.62, 250.63, 250.70, 250.71, 250.72, 250.73, 250.80, 250.81, 250.82, 250.83, 250.90, 250.91, 250.92, 250.93          | E10.21, E10.22, E10.29, E10.311, E10.319, E10.321, E10.331, E10.341, E10.349, E10.351, E10.359, E10.36, E10.39, E10.36, E10.39, E10.40, E10.41, E10.42, E10.43, E10.44, E10.49, E10.51, E10.52, E10.59, E10.610, E10.618, E10.620, E10.621, E10.622, E10.628, E10.630, E10.638, E10.69, E10.8, E11.21, E11.22, E11.29, E11.311, E11.319, E11.321, E11.329, E11.331, E11.339, E11.341, E11.349, E11.351, E11.359, E11.36, E11.40, E11.41, E11.42, E11.43, E11.44, E11.49, E11.51, E11.52, E11.59, E11.610, E11.618, E11.620, E11.621, E11.622, E11.628, E11.630, E11.638, E11.69, E11.8 |
| COPD or asthma  | 491.0, 491.1, 491.20, 491.21, 491.8, 491.9, 492.0, 492.8, 494.0, 494.1, 496, 466.0, 490, 493.00, 493.01, 493.02, 493.10, 493.11, 493.12, 493.20, 493.21, 493.22, 493.81, 493.82, 493.90, 493.91, 493.92 | J41.0, J41.1, J41.8, J42.0, J43.1, J43.2, J43.8, J43.9, J44.0, J44.1, J44.9, J47.0, J47.1, J47.9, J20.x, J40, J45.21, J45.22, J45.31, J45.32, J45.41, J45.42, J45.51, J45.52, J45.901, J45.902, J45.990, J45.991, J45.998  |
| Heart failure   | 398.91, 428.0, 428.1, 428.20, 428.21, 428.22, 428.23, 428.30, 428.31, 428.32, 428.33, 428.40,   | I09.81, I50.1, I50.2, I50.21, I50.22, I50.23, I50.30, I50.31, I50.32, I50.33, I50.40, I50.41, I50.42, I50.43, I50.9  |

| Variable                             | ICD-9 Code  | ICD-10 Code   |
|--------------------------------------|---|---|
|                                      | 428.41, 428.42, 428.43, 428.9   |   |
| Dehydration                          | 276.50, 276.51, 276.52, 276.0, 008.61, 008.62, 008.63, 008.64, 008.65, 008.66, 008.67, 008.69, 008.8, 009.1, 009.2, 009.3, 558.9, 584.5, 584.6, 584.7, 584.8, 584.9, 586, 997.5 | E86.0, E86.1, E86.9, E87.0, A08.0, A08.11, A08.19, A08.2, A08.31, A08.32, A08.39, A08.4, A08.8, A09, K52.89, K52.9, N17.0, N17.1, N17.2, N17.8, N17.9, N19, N99.0 |
| Bacterial Pneumonia                  | 481, 482.2, 482.30, 482.31, 482.32, 482.39, 482.41, 482.42, 482.9, 483.0, 483.1, 483.8, 485, 486  | J13, J14, J15.211, J15.212, J15.3, J15.4, J15.7, J15.9, J16.0, J16.8, J18.0, J18.1, J18.8, J18.9  |
| Urinary tract infection              | 590.10, 590.11, 590.2, 590.3, 590.80, 590.81, 590.9, 595.0, 595.9, 599.0  | N10, N11.9, N12, N15.1, N15.9, N16, N28.84, N28.85, N28.86, N30.00, N30.01, N30.90, N30.91, N39.0   |
| Uncontrolled diabetes                | 250.002, 250.03   | E10.65, E11.65, E10.649, E11.649  |
| Delirium                             | 292.81, 293.1, 293.0, 780.97  | R41.82, R41.0   |
| Depression                           | 296.2, 296.3, 296.9, 311  | F32.x, F33.x, F34.x, F39.x  |
| Falls                                | E880, E888, E881, E882, E883, E884, E885, E886, E887  | W00.x, W01.x, W02.x, W03.x, W04.x, W05.x, W06.x, W07.x, W08.x, W09.x, W10.x, W11.x, W12.x, E13.x, W14.x, W15x, W16.x, W17.x, W18.x, W19.x, R29.6                  |
| Fecal incontinence                   | 787.6, 787.60   | R15.9   |
| Hip fractures*                       | 81.51, 81.52, 820.x   | S72.x, M84.459  |
| Urinary incontinence                 | 788.31, 788.36, 788.39, 596.55, 788.32, 788.35, 625.6, 625.60, 599.84, 788.33, 788.30, 788.34, 788.37, 788.38, 596.54, 596.55, 596.59   | N39.3, N39.41, N39.46, N32.81, R32.x, R39.81  |
| Weight loss                          | 783.21  | R63.4   |
| <b>Diagnosis Specificity Outcome</b> |   |   |
| Alzheimer's Disease                  | 331.0   | G30.x   |
| Vascular Dementia                    | 290.4x  | F01.5x  |
| Frontotemporal Dementia              | 331.1, 331.19   | G31.0, G31.09   |
| Pick's disease                       | 331.11  | G31.01  |
| Dementia with Lewy Bodies            | 331.82  | G31.83  |

| Variable   | ICD-9 Code   | ICD-10 Code  |
|--|--|--|
| Parkinson's Disease (or secondary Parkinson's) + Dementia diagnosis  | 332.0 + 331.0, 332.0 + *, 332.1 + *  | G20 + G30.x, G20 + *, G21 + *, G21.8 + *, G21.9 + *  |
| Variant Creutzfeldt-Jakob disease or other/unspecified Creutzfeldt-Jakob   | 046.11, 046.19   | A81.01, A81.0, A81.09  |
| Drug-induced persisting dementia   | 292.82   | F19.97, G31.2  |
| Huntington's disease   | 333.4  | G10  |
| ALS or Motor Neuron Disease + Dementia diagnosis   | 335.29 + *, 335.20 + *   | G12.20 + *, G12.21 + *   |
| Progressive bulbar palsy   | 335.22   | G12.22   |
| Corticobasal degeneration  | 331.6  | G31.85   |
| <b>Model covariates</b>  |  |  |
| <i>Case Mix (defined at the provider-level as the % of patients seen per year with the following conditions)</i> |  |  |
| Depression   | 296.2, 296.3, 296.9, 311   | F32.x, F33.x, F34.x, F39.x   |
| Hypertension   | 362.11, 401.x-404.xx, 437.2  | I10, I11, I12, I13, I16, H35.03x, I67.4  |
| Diabetes   | 250.xx   | E10, E11, E13  |
| Stroke (Ischemic and Hemorrhagic)  | 433.01, 433.11, 433.21, 433.31, 433.81, 433.91, 434.xx, 430, 431, 432            | I63, I66, I60, I61, I62  |
| Myocardial Infarction  | 410.xx   | I21.xx   |
| Ischemic Heart Disease   | 411.xx, 413.x, 414.0x, 414.12, 414.2, 414.3, 414.4, 414.8, 414.9, 414.10, 414.19 | I241, I200, I208, I201, I209, I240, I248, I24.9, I25810, I25811, I25812, I2542, I2582, I2583, I2584, I255, I2589, I259 |
| Congestive Heart Failure   | 402.01, 402.11, 402.91, 404.01, 404.03, 404.11, 404.13, 404.91, 404.93, 428.xx   | I110, I130, I132, I50  |
| Chronic Kidney Disease   | 585.3, 585.4, 585.5  | N18.3, N18.4, N18.5  |
| Asthma   | 493.xx   | J45.xx   |
| COPD   | 491.xx, 492.xx, 496.xx   | J41-J44  |
| Chronic Liver Disease  | 571  | K70, K73-K74   |
| <b>Descriptive covariates</b>  |  |  |
| Diabetes   | 250.xx   | E10, E11, E13  |
| Depression   | 296.2, 296.3, 296.9, 311   | F32.x, F33.x, F34.x, F39.x   |
| Hypertension   | 362.11, 401.x-404.xx, 437.2  | I10, I11, I12, I13, I16, H35.03x, I67.4  |
| Congestive heart failure   | 402.01, 402.11, 402.91, 404.01, 404.03, 404.11,                                  | I110, I130, I132, I50  |

| <b>Variable</b>                   | <b>ICD-9 Code</b>   | <b>ICD-10 Code</b>      |
|-----------------------------------|---|-------------------------|
|                                   | 404.13, 404.91, 404.93,<br>428.xx   |                         |
| Chronic kidney disease            | 585.3, 585.4, 585.5   | N18.3, N18.4, N18.5     |
| Stroke (Ischemic and Hemorrhagic) | 433.01, 433.11, 433.21,<br>433.31, 433.81, 433.91,<br>434.xx, 430, 431, 432 | I63, I66, I60, I61, I62 |

\*We additionally used procedure codes (HCPCS) codes to identify hip fracture (27125, 27130, 27230, 27232, 27235, 27236, 27246, 27248, 73530).

**Table S2.** Departments included as specialty memory care centers. A list of UCSF departments was identified using terms “Memory”, “Psych”, and “Neuro.” These departments were manually reviewed for relevance. Final departments included in this definition are indicated in the second column.

| <b>Department Name</b>             | <b>Included in Exposure</b> |
|------------------------------------|-----------------------------|
| CHILD NEURO MZ                     | X                           |
| GEN NEURO WEILL                    |                             |
| ID NEURO PARN                      |                             |
| MEMORY PARN                        | X                           |
| MEMORY WEILL                       | X                           |
| MH NEURO SAUS                      | X                           |
| NEURO BOPC                         | X                           |
| NEURO COMPLEX DX WEILL             | X                           |
| NEURO DX WEILL                     | X                           |
| NEURO EXPEDITED CARE               | X                           |
| NEURO MARIN                        | X                           |
| NEURO ONC METS MB                  |                             |
| NEURO ONC METS PARN                |                             |
| NEURO ONC PARN                     |                             |
| NEURO ONC PSYCH PARN               |                             |
| NEURO PARN                         | X                           |
| NEURO RECOVERY WEILL               | X                           |
| NEURO SAN MATEO                    | X                           |
| NEURO SPINE PARN 2                 |                             |
| NEURO SPINE PARN 8                 |                             |
| NEURO WEILL                        | X                           |
| NEURODIAGNOSTIC SERVICES           | X                           |
| NEURO-INTERVENTIONAL RADIOLOGY SVC |                             |
| NEUROMUSC PARN                     | X                           |
| NEUROSURG ADLT PARN                |                             |
| NEUROSURG ADLT WEILL               |                             |
| NEUROSURG BOPC                     |                             |
| NEUROSURG MARIN                    |                             |
| NEUROSURG NAPA                     |                             |
| NEUROSURG RMC SAN JOSE             |                             |
| NEUROSURGERY SAN MATEO             |                             |
| OPHTH NEURO OP MB 490              |                             |
| OPHTH NEURO OP PARN                |                             |
| PED NEURO MARIN                    |                             |
| PK RAD NEURO IR PARN               |                             |
| PSYCH EMBED GERIATRIC GEARY        | X                           |

|                              |   |
|------------------------------|---|
| PSYCH NEUROPSYCH PRITZKER    |   |
| RAD NEURO IR PARN            |   |
| REHAB PT NEURO PARN          | X |
| SFGH NEUROLOGY               | X |
| VASCULAR LAB NEURO           | X |
| ZZZGERIATRIC CARE PSYCH      | X |
| ZZZMEMORY ECC MB             | X |
| ZZZMEMORY MB                 | X |
| ZZZMOVEMENT DIS NEUROMOD MZ  | X |
| ZZZNEURO CONCUSSION MB       |   |
| ZZZNEURO CONCUSSION PARN     |   |
| ZZZNEURO DX MB               | X |
| ZZZNEURO DX PARN             | X |
| ZZZNEURO PSYCH MB            |   |
| ZZZNEURO PSYCH PARN          |   |
| ZZZNEURO RECOVERY PARN       | X |
| ZZZNEURO SURG MARIN          |   |
| ZZZNEUROSURG MZ              |   |
| ZZZOPHTH NEURO PEDS PARN     |   |
| ZZZOPHTH NEURO PEDS PARN 400 |   |
| ZZZPSYCH EMBED GERIATRIC     | X |
| ZZZPSYCH NEUROPSYCH PARN     |   |
| ZZZRAD NEURO IR OLD          |   |

**Table S3.** Descriptive characteristics of primary care providers represented in this cohort. Characteristics are stratified by whether a provider referred above or below the average proportion of referrals in this cohort (mean = 18.4%). Values are n(%) or mean(sd).

| Characteristic   | Referred at or above average (n=159) | Referred below average (n=310) | All providers (n=469) |
|--|--------------------------------------|--------------------------------|-----------------------|
| <i>Model covariates</i>                                |                                      |                                |                       |
| Provider Degree  |                                      |                                |                       |
| MD/DO  | 136 (85.5)                           | 269 (86.8)                     | 405 (86.4)            |
| Other  | 23 (14.5)                            | 41 (13.2)                      | 64 (13.6)             |
| Provider Specialty                                     |                                      |                                |                       |
| Family Medicine  | 35 (22.0)                            | 64 (20.6)                      | 99 (21.2)             |
| Geriatrics   | 1 (0.6)                              | 21 (6.8)                       | 22 (4.7)              |
| Internal Medicine                                      | 54 (34.0)                            | 92 (29.7)                      | 146 (31.1)            |
| Other*   | 69 (43.4)                            | 133 (42.9)                     | 202 (43.1)            |
| <i>Additional descriptive covariates</i>               |                                      |                                |                       |
| Average number of patients seen per year*              | 334 (304)                            | 300 (433)                      | 312 (394)             |
| Percent of patients with cognitive impairment per year | 14.1 (12.3)                          | 18.4 (20.2)                    | 17.0 (18.0)           |
| Provider Sex   |                                      |                                |                       |
| Female   | 102 (64.2)                           | 199 (64.2)                     | 301 (64.2)            |
| Male   | 51 (32.1)                            | 92 (29.7)                      | 143 (30.5)            |
| Unknown  | 6 (3.8)                              | 19 (6.1)                       | 25 (5.3)              |

\*This category includes the following primary specialties: addiction medicine, cardiology, electrophysiology, endocrinology, gastroenterology, general practice, gynecology, hematology and oncology, hepatology, hospital medicine, infectious diseases, nephrology, neurology, nurse practitioner, palliative care medicine, pediatrics, psychiatry, pulmonology, rheumatology, sports medicine, transplant hepatology, urgent care, women's health, and missing.

\*\*One outlier was removed for having seen 33,780 average patients per year, which we believe is due to unresolvable error within the EHR database.

**Table S4.** Incidence of quality-of-care outcomes and diagnosis specificity over varying lengths of follow-up time after diagnosis with cognitive impairment. At each time point, individuals who were no longer in the cohort (due to death or censoring) were removed from the risk set.

| Outcome                      | Prevalent cases at baseline | 1 Year        |             | 2 Years       |             | 5 Years       |             |
|------------------------------|-----------------------------|---------------|-------------|---------------|-------------|---------------|-------------|
|                              |                             | n cases (%)   | N in cohort | n cases (%)   | N in cohort | n cases (%)   | N in cohort |
| Antipsychotics               | 664                         | 312 (7.1%)    | 4,364       | 374 (11.1%)   | 3,360       | 416 (19.6%)   | 2,119       |
| Benzodiazepines              | 2,272                       | 387 (12.8%)   | 3,019       | 494 (21.9%)   | 2,252       | 455 (34.2%)   | 1,332       |
| Delirium                     | 959                         | 287 (6.9%)    | 4,182       | 367 (11.3%)   | 3,250       | 344 (16.6%)   | 2,071       |
| Depression                   | 2,365                       | 268 (9%)      | 2,979       | 328 (14.7%)   | 2,233       | 293 (21.1%)   | 1,386       |
| ED visit                     | n/a                         | 1,104 (22.6%) | 4,890       | 1,320 (34.9%) | 3,783       | 1,148 (47.3%) | 2,425       |
| Falls                        | 1,966                       | 351 (10.5%)   | 3,352       | 465 (18%)     | 2,580       | 441 (27.1%)   | 1,630       |
| Fecal Incontinence           | 321                         | 69 (1.5%)     | 4,630       | 102 (2.9%)    | 3,568       | 116 (5.1%)    | 2,274       |
| Hip Fracture                 | 311                         | 45 (1%)       | 4,651       | 80 (2.2%)     | 3,599       | 92 (4%)       | 2,305       |
| Hospitalization              | n/a                         | 842 (17.2%)   | 4,890       | 1,017 (26.9%) | 3,783       | 950 (39.2%)   | 2,425       |
| Potentially Inappropriate Rx | 3,186                       | 566 (24.3%)   | 2,325       | 653 (38.3%)   | 1,704       | 532 (55.7%)   | 955         |
| Preventable Hospitalization  | n/a                         | 97 (2%)       | 4,890       | 123 (3.3%)    | 3,783       | 128 (5.3%)    | 2,425       |
| Urinary Incontinence         | 1,739                       | 244 (6.9%)    | 3,514       | 312 (11.6%)   | 2,695       | 293 (17.1%)   | 1,716       |
| Weight Loss                  | 1,507                       | 257 (6.9%)    | 3,745       | 347 (12%)     | 2,889       | 330 (17.6%)   | 1,876       |
| Diagnosis Specificity        | 5,870                       | 558 (12.8%)   | 4,364       | 536 (15.8%)   | 3,402       | 417 (18.7%)   | 2,225       |

**Table S5.** Proportion of cohort who were lost to follow-up by referral group and time. Loss to follow-up occurred 100 days after an individual's last healthcare encounter. Loss to follow-up by death is excluded here, or in other words, this is the loss to follow-up among those who have not passed away.

| Group                  | Proportion of cohort censored by loss to follow-up by endpoint; n (%) |               |               |
|------------------------|---|---------------|---------------|
|                        | 1 year  | 2 years       | 5 years       |
| Referred (n=1,019)     | 165 (16.19)   | 306 (30.03)   | 442 (43.38)   |
| Not referred (n=5,605) | 1,187 (21.18)   | 1,839 (32.81) | 2,275 (40.59) |
| All (n=6,624)          | 1352 (20.41)  | 2,145 (32.38) | 2,717 (41.02) |

**Table S6.** Proportion of cohort who died by referral group and time. Deaths were obtained from inpatient hospitalizations and California death records.

| <b>Group</b>           | <b>Proportion of cohort that died by endpoint; n (%)</b> |             |               |
|------------------------|--|-------------|---------------|
|                        | 1 years  | 2 years     | 5 years       |
| Referred (n=1,019)     | 32 (3.14)  | 66 (6.48)   | 152 (14.92)   |
| Not referred (n=5,605) | 350 (6.24)   | 630 (11.24) | 1,330 (23.73) |
| All (n=6,624)          | 382 (5.77)   | 696 (10.51) | 1,482 (22.37) |

**Table S7.** Coefficients from Aalen additive hazards models for the association between referral, 13 quality-of-care outcomes, and diagnosis specificity using both observed and instrumental variable (physician preference) approaches. The coefficient for referral to specialty memory care represents average instantaneous risk over 5 years of follow-up. Confidence intervals for the instrumental variable model were calculated from bootstrapped standard errors. Models were adjusted for age, sex, self-reported race, self-reported Hispanic identity, insurance type, categorical indicator for year of diagnosis, diagnosed cognitive condition, provider medical degree, provider medical specialty, and provider's case complexity.

| Outcome                      | Sample Size | Coefficient for referral (95% CI)  |                                    |
|------------------------------|-------------|------------------------------------|------------------------------------|
|                              |             | Observed Model                     | Instrumental Variable Model        |
| Antipsychotics Use           | 5,960       | 3.11e-05<br>(-2.35e-05, 8.56e-05)  | 7.47e-05<br>(-6.13e-04, 7.63e-04)  |
| Benzodiazepine Use           | 4,352       | 5.84e-05<br>(-3.15e-05, 1.48e-04)  | 3.31e-04<br>(-2.75e-04, 9.37e-04)  |
| Delirium                     | 5,665       | 4.56e-05<br>(-1.02e-05, 1.01e-04)  | -6.67e-05<br>(-5.40e-04, 4.06e-04) |
| Depression                   | 4,259       | 1.34e-04<br>(3.99e-05, 2.28e-04)   | -4.50e-05<br>(-5.99e-04, 5.09e-04) |
| Emergency department visit   | 6,624       | 1.79e-05<br>(-1.33e-05, 4.91e-05)  | 7.71e-05<br>(-3.45e-04, 4.99e-04)  |
| Falls                        | 4,658       | 3.59e-05<br>(-2.80e-05, 9.98e-05)  | -1.14e-04<br>(-5.98e-04, 3.71e-04) |
| Fecal Incontinence           | 6,303       | 1.61e-05<br>(-7.68e-05, 1.09e-04)  | 3.86e-05<br>(-1.16e-03, 1.24e-03)  |
| Hip Fracture                 | 6,313       | -1.51e-05<br>(-1.17e-04, 8.68e-05) | -2.87e-04<br>(-1.53e-03, 9.58e-04) |
| Hospitalization              | 6,624       | 2.24e-05<br>(-9.16e-06, 5.39e-05)  | 9.34e-05<br>(-3.36e-04, 5.23e-04)  |
| Potentially Inappropriate Rx | 3,438       | 2.45e-05<br>(-8.59e-05, 1.35e-04)  | 5.07e-04<br>(-3.56e-05, 1.05e-03)  |
| Preventable Hospitalization  | 6,624       | -2.87e-05<br>(-1.05e-04, 4.71e-05) | -1.20e-05<br>(-1.04e-03, 1.02e-03) |
| Urinary Incontinence         | 4,885       | -3.94e-06<br>(-7.20e-05, 6.42e-05) | 1.62e-04<br>(-5.00e-04, 8.23e-04)  |
| Weight Loss                  | 5,117       | -5.51e-05<br>(-1.15e-04, 4.85e-06) | -3.83e-04<br>(-9.28e-04, 1.62e-04) |
| Diagnosis Specificity        | 5,870       | 1.11e-04<br>(6.96e-05, 1.53e-04)   | 6.87e-05<br>(-4.12e-04, 5.50e-04)  |

**Table S8.** Proportion of cohort with confirmed visits to specialty memory care by referral group and time. Encounters were limited to office visits, evaluations, or telehealth visits. Average time from cognitive impairment diagnosis to first confirmed visit was also calculated among individuals with confirmed visits to specialty memory care.

| Group                  | Proportion of cohort with confirmed visit to specialty memory care by endpoint; n (%) |               |               | Average time to confirmed visit; years (sd) |
|------------------------|---|---------------|---------------|---|
|                        | 1 year  | 2 years       | 5 years       |   |
| Referred (n=1,019)     | 807 (79.20)   | 834 (81.84)   | 857 (84.10)   | 0.376 (0.513)                               |
| Not referred (n=5,605) | 1,085 (19.36)   | 1,403 (25.03) | 1,833 (32.70) | 1.218 (1.262)                               |
| All (n=6,624)          | 1,892 (28.56)   | 2,237 (33.77) | 2,690 (40.61) | 0.95 (1.15)                                 |

**Table S9.** Patient and provider-level predictors (odds ratios) of referral from clinical and social covariates available in EHRs. Adjusted model includes adjustment for all characteristics in table. Estimates for year of diagnosis (categorical) did not converge.

| Characteristic   | Odds ratio for referral (95% CI) |                  |
|--|----------------------------------|------------------|
|  | Unadjusted                       | Fully adjusted   |
| Age (per 10 year increase)   | 0.84 (0.78-0.91)                 | 0.91 (0.82-1.01) |
| Female   | 0.81 (0.71-0.92)                 | 0.85 (0.73-0.99) |
| Racial Identity (ref=White)  |                                  |                  |
| Asian  | 0.94 (0.80-1.10)                 | 0.98 (0.82-1.17) |
| Black  | 0.97 (0.75-1.25)                 | 1.00 (0.76-1.32) |
| Other  | 0.93 (0.75-1.14)                 | 1.10 (0.86-1.41) |
| Hispanic ethnicity (ref=No)  |                                  |                  |
| Yes  | 0.85 (0.66-1.10)                 | 0.85 (0.63,1.16) |
| Unknown  | 0.99 (0.68-1.44)                 | 1.04 (0.69-1.56) |
| Insurance Type (ref: Private)  |                                  |                  |
| Public   | 0.81 (0.66-1.00)                 | 1.1 (0.87-1.38)  |
| Self-Pay   | 0.37 (0.29-0.48)                 | 1.45 (1.08-1.94) |
| Cognitive Condition (ref: ADRD)  |                                  |                  |
| MCI  | 1.7 (1.31-2.19)                  | 1.1 (0.84-1.44)  |
| Memory Loss  | 2.32 (1.93-2.79)                 | 1.47 (1.2-1.82)  |
| Marital Status (ref: Married)  |                                  |                  |
| Single   | 0.94 (0.78-1.13)                 | 1.01 (0.82-1.24) |
| Widowed  | 0.74 (0.62-0.88)                 | 1.06 (0.87-1.29) |
| Other  | 1.11 (0.91-1.35)                 | 1.13 (0.92-1.4)  |
| Smoking Status (ref: Never)  |                                  |                  |
| Former   | 1.1 (0.96-1.27)                  | 1.03 (0.89-1.2)  |
| Current  | 1.11 (0.76-1.62)                 | 1 (0.66-1.5)     |
| Unknown  | 0.03 (0.01-0.13)                 | 0.4 (0.09-1.68)  |
| Years as patient at UCSF   | 1.05 (0.99-1.11)                 | 0.98 (0.92-1.05) |
| Average number of encounters in year before baseline                     | 1.07 (1.05-1.09)                 | 1.01 (0.99-1.04) |
| History of diabetes  | 1.02 (0.88-1.17)                 | 1.03 (0.87-1.21) |
| History of depression  | 1.22 (1.06-1.40)                 | 1.05 (0.9-1.22)  |
| History of hypertension  | 0.95 (0.82-1.10)                 | 1.09 (0.91-1.29) |
| History of congestive heart failure                                      | 0.96 (0.8-1.16)                  | 1.11 (0.9-1.38)  |
| History of chronic kidney disease  | 1.07 (0.87-1.31)                 | 1 (0.8-1.26)     |
| History of stroke  | 0.99 (0.81-1.2)                  | 1.02 (0.83-1.27) |
| Provider degree (ref: MD/DO)   |                                  |                  |
| Other  | 0.86 (0.67-1.11)                 | 0.97 (0.73-1.28) |
| Provider specialty (ref: IM)   |                                  |                  |
| Family medicine  | 1.08 (0.92-1.27)                 | 0.72 (0.6-0.87)  |
| Geriatrics   | 0.1 (0.05-0.18)                  | 0.14 (0.08-0.26) |
| Other  | 0.89 (0.73-1.09)                 | 0.8 (0.65-1)     |
| Percent of patients with cognitive impairment provider saw in prior year | 0.1 (0.07-0.16)                  | 0.16 (0.1-0.28)  |

**Table S10.** Proportion of cohort with referrals from their primary care provider at baseline to other clinical departments by group and time. All referrals that were not to specialty memory care departments and made by the same clinician as the baseline encounter were included.

| Group   | Proportion of cohort referred to other clinical departments by endpoint; n (%) |               |               |
|---|--|---------------|---------------|
|   | 1 year   | 2 years       | 5 years       |
| <i>Observed referral status</i>                   |  |               |               |
| Referred (n=1,017)                                | 279 (27.38)  | 318 (31.21)   | 351 (34.45)   |
| Not referred (n=5,604)                            | 918 (16.38)  | 1,165 (20.79) | 1,447 (25.82) |
| All (n=6,621)                                     | 1,197 (18.07)  | 1,483 (22.39) | 1,798 (27.14) |
| <i>Value of physician preference</i>              |  |               |               |
| Higher physician preference: above median value   | 899 (27.14)  | 1,033 (31.19) | 1,108 (33.45) |
| Lower physician preference: median or below value | 298 (9.00)   | 450 (13.59)   | 690 (20.83)   |

**Table S11.** P-values for the interaction between referral (exposure) and physician preference (instrumental variable) for each outcome from Aalen additive hazard models. Models were adjusted for age, sex, self-reported race, self-reported Hispanic identity, insurance type, categorical indicator for year of diagnosis, diagnosed cognitive condition, provider medical degree, provider medical specialty, and provider’s case complexity.

| <b>Outcome</b>               | <b>p-value for interaction</b> |
|------------------------------|--------------------------------|
| Antipsychotics Rx            | 0.983                          |
| Benzodiazepine Rx            | 0.408                          |
| Delirium                     | 0.506                          |
| Depression                   | 0.697                          |
| Emergency Department Visit   | 0.082                          |
| Falls                        | 0.158                          |
| Fecal Incontinence           | 0.131                          |
| Hip Fracture                 | 0.575                          |
| Hospitalization              | 0.437                          |
| Potentially Inappropriate Rx | 0.695                          |
| Preventable Hospitalization  | 0.961                          |
| Urinary Incontinence         | 0.187                          |
| Weight Loss                  | 0.804                          |
| Diagnosis Specificity        | 0.710                          |

**Table S12.** Association between referral to specialty memory care and measured weight (pounds) using both traditional and IV approaches. Traditional models use linear regressions, and IV models use two-stage least squares estimators. Models included adjustment for weight at baseline, age, sex, self-reported race, self-reported Hispanic identity, insurance type, categorical indicator for year of diagnosis, diagnosed cognitive condition, provider medical degree, provider medical specialty, and provider's case complexity.

| Weight Outcome (Pounds) | Sample Size | Coefficient for referral (95% CI) |                             |
|-------------------------|-------------|-----------------------------------|-----------------------------|
|                         |             | Observed Model                    | Instrumental Variable Model |
| 1 year                  | 4,261       | -0.333 (-1.901, 1.236)            | -5.854 (-12.852, 1.145)     |
| 2 years                 | 3,427       | 0.265 (-1.525, 2.055)             | -4.884 (-13.471, 3.703)     |
| 5 years                 | 2,197       | -0.033 (-2.396, 2.329)            | -3.838 (-13.676, 6.000)     |

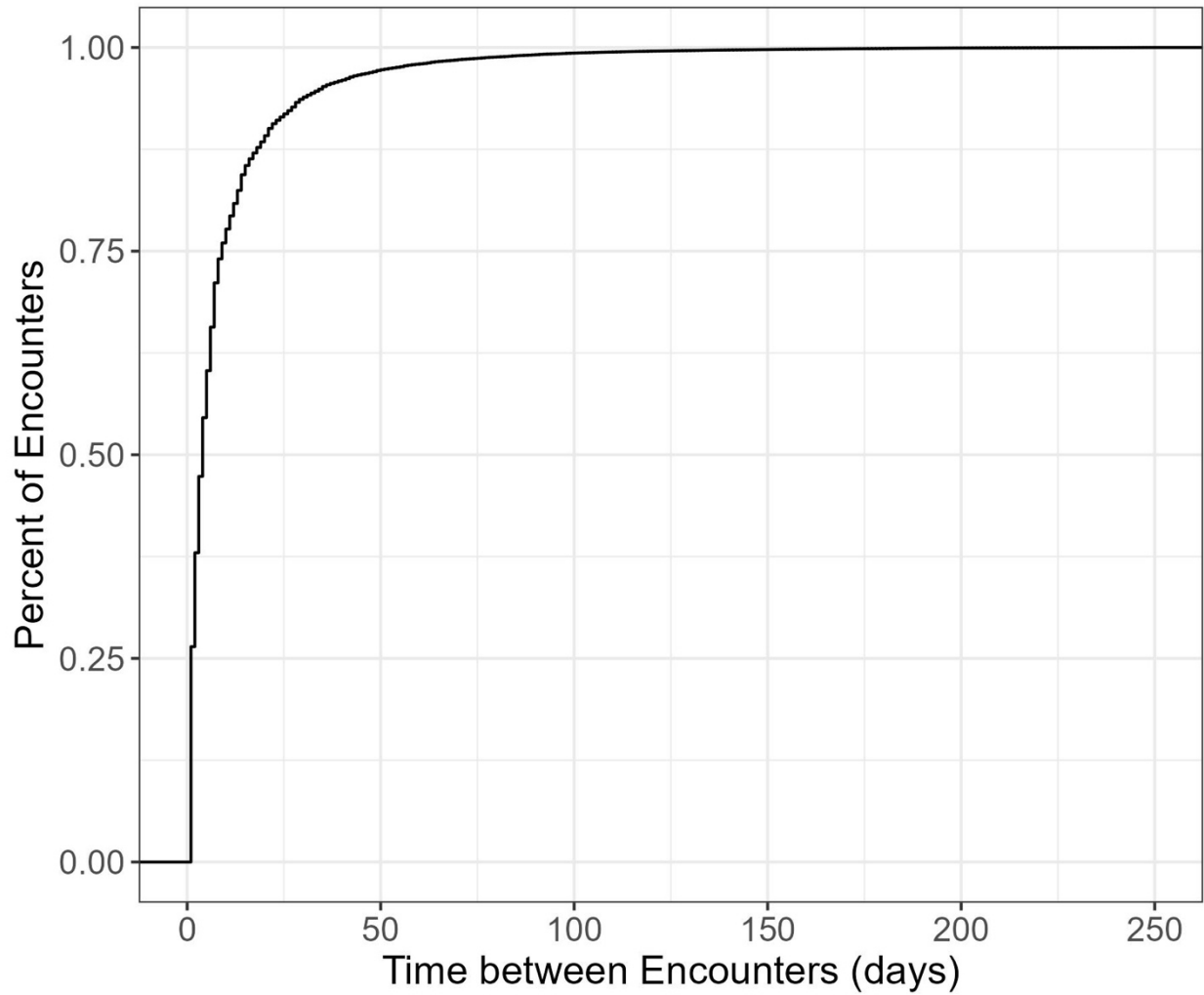
**Table S13.** Cumulative coefficients from Aalen additive hazards models for the association between referral, 13 quality-of-care outcomes, and diagnosis specificity when excluding diagnoses made by geriatricians (n=578). The coefficient for referral to specialty memory care represents cumulative excess risk over 5 years of follow-up. Confidence intervals for the instrumental variable model were calculated from bootstrapped standard errors. Models were adjusted for age, sex, self-reported race, self-reported Hispanic identity, insurance type, categorical indicator for year of diagnosis, diagnosed cognitive condition, provider medical degree, provider medical specialty, and provider's case complexity.

| Outcome                      | Sample Size | Cumulative coefficient for referral (95% CI) |                             |
|------------------------------|-------------|--|-----------------------------|
|                              |             | Observed Model                               | Instrumental Variable Model |
| Antipsychotics Rx            | 5,466       | 0.065<br>(-0.011, 0.141)                     | 0.107<br>(-0.245, 0.459)    |
| Benzodiazepine Rx            | 3,876       | 0.095<br>(-0.082, 0.272)                     | 0.123<br>(-0.357, 0.604)    |
| Delirium                     | 5,210       | 0.02<br>(-0.05, 0.089)                       | -0.181<br>(-0.418, 0.056)   |
| Depression                   | 3,847       | 0.081<br>(-0.01, 0.173)                      | -0.059<br>(-0.323, 0.206)   |
| Emergency department visit   | 6,046       | -0.052<br>(-0.18, 0.076)                     | -0.162<br>(-0.739, 0.415)   |
| Falls                        | 4,255       | 0.034<br>(-0.06, 0.127)                      | 0.004<br>(-0.333, 0.34)     |
| Fecal Incontinence           | 5,759       | -0.014<br>(-0.041, 0.013)                    | -0.041<br>(-0.154, 0.071)   |
| Hip Fracture                 | 5,760       | -0.01<br>(-0.033, 0.012)                     | -0.078<br>(-0.169, 0.013)   |
| Hospitalization              | 6,046       | -0.011<br>(-0.117, 0.095)                    | 0.131<br>(-0.338, 0.6)      |
| Potentially Inappropriate Rx | 3,059       | 0.153<br>(-0.169, 0.475)                     | 0.74<br>(-0.136, 1.615)     |
| Preventable Hospitalization  | 6,046       | -0.019<br>(-0.047, 0.01)                     | 0.015<br>(-0.145, 0.176)    |
| Urinary Incontinence         | 4,466       | -0.019<br>(-0.078, 0.04)                     | 0.07<br>(-0.27, 0.41)       |
| Weight Loss                  | 4,642       | -0.037<br>(-0.102, 0.029)                    | -0.419<br>(-0.645, -0.192)  |
| Diagnosis Specificity        | 5,552       | 0.083<br>(0.024, 0.142)                      | 0.037<br>(-0.202, 0.277)    |

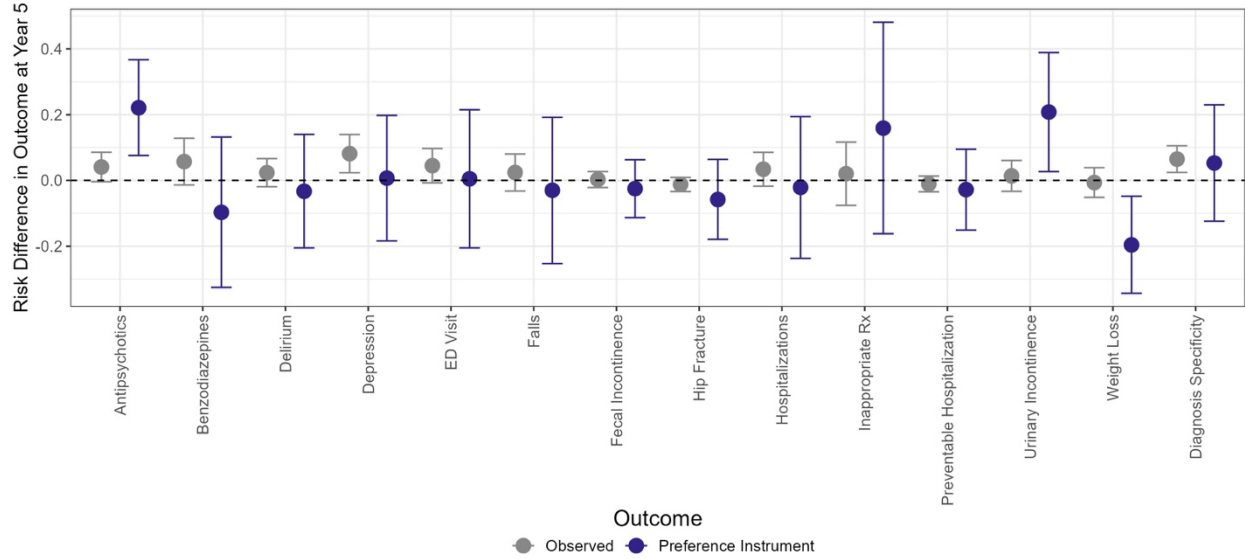
**Table S14.** Cumulative coefficients from Aalen additive hazards models for the association between referral, 13 quality-of-care outcomes, and diagnosis specificity when extending the measurement period of referral to two years. These models were restricted to individuals who survived and were not lost to follow-up in the two years after diagnosis (n=3,164). The coefficient for referral to specialty memory care represents cumulative excess risk over 5 years of follow-up. Confidence intervals for the instrumental variable model were calculated from bootstrapped standard errors. Models were adjusted for age, sex, self-reported race, self-reported Hispanic identity, insurance type, categorical indicator for year of diagnosis, diagnosed cognitive condition, provider medical degree, provider medical specialty, and provider's case complexity.

| Outcome                      | Sample Size | Cumulative coefficient for referral (95% CI) |                             |
|------------------------------|-------------|--|-----------------------------|
|                              |             | Observed Model                               | Instrumental Variable Model |
| Antipsychotics Rx            | 2,718       | 0.046<br>(-0.022, 0.113)                     | 0.047<br>(-0.202, 0.296)    |
| Benzodiazepine Rx            | 2,126       | 0.003<br>(-0.112, 0.118)                     | 0.013<br>(-0.372, 0.397)    |
| Delirium                     | 2,671       | -0.003<br>(-0.063, 0.058)                    | -0.133<br>(-0.324, 0.058)   |
| Depression                   | 2,012       | -0.005<br>(-0.087, 0.077)                    | -0.14<br>(-0.446, 0.166)    |
| Emergency department visit   | 2,013       | -0.095<br>(-0.203, 0.014)                    | -0.294<br>(-0.672, 0.085)   |
| Falls                        | 2,340       | 0.011<br>(-0.067, 0.09)                      | 0.105<br>(-0.212, 0.423)    |
| Fecal Incontinence           | 3,027       | -0.021<br>(-0.043, 0.002)                    | -0.029<br>(-0.12, 0.061)    |
| Hip Fracture                 | 3,068       | -0.007<br>(-0.028, 0.014)                    | -0.028<br>(-0.113, 0.056)   |
| Hospitalization              | 2,264       | -0.06<br>(-0.151, 0.032)                     | -0.082<br>(-0.452, 0.288)   |
| Potentially Inappropriate Rx | 1,427       | -0.081<br>(-0.291, 0.129)                    | 0.154<br>(-0.542, 0.849)    |
| Preventable Hospitalization  | 3,049       | -0.014<br>(-0.039, 0.011)                    | 0.034<br>(-0.089, 0.157)    |
| Urinary Incontinence         | 2,484       | -0.009<br>(-0.067, 0.049)                    | 0.094<br>(-0.156, 0.344)    |
| Weight Loss                  | 2,569       | 0.008<br>(-0.051, 0.067)                     | -0.269<br>(-0.432, -0.106)  |
| Diagnosis Specificity        | 2,395       | -0.018<br>(-0.064, 0.028)                    | -0.085<br>(-0.263, 0.093)   |

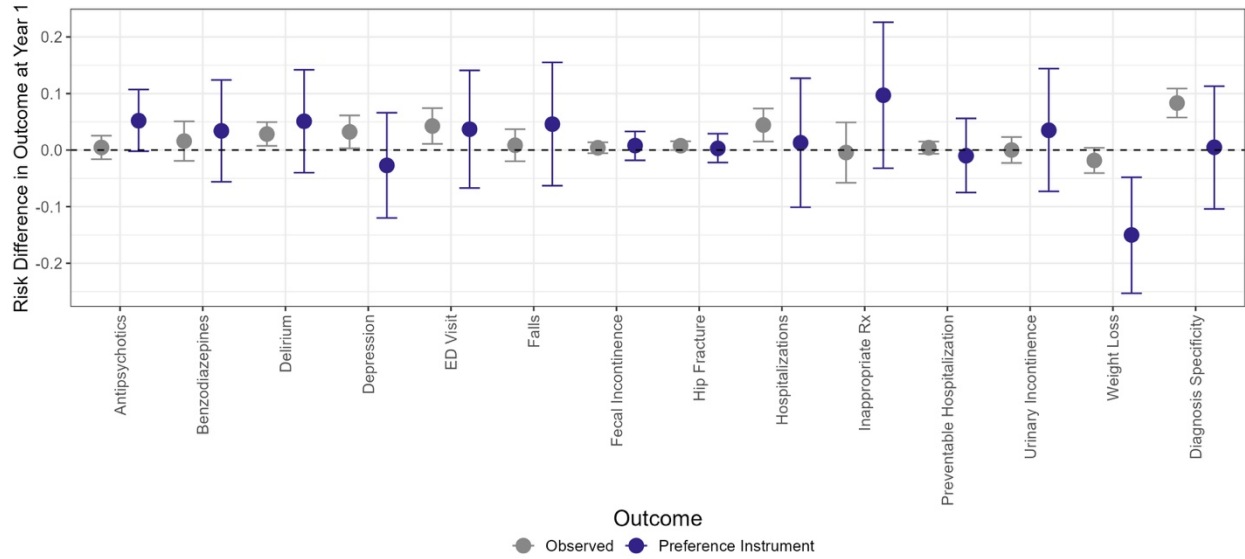
**Figure S1.** Empirical cumulative distribution function of time between encounters during the 5 years of follow-up. Encounters included any contact with the health system, such as office visits, telehealth visits, and phone calls. For inpatient visits, only the first and last days of stay were included as encounters. The average time between encounters was 9.96 days (sd = 26.67, n encounters = 888,551). The 95<sup>th</sup> percentile for this time difference was 35 days.



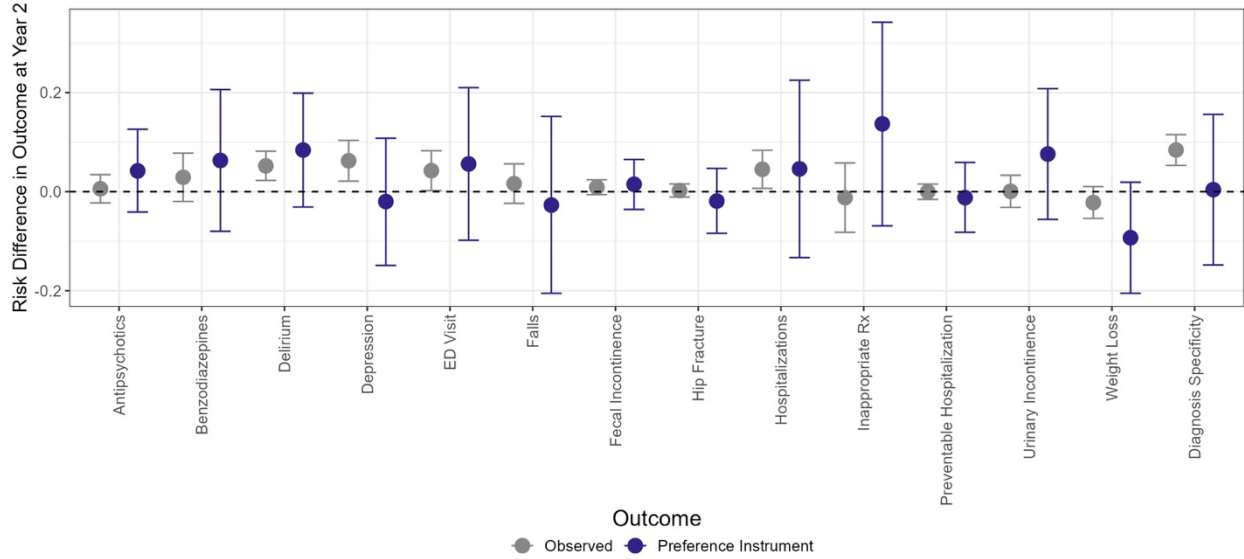
**Figure S2.** Linear observational and biprobit IV associations between referral to care, 13 quality-of-care outcomes, and diagnostic specificity at year 5 among survivors. Coefficients can be interpreted as risk differences. Models were adjusted for age, sex, self-reported race, self-reported Hispanic identity, insurance type, categorical indicator for year of diagnosis, diagnosed cognitive condition, provider medical degree, provider medical specialty, and provider's case complexity.



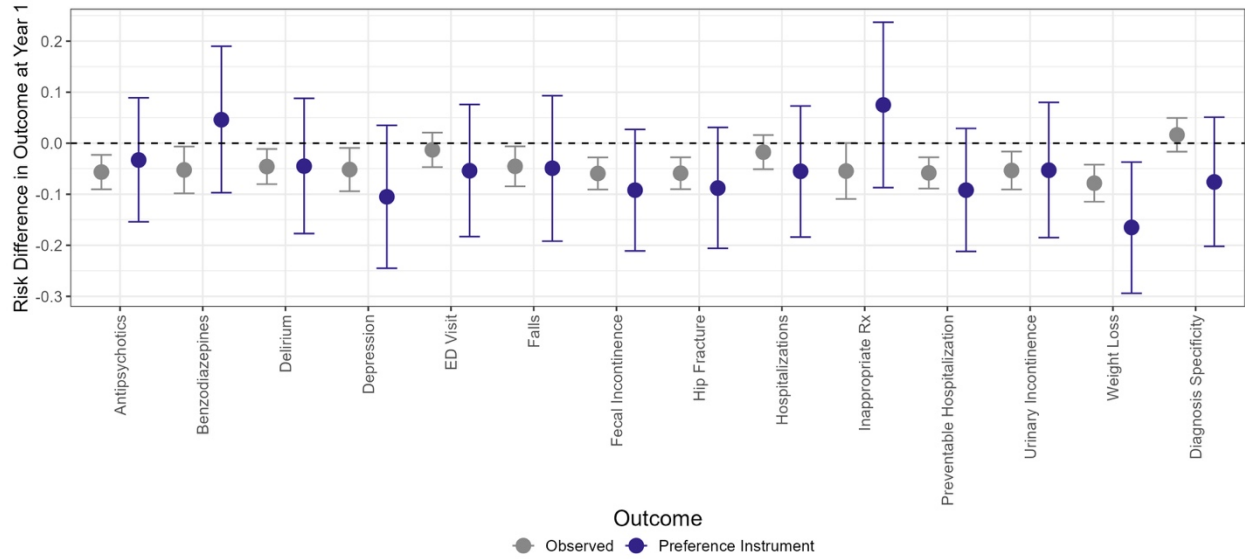
**Figure S3.** Linear observational and biprobit IV associations between referral to care, 13 quality-of-care outcomes, and diagnostic specificity at year 1 among survivors. Coefficients can be interpreted as risk differences. Models were adjusted for age, sex, self-reported race, self-reported Hispanic identity, insurance type, categorical indicator for year of diagnosis, diagnosed cognitive condition, provider medical degree, provider medical specialty, and provider's case complexity.



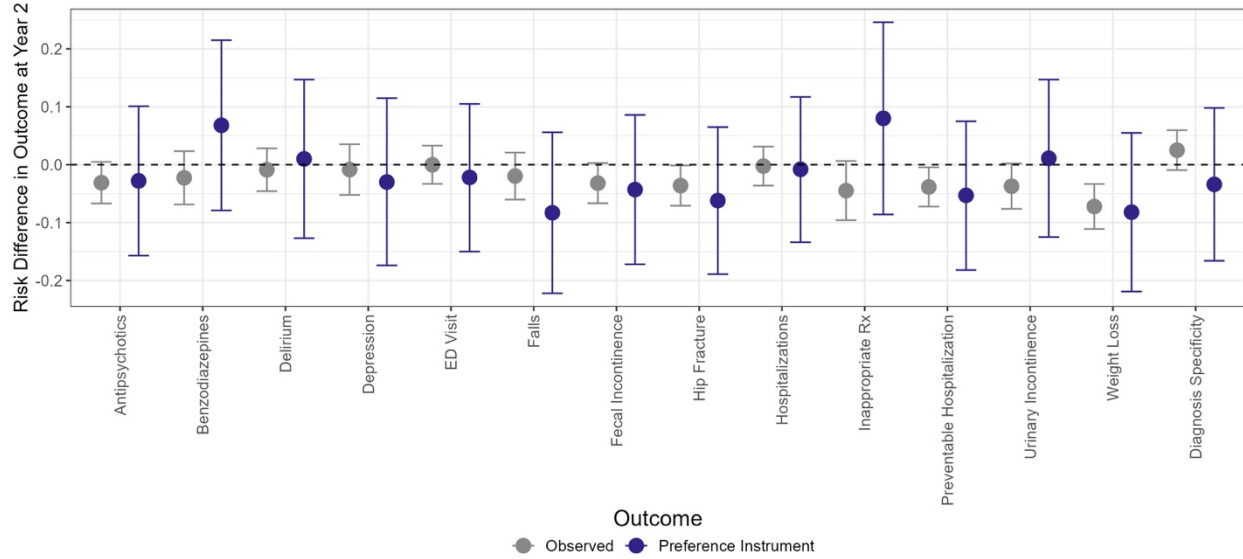
**Figure S4.** Linear observational and biprobit IV associations between referral to care, 13 quality-of-care outcomes, and diagnostic specificity at year 2 among survivors. Coefficients can be interpreted as risk differences. Models were adjusted for age, sex, self-reported race, self-reported Hispanic identity, insurance type, categorical indicator for year of diagnosis, diagnosed cognitive condition, provider medical degree, provider medical specialty, and provider's case complexity.



**Figure S5.** Observational and biprobit IV associations between referral to care and composite outcomes (outcome of interest, death, or loss to follow-up) at year 1. Coefficients can be interpreted as risk differences. Models were adjusted for age, sex, self-reported race, self-reported Hispanic identity, insurance type, categorical indicator for year of diagnosis, diagnosed cognitive condition, provider medical degree, provider medical specialty, and provider's case complexity.



**Figure S6.** Observational and biprobit IV associations between referral to care and composite outcomes (outcome of interest, death, or loss to follow-up) at year 2. Coefficients can be interpreted as risk differences. Models were adjusted for age, sex, self-reported race, self-reported Hispanic identity, insurance type, categorical indicator for year of diagnosis, diagnosed cognitive condition, provider medical degree, provider medical specialty, and provider's case complexity.



**Figure S7.** Observational and biprobit IV associations between referral to care and composite outcomes (outcome of interest, death, or loss to follow-up) at year 5. Coefficients can be interpreted as risk differences. Models were adjusted for age, sex, self-reported race, self-reported Hispanic identity, insurance type, categorical indicator for year of diagnosis, diagnosed cognitive condition, provider medical degree, provider medical specialty, and provider's case complexity.

