

Predicting Nursing Home Placement Among Home- and Community-Based Services Program Participants

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Lifetime risk of nursing home use is estimated at more than 40% and is projected to increase with greater life expectancy among Baby Boomer retirees.¹ Medicaid is the primary payer of nursing home services in the United States at an average annual cost of \$84,000 per beneficiary.² In 2010, long-term care services for older patients accounted for more than one-third of state Medicaid spending.³ At a total annual cost of over \$140 billion, Medicaid costs for long-term care will likely be part of ongoing discussions about state and federal deficit reduction.^{2,3}

In efforts to curb these costs, many states have moved towards home- and community-based services (HCBS)—programs that aim to prevent placement of high-risk Medicaid beneficiaries into long-term nursing facilities. These programs account for 45% of Medicaid long-term care spending,³ and research has shown that such programs may be effective.⁴⁻⁸ The Patient Protection and Affordable Care Act (PPACA) provides monetary incentives to states that implement HCBS programs as alternatives to nursing homes.⁹

Although a fair amount is known about the predictors of nursing home use,¹⁰⁻¹⁹ validated prediction models for long-term nursing home placement in high-risk, HCBS populations have not been studied.^{20,21} Understanding the risk factors for nursing home placement and identifying services that may prevent such placement can facilitate efficient allocation of resources among HCBS program participants. We used clinical and administrative databases for elderly participants in a state- and waiver-funded HCBS program to develop a practical model to predict the risk of long-term nursing home placement and to examine associated participant characteristics and program services.

METHODS

Data Sources

We used clinical and administrative data from the Connecticut Home Care Program for Elders (CHCPE) provided

ABSTRACT

Background

Several states offer publicly funded-care management programs to prevent long-term care placement of high-risk Medicaid beneficiaries. Understanding participant risk factors and services that may prevent long-term care placement can facilitate efficient allocation of program resources.

Objectives

To develop a practical prediction model to identify participants in a home- and community-based services program who are at highest risk for long-term nursing home placement, and to examine participant-level and program-level predictors of nursing home placement.

Study Design

In a retrospective observational study, we used deidentified data for participants in the Connecticut Home Care Program for Elders who completed an annual assessment survey between 2005 and 2010.

Methods

We analyzed data on patient characteristics, use of program services, and short-term facility admissions in the previous year. We used logistic regression models with random effects to predict nursing home placement. The main outcome measures were long-term nursing home placement within 180 days or 1 year of assessment.

Results

Among 10,975 study participants, 1249 (11.4%) had nursing home placement within 1 year of annual assessment. Risk factors included Alzheimer's disease (odds ratio [OR], 1.30; 95% CI, 1.18-1.43), money management dependency (OR, 1.33; 95% CI, 1.18-1.51), living alone (OR, 1.53; 95% CI, 1.31-1.80), and number of prior short-term skilled nursing facility stays (OR, 1.46; 95% CI, 1.31-1.62). Use of a personal care assistance service was associated with 46% lower odds of nursing home placement. The model C statistic was 0.76 in the validation cohort.

Conclusions

A model using information from a home- and community-based service program had strong discrimination to predict risk of long-term nursing home placement and can be used to identify high-risk participants for targeted interventions.

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Take-Away Points

A model using information from a home- and community-based service program had strong discrimination to predict risk of long-term nursing home placement and can be used to identify high-risk participants for targeted interventions.

- Approximately 11% of participants in a home- and community-based service program were placed in a nursing home within 1 year.
- Risk factors for long-term nursing home placement include Alzheimer's disease, money management dependency, living alone, and the number of prior short-term skilled nursing facility stays.
- Use of a personal care assistance service is associated with significantly lower odds of nursing home placement.

by Connecticut Community Care, Inc (CCCI). CHCPE is a publicly funded care-management program that provides preventive home care services to older Connecticut residents who are at risk for permanent nursing home placement. CCCI provided deidentified data for all clients from 2005 through 2011. The data included baseline eligibility evaluations and annual reassessments conducted by CCCI primary care managers, which contain demographic characteristics, medical history, functional ability, social support, and financial assistance data elements in the “Modified Community Assessment Tool” published by the Connecticut Department of Social Services (CDSS).²² Additional data included information on program status, funded and unpaid program services, hospital visits, short-term skilled nursing facility stays, and medications.

Study Population

The study population included at-risk residents who were referred to and deemed eligible for the CHCPE program. Program eligibility is based on the number of critical needs, income, and total assets. The state defines critical needs as functional dependencies in specific activities of daily living (ADLs) and instrumental activities of daily living (IADLs) and/or cognitive impairment requiring supervision.²³ We included CHCPE participants 65 years and older who completed an annual assessment between January 1, 2005, and December 31, 2010. If a participant had multiple assessments, we used the earliest reassessment for analysis.

Potential Predictors of Long-Term Nursing Home Placement

Potential predictors included demographic characteristics, clinical characteristics, social support, living arrangements, financial assistance, and program-level variables. Demographic information included age, sex, race, marital status, and primary spoken language. We categorized participants' race/ethnicity as black, Hispanic, white, or other. Clinical information included medical diagnoses (coded 0 [none], 1 [secondary], or 2 [major]); ADLs and

IADLs (coded 0 [independent], 1 [requires assistance], or 2 [total dependence]); mental status quotient (0 to 10 errors); behavioral and psychological issues; vision and hearing assessments; and medications. A dichotomous variable for “meets nursing home level of care” was based on 3 or more critical care needs as defined by the CDSS.²³

Program-level variables included health-care utilization, program services, and the patient's primary care manager and team. We

assessed hospital admissions, emergency department visits, and short-term skilled nursing facility stays during the year before the assessment. We grouped services into categories (eAppendix A, available at www.ajmc.com); identified the services in place at the time of and in the 12 months before the assessment; and calculated average monthly total costs, medical costs, and social service costs. The personal care assistant service pilot offered during the period of our study gave participants authority to hire a single person, including a family member, to perform services that might otherwise be provided by multiple persons. The assessment year, time since the initial assessment, and time since program activation were used to account for variation in subjects' program participation time.

Most variables had low rates of missingness (ie, less than 2%). We imputed missing values as follows: “no” for dichotomous variables, the most frequent level or category for multichotomous variables, and median values for continuous variables.²⁴ Since missing values for the mental status quotient (3%) were likely attributable to pronounced cognitive or communication impairments, we imputed missing values to 11.

Outcomes

The primary outcome of interest was placement in a long-term nursing home within 180 or 365 days after the assessment. We calculated the days from assessment to nursing home placement based on a termination record in the program status file.

Statistical Analysis

We present patient characteristics at the time of the annual assessment, using proportions for categorical variables and using means with standard deviations or medians with interquartile ranges for continuous variables. We calculated the frequency and Kaplan-Meier estimates of 1-year or 6-month nursing home placement.

Since the goal of this study was to develop a prediction model that would be useful in practice, we carefully pre-

selected potential predictors based on clinical knowledge and previous literature,^{10,13,15,25,26} and adhered to the rule of 10 events per examined variable to avoid overfitting.²⁷⁻³⁰ We used logistic regression models to predict 1-year and 6-month nursing home placement. We chose logistic regression to facilitate both internal- and external-model validation using well-established methods and practical implementation of the prediction model scoring mechanism in the electronic data systems of 2 HCBS programs. In all models, we incorporated random effects to account for variance in nursing home placement among primary care-manager teams. As a sensitivity analysis, we used Cox proportional hazards models with robust standard errors to account for clustering of participants within primary care-management teams. For the Kaplan-Meier and Cox survival analyses, we censored data for participants if they terminated the program and at the time of death.

We randomly selected a derivation sample consisting of 66% of the study cohort and a validation sample consisting of the remaining 34% of the study cohort. We developed the logistic regression models in the derivation sample and then applied the results from these models to the validation sample. We evaluated the calibration and discrimination of all models in both samples and refit the models for the entire study cohort.^{31,32} Using the derivation model estimates, we generated predicted probabilities of nursing home placement in the derivation and validation samples. To assess the clinical usefulness of the prediction models, we considered patients who were in the top 10%, 15%, 25%, or 50% of the predicted probabilities to be those whom the model predicted would have nursing home placement.³³ At each threshold, we calculated the model's sensitivity, false-negative rate, specificity, false-positive rate, and positive predictive value. We calculated the area under the curve (C statistic) to assess overall model discrimination. To assess model calibration, we plotted percent of predicted nursing home placement versus percent of observed nursing home placement by decile of predicted probability and calculated E_{avg}^{30} . Additional details about methods are provided in [eAppendix B](#).

RESULTS

Among 10,975 CHCPE participants who completed an annual assessment between 2005 and 2010, the mean time since program activation was 425 days. The mean available follow-up for the study outcome was 320 days (range, 1-365). The median age was 75 to 79 years, 74% of participants were women, and 74% were white ([Table 1](#)). More than two-thirds of participants were eligible for

Medicaid. Common medical diagnoses included hypertension (59%), diabetes (33%), and Alzheimer's disease (20%). Common functional dependencies included bathing (80%), meal preparation (92%), housework (97%), and money management (75%). Most participants were able to perform eating/feeding (89%) and toileting (86%) activities without assistance. Over half of participants lived alone, and most had regular contact with their support system.

The most common services received were: housekeeping or shopping (95%); skilled nursing care or medication administration (80%); emergency response system (72%); and adult care, companionship, or supervision (62%) ([Table 2](#)). In addition to formal services paid for through the program, most participants also received unpaid services typically performed by someone in their support system, including household/shopping, safety checks, and hands-on care. The pilot personal care assistance service was used by 160 (1.5%) participants, for an average of about 90 hours per month. The mean total monthly cost for paid program services was \$2296, the mean non-Medicaid medical service cost was \$714, and the social service cost was \$1549.

Within 1 year of assessment, 1249 (11.4%) participants had nursing home placement, 836 (7.6%) died, and 521 (4.7%) terminated the program for other reasons. The Kaplan-Meier 1-year nursing home rate was 12.2%. Among participants with nursing home placement within 1 year, the median time to placement was 170 days.

Significant risk factors for 1-year nursing home placement included age (OR, 1.19; 95% CI, 1.13-1.25), Alzheimer's disease (OR, 1.30; 95% CI, 1.18-1.43), money management dependency (OR, 1.33; 95% CI, 1.18-1.51), living alone (OR, 1.53; 95% CI, 1.31-1.80), meeting a nursing home level of care (OR, 1.30; 95% CI, 1.04-1.63), and English as primary language (OR, 2.22; 95% CI, 1.66-2.97) ([Table 3](#)). Each additional short-term skilled nursing facility stay in the previous 12 months was associated with 46% higher odds of nursing home placement (95% CI, 1.31-1.62). Women, black patients, and patients with regular contact with a support system had lower risks of nursing home placement than other patients. Participants with monthly medical service costs above the median (>\$511) had on average 7% higher odds of nursing home placement than other patients. Use of a personal care assistance service was associated with 46% lower odds of nursing home placement. However, none of the other service or cost variables improved model performance, so they were not included in the final models. Results for the 6-month models were similar ([eAppendix C](#)).

Table 1. Characteristics of the Study Population

Characteristic	All Participants (N = 10,975)	Derivation Sample (n = 7244)	Validation Sample (n = 3731)
Age in years, n (%)			
65-69	2278 (20.8)	1493 (20.6)	785 (21.0)
70-74	1635 (14.9)	1050 (14.5)	585 (15.7)
75-79	1914 (17.4)	1277 (17.6)	637 (17.1)
80-84	2609 (23.8)	1694 (23.4)	915 (24.5)
85-89	1451 (13.2)	1000 (13.8)	451 (12.1)
≥90	1088 (9.9)	730 (10.1)	358 (9.6)
Women, n (%)	8093 (73.7)	5337 (73.7)	2756 (73.9)
Race/ethnicity, n (%)			
Black	1041 (9.5)	705 (9.7)	336 (9.0)
Hispanic	1650 (15.0)	1070 (14.8)	580 (15.5)
White	8076 (73.6)	5325 (73.5)	2751 (73.7)
Other	208 (1.9)	144 (2.0)	64 (1.7)
Married, n (%)	2088 (19.0)	1409 (19.5)	679 (18.2)
Primary spoken language, n (%)			
English	8578 (78.2)	5666 (78.2)	2912 (78.0)
Spanish	1580 (14.4)	1039 (14.3)	541 (14.5)
Other	817 (7.4)	539 (7.4)	278 (7.5)
Rural location, n (%)	909 (8.3)	626 (8.6)	283 (7.6)
Medical history, n (%)			
Alzheimer's disease	2161 (19.7)	1426 (19.7)	735 (19.7)
Cancer	683 (6.2)	476 (6.6)	207 (5.5)
Cerebrovascular accident	760 (6.9)	489 (6.8)	271 (7.3)
Decubitus ulcers	155 (1.4)	100 (1.4)	55 (1.5)
Diabetes	3587 (32.7)	2396 (33.1)	1191 (31.9)
Hearing impairment	1816 (16.5)	1224 (16.9)	592 (15.9)
Hypertension	6421 (58.5)	4225 (58.3)	2196 (58.9)
Hip fracture	145 (1.3)	95 (1.3)	50 (1.3)
Mental illness	1512 (13.8)	998 (13.8)	514 (13.8)
Visual impairment	2648 (24.1)	1732 (23.9)	916 (24.6)
Assistance with ADLs, n (%)			
Bathing	8727 (79.5)	5789 (79.9)	2938 (78.7)
Bladder	1900 (17.3)	1273 (17.6)	627 (16.8)
Bowel	1050 (9.6)	710 (9.8)	340 (9.1)
Dressing	4392 (40.0)	2909 (40.2)	1483 (39.7)
Eating/feeding	1262 (11.5)	842 (11.6)	420 (11.3)
Mobility	5111 (46.6)	3352 (46.3)	1759 (47.1)
Stair climbing	6662 (60.7)	4394 (60.7)	2268 (60.8)
Toileting	1488 (13.6)	983 (13.6)	505 (13.5)
Transferring	1588 (14.5)	1047 (14.5)	541 (14.5)
Walking	2144 (19.5)	1419 (19.6)	725 (19.4)
Wheeling	2121 (19.3)	1423 (19.6)	698 (18.7)
Summary score^a			
Mean (SD)	4.1 (4.2)	4.1 (4.2)	4.0 (4.1)
Median (range)	3.0 (0.0-22.0)	3.0 (0.0-22.0)	3.0 (0.0-22.0)

(Continued)

Table 1. Characteristics of the Study Population (*continued*)

Characteristic	All Participants (N = 10,975)	Derivation Sample (n = 7244)	Validation Sample (n = 3731)
Assistance with IADLs, n (%)			
Housework	10,669 (97.2)	7043 (97.2)	3626 (97.2)
Laundry	9827 (89.5)	6486 (89.5)	3341 (89.5)
Meal preparation	10,083 (91.9)	6655 (91.9)	3428 (91.9)
Medication administration	8734 (79.6)	5766 (79.6)	2968 (79.5)
Money management	8172 (74.5)	5385 (74.3)	2787 (74.7)
Shopping	10,383 (94.6)	6848 (94.5)	3535 (94.7)
Telephoning	1885 (17.2)	1258 (17.4)	627 (16.8)
Travel from residence	9362 (85.3)	6168 (85.1)	3194 (85.6)
Summary score^a			
Mean (SD)	8.7 (3.4)	8.7 (3.4)	8.7 (3.4)
Median (range)	8.0 (0.0-16.0)	8.0 (0.0-16.0)	8.0 (0.0-16.0)
Facility history, n (%)			
Prior or current hospital admission	3313 (30.2)	2222 (30.7)	1091 (29.2)
Prior or current emergency department visit	632 (5.8)	427 (5.9)	205 (5.5)
Prior or current short-term skilled nursing facility stay	1724 (15.7)	1148 (15.8)	576 (15.4)
Facility visits among those with any visit, median (IQR)			
Prior or current hospital admission	1.0 (1.0-2.0)	1.0 (1.0-2.0)	1.0 (1.0-2.0)
Prior or current emergency department visit	1.0 (1.0-1.0)	1.0 (1.0-1.0)	1.0 (1.0-1.0)
Prior or current short-term skilled nursing facility stay	1.0 (1.0-1.0)	1.0 (1.0-1.0)	1.0 (1.0-2.0)
Overall health			
Perception of health ^b	1.7 (0.6)	1.7 (0.6)	1.6 (0.6)
Met nursing home level of care, n (%)	8386 (76.4)	5535 (76.4)	2851 (76.4)
Vision and hearing loss assessment, mean (SD)^c			
Vision loss	1.3 (0.6)	1.3 (0.6)	1.3 (0.6)
Hearing loss	1.3 (0.5)	1.3 (0.5)	1.3 (0.5)
Mental status quotient, mean (SD)^d	1.5 (2.6)	1.6 (2.7)	1.5 (2.6)
Behavior pattern, mean (SD)^e			
Requires supervision	0.7 (1.1)	0.7 (1.1)	0.7 (1.1)
Mood, mean (SD)^f			
Feeling depressed	0.2 (0.4)	0.2 (0.4)	0.2 (0.4)
Loss of interest	0.0 (0.2)	0.0 (0.2)	0.0 (0.2)
Suicidal talk	0.0 (0.1)	0.0 (0.1)	0.0 (0.1)
Depression score^g			
Mean (SD)	0.3 (0.6)	0.3 (0.6)	0.3 (0.5)
Median (range)	0.0 (0.0-5.0)	0.0 (0.0-5.0)	0.0 (0.0-4.0)
Social network of individuals in support system			
Support network score^h			
Mean (SD)	2.4 (1.3)	2.4 (1.3)	2.4 (1.3)
Median (range)	2.0 (0.0-13.0)	2.0 (0.0-12.0)	2.0 (0.0-13.0)
Support intensity scoreⁱ			
Mean (SD)	1.5 (0.7)	1.5 (0.7)	1.5 (0.7)
Median (range)	1.0 (0.0-4.0)	1.0 (0.0-4.0)	1.0 (0.0-4.0)
Spouse's health, mean (SD) ^j	3.6 (0.9)	3.6 (0.9)	3.6 (0.9)

(Continued)

Table 1. Characteristics of the Study Population (*continued*)

Characteristic	All Participants (N = 10,975)	Derivation Sample (n = 7244)	Validation Sample (n = 3731)
Main supporter health, mean (SD) ^k	1.6 (1.0)	1.6 (1.0)	1.5 (1.0)
How often do you see supporters? ^l	2.8 (0.5)	2.8 (0.5)	2.8 (0.5)
Housing and living arrangement, n (%)			
Owns house or condominium	1626 (14.8)	1051 (14.5)	575 (15.4)
Lives alone	6116 (55.7)	4006 (55.3)	2110 (56.6)
Lives with spouse and/or children	4098 (37.3)	2749 (37.9)	1349 (36.2)
Lives with relatives, not including children	420 (3.8)	275 (3.8)	145 (3.9)
Lives with others, nonrelatives	341 (3.1)	214 (3.0)	127 (3.4)
Eligibility for financial assistance, n (%)			
Food stamps	3507 (32.0)	2295 (31.7)	1212 (32.5)
Medicaid	7458 (68.0)	4922 (67.9)	2536 (68.0)
Supplemental Security Income	1649 (15.0)	1096 (15.1%)	553 (14.8%)
Category of service, n (%)			
State funded, 1-2 critical needs ^m	2039 (18.6)	1327 (18.3)	712 (19.1)
State funded (≥3 critical needs) ⁿ	2831 (25.8)	1864 (25.7)	967 (25.9)
Medicaid funded (≥3 critical needs) ^o	6105 (55.6)	4053 (55.9)	2052 (55.0)
Medications			
Daily medication dose count			
Mean (SD)	10.6 (6.5)	10.6 (6.5)	10.6 (6.4)
Median (range)	10.0 (0.0-50.0)	10.0 (0.0-50.0)	10.0 (0.0-50.0)
Insulin, n (%)	1238 (11.3)	810 (11.2)	428 (11.5)
Warfarin, n (%)	1322 (12.0)	877 (12.1)	445 (11.9)

ADL indicates activity of daily living; IADL, instrumental activity of daily living; IQR, interquartile range.

^aSum of assistance with activities on an ordinal scale (ie, 0, 1, or 2).

^bA score of 1 indicates good, 2 fair, 3 poor.

^cA score of 1 indicates normal/minimal loss, 2 moderate loss, 3 severe loss, 4 total loss.

^dMeasured as a cognition exam error count from 0 to 10 (with missing data coded as 11).

^eA score of 0 indicates never, 1 sometimes, 2 frequently, 3 daily.

^fA score of 0 indicates no problem, 1 sometimes/moderate, 2 daily/serious.

^gSum of feeling depressed, loss of interest, suicidal talk.

^hSum of children, spouses, other relatives, neighbors, landlords, and others listed as supporters.

ⁱNumber of different support types in the network.

^jScore of 1 indicates good, 2 fair, 3 poor, 4 no spouse.

^kScore of 1 indicates good, 2 fair, 3 poor, 4 no supporter.

^lScore of 0 indicates no supporter, 1 rarely, 2 sometimes, 3 regularly.

^mCap of \$1398 per month.

ⁿCap of \$2796 per month.

^oCap of \$5592 per month.

The prediction models were well calibrated for predicting nursing home placement. In the 1-year model, the E_{avg} was 0.01 for the derivation sample and 0.57 for the validation sample, indicating overall consistency between observed and predicted outcome rates. The predicted probability distributions were highly consistent, and the percentages of predicted and observed nursing home placement were similar within deciles (**Figure**). **Table 4** summarizes the performance of the model for predicting 1-year nursing home placement after assessment. Using the 10% threshold for predicted probabilities in the validation sample, 29% of the participants who actu-

ally had nursing home placement to have nursing home placement. The sensitivity of the model improved as the threshold became less stringent, reaching 83% at the 50% threshold. On the other hand, using the 10% threshold, 92% of the participants who actually had no nursing home placement were predicted to have no nursing home placement. The specificity of the model declined as the threshold became less stringent. The C statistic was 0.79 in the the derivation cohort and 0.76 in the validation cohort. In the 6-month models, the calibration and performance measures improved slightly (**eAppendices D and E**). In the sensitivity analysis using Cox regression mod-

els, the discrimination, calibration, and model predictor variables were similar (eAppendices F-I).

DISCUSSION

We used clinical and administrative data for 10,975 participants in an HCBS program to derive and validate models to predict risks for nursing home placement within 6 months and 1 year after an annual assessment. The models were well calibrated and had good discriminatory power. After adjustment for multiple participant-level predictors, the personal care assistance service was associated with lower risk of nursing home placement, and higher monthly medical service cost was associated with higher risk.

To our knowledge, ours is the first study to develop a practical, implementable, and validated nursing home prediction model using data from participants in an HCBS program. Several studies have examined predictors of nursing home placement, but only 1 published discrimination measurements for a validated prediction model for use in identifying the highest-risk patients with dementia.³⁴ That study's model for 3-year nursing home placement had a C statistic of 0.63 in the validation cohort, a low discriminatory power likely attributable to the fact that all study participants had dementia, which itself is a significant risk factor for nursing home placement. Furthermore, the generalizability of the model was limited to patients with dementia. Our population of community-dwelling older participants in an HCBS program is heterogeneous, including participants with a variety of functional dependencies and those with and without cognitive impairment. Therefore, our results are likely to have broader generalizability.

Consistent with studies of nursing home predictors in the general population, we found that higher risk was associated with greater age, Alzheimer's disease, being white, living alone, previous skilled nursing facility stays, and receiving a nursing home-level of care.^{13,15} Even after

adjustment for race/ethnicity, we also found that participants whose primary spoken language was English had twice the risk of nursing home placement. It is possible that language serves as a proxy for cultural and/or socioeconomic factors that influence use of nursing homes.

Although other studies have found associations between nursing home risk and multiple ADL dependencies, we identified dependence on money management as an independent predictor. Difficulty with money management is likely a marker of worse cognitive function, and a community-based money management program may be effective in preventing nursing home placement.³⁵ Such assistance may prevent loss of home or other assets, eviction, and financial abuse—events that often precipitate nursing home placement. Further research is needed to understand the effectiveness of money management interventions.

Use of a personal care assistance service was associated with 46% lower odds of nursing home placement.

Table 2. Services Ordered^a and Monthly Costs at Assessment or up to 12 Months Prior

Services and Costs	
Service, n (%)	
Adult care/companion/supervision	6776 (61.7)
Chores ^b	683 (6.2)
Counseling	454 (4.1)
Emergency response system	7906 (72.0)
Financial management	4900 (44.6)
Informal/in-kind service	9642 (87.9)
Respite care	51 (0.5)
Home-delivered meals	5554 (50.6)
Home health aide	5466 (49.8)
Home modification/safety	26 (0.2)
Housekeeping/shopping	10405 (94.8)
Occupational/physical/speech therapy	2789 (25.4)
Personal care (excluding personal care assistant)	4534 (41.3)
Personal care assistant (pilot program)	160 (1.5)
Skilled nursing care/medication administration	8802 (80.2)
Socialization	2744 (25.0)
Transportation	323 (2.9)
Housekeeping/shopping hours per month, mean (SD)	36.2 (26.2)
Monthly cost in \$, mean (SD)	
Overall service cost	2295.6 (1364.3)
Medical service cost	713.5 (667.3)
Social service cost	1548.8 (1038.8)

^aThe service rates represent allocations for participants in the CHCPE care management program. It should be noted that the primary care managers develop a service plan to meet each participant's specific needs and are restricted to monthly caps per qualifying category of service (see Table 1).

^bHeavy indoor/outdoor chores.

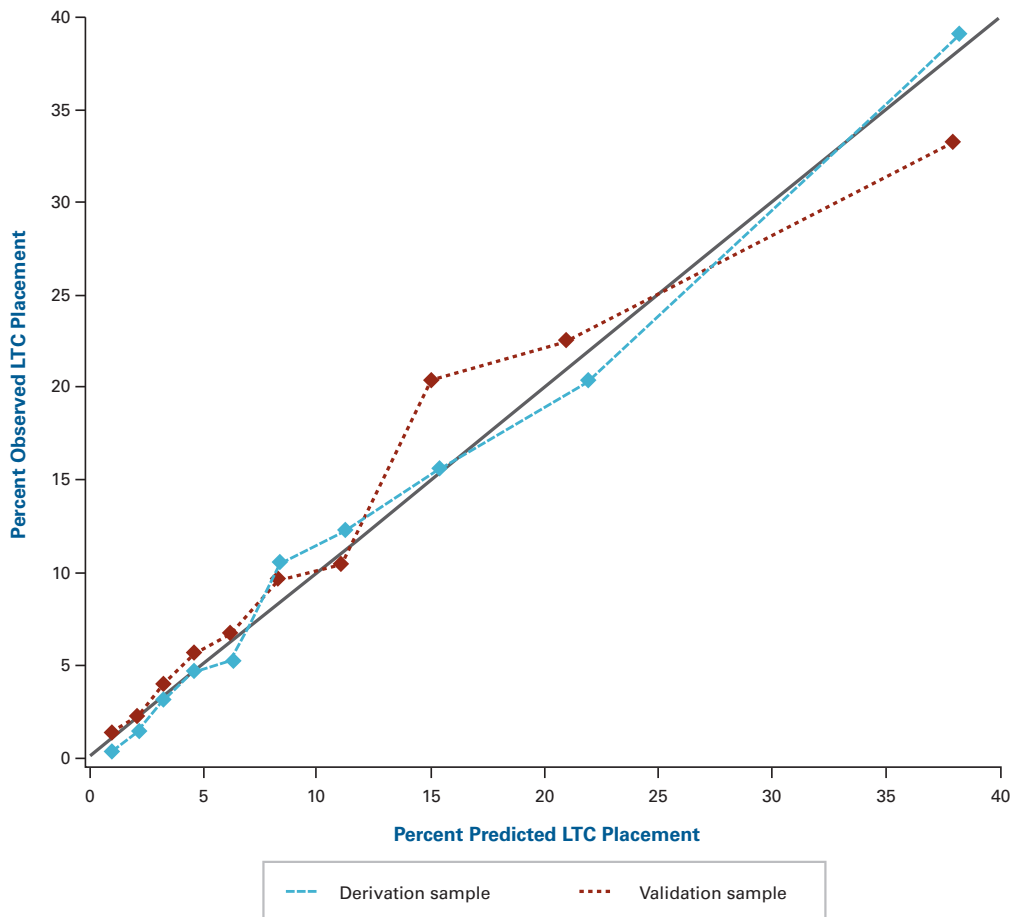
Table 3. Univariate and Multivariable Adjusted 1-Year Nursing Home Placement Refitted Model

Variable	Unadjusted Model		Adjusted Model ^a		
	OR (95% CI)	P	Adjusted Estimate	OR (95% CI)	P
Intercept	—	—	-5.6135	—	<.001
Age group	1.39 (1.34-1.45)	<.001	0.1704	1.19 (1.13-1.25)	<.001
Female	0.97 (0.85-1.11)	.66	-0.1982	0.82 (0.70-0.96)	.01
Race/ethnicity					
Black	0.56 (0.44-0.70)	<.001	-0.5367	0.58 (0.45-0.76)	<.001
Hispanic	0.30 (0.24-0.39)	<.001	-0.2352	0.79 (0.55-1.13)	.20
White	1.00 [Reference]			1.00 [Reference]	
Other	0.50 (0.30-0.85)	.01	-0.3075	0.74 (0.41-1.31)	.30
Married	0.94 (0.81-1.10)	.46	-0.02963	0.97 (0.80-1.18)	.77
English as primary language	2.71 (2.24-3.29)	<.001	0.7980	2.22 (1.66-2.97)	<.001
Medical history					
Alzheimer's disease	1.92 (1.80-2.06)	<.001	0.2604	1.30 (1.18-1.43)	<.001
Cancer	1.12 (0.98-1.29)	.11	0.08579	1.09 (0.93-1.27)	.27
Cerebrovascular accident	1.04 (0.91-1.20)	.55	-0.08338	0.92 (0.79-1.07)	.28
Decubitus ulcers	1.23 (0.92-1.66)	.16	-0.04075	0.96 (0.70-1.33)	.80
Diabetes mellitus	0.80 (0.73-0.86)	<.001	-0.05222	0.95 (0.85-1.06)	.33
Hearing assessment	1.49 (1.35-1.64)	<.001	0.02801	1.03 (0.92-1.16)	.64
Hip fracture	1.72 (1.32-2.24)	<.001	0.2800	1.32 (0.99-1.77)	.06
Hypertension	0.88 (0.81-0.97)	.009	0.01568	1.02 (0.92-1.13)	.76
Mental illness	0.87 (0.77-0.99)	.04	-0.03212	0.97 (0.84-1.12)	.67
Vision assessment	1.12 (1.02-1.23)	.02	-0.02626	0.97 (0.88-1.08)	.63
Activities of daily living					
Laundry	1.89 (1.70-2.10)	<.001	0.04242	1.04 (0.92-1.19)	.52
Money management	2.30 (2.11-2.52)	<.001	0.2887	1.33 (1.18-1.51)	<.001
Toileting	2.01 (1.82-2.22)	<.001	0.2004	1.22 (1.01-1.48)	.04
Summary score of additional measures	1.09 (1.08-1.10)	<.001	0.1597	1.17 (1.11-1.24)	<.001
Square of summary score of additional measures	1.00 (1.00-1.00)	<.001	-0.00456	1.00 (0.99-1.00)	<.001
Health, cognition, behavior, mood					
Perception of health	1.18 (1.07-1.30)	.001	0.1581	1.17 (1.05-1.31)	.006
Meets nursing home level of care	3.34 (2.75-4.07)	<.001	0.2607	1.30 (1.04-1.63)	.02
Mental status quotient	1.16 (1.14-1.19)	<.001	0.2052	1.23 (1.14-1.32)	<.001
Square of mental status quotient	1.01 (1.01-1.01)	<.001	-0.01467	0.99 (0.98-0.99)	<.001
Requires supervision	1.46 (1.39-1.53)	<.001	0.09670	1.10 (1.04-1.17)	.001
Depression score	1.06 (0.96-1.18)	.25	0.06197	1.06 (0.95-1.20)	.30
Living arrangements/support					
Lives alone	0.78 (0.69-0.88)	<.001	0.4282	1.53 (1.31-1.80)	<.001
Support intensity score	1.07 (0.98-1.17)	.13	0.01763	1.02 (0.92-1.13)	.74
How often do you see supporters?	1.00 (0.89-1.12)	.99	-0.2214	0.80 (0.71-0.90)	<.001
Owns house or condominium	1.27 (1.09-1.49)	.003	-0.1289	0.88 (0.74-1.05)	.15
Financial factors					
Medicaid	0.84 (0.74-0.95)	.006	0.09520	1.10 (0.95-1.27)	.19
Supplemental Security Income	0.32 (0.25-0.41)	<.001	-0.3922	0.68 (0.51-0.89)	.006
Facility history ≤12 months before assessment					
Prior or current hospital admission	1.67 (1.48-1.89)	<.001	0.07575	1.08 (0.92-1.27)	.36
Prior or current short-term skilled nursing facility stay	1.83 (1.69-1.98)	<.001	0.3761	1.46 (1.31-1.62)	<.001
Medications					
Daily medication dose count	0.99 (0.99-1.00)	.28	-0.00171	1.00 (0.99-1.01)	.76
Insulin	0.80 (0.66-0.98)	.03	0.1003	1.11 (0.86-1.42)	.43
Warfarin	1.10 (0.92-1.31)	.31	-0.02998	0.97 (0.80-1.17)	.76
Services ≤12 months before assessment					
Mean monthly medical cost per \$100	1.03 (1.03-1.04)	<.001	0.04133	1.04 (1.01-1.08)	.01
Square of mean monthly medical cost per \$100	1.00 (1.00-1.00)	<.001	-0.00163	1.00 (1.00-1.00)	.02
Personal care assistant (pilot)	1.09 (0.68-1.74)	.73	-0.6165	0.54 (0.33-0.89)	.02
Time from initial assessment per day	1.00 (1.00-1.00)	.07	0.000256	1.00 (1.00-1.00)	.02

OR indicates odds ratio.

^aThe multivariable model included all variables listed.

■ **Figure.** Predicted Versus Observed Nursing Home Placement Within 1 Year



LTC indicates long-term care.

Based on the success of the pilot and recommendations from a study investigating reasons for CHCPE nursing home placements,³⁶ CMS approved personal care assistance as a waiver service and extended it to new enrollees starting in 2011. In contrast to the traditional agency-directed HCBS program model, recent studies have shown that clients reported greater satisfaction, greater sense of security, and fewer unmet IADLs in a consumer-directed program.^{37,38} In a study of the Indiana Medicaid Aged and Disabled Waiver program, use of a similar personal care assistance service lowered the risk of nursing home placement by 5% per each 5-hour increment per month.³⁹ We also found that higher medical service cost, which may be a proxy for intensity of services, was generally associated with greater risk of nursing home placement. In a study of disabled older adults, greater use of formal services was associated with higher risk of nursing home use, except in a subset of patients with cognitive impairment.⁴⁰

The CMS Office of the Actuary estimated that, as a result of the PPACA expansion, 26 million Medicaid enrollees will be added in 2020.⁴¹ With expanding Medicaid rolls, shrinking revenues, and PPACA incentives, states are expected to continue to shift long-term care costs away from institutional care and toward HCBS programs.^{42,43} Many have argued that HCBS waiver programs increase overall Medicaid spending because of the so-called woodwork effect, whereby new applicants are attracted to Medicaid, and because of cost-shifting from higher inpatient and emergency department use by HCBS participants.^{37,44,45} CMS requires only that HCBS waiver programs demonstrate cost neutrality compared with institutional care. This flexibility has led to much variation in states' program implementation and cost-containment strategies.⁴³ Kaye and colleagues⁴⁶ observed cost savings in states with expanded HCBS programs, although it generally took several years to reduce the number of Medicaid-funded nursing home residents and recoup program start-up costs.

Table 4. Discrimination and Clinical Usefulness Measures of the 1-Year Nursing Home Placement Derivation Prediction Model

Measure	Long-Term Care Placement Prediction Threshold			
	Upper 10%	Upper 15%	Upper 25%	Upper 50%
Derivation Sample				
Number of subjects	724	1086	1811	3622
Observed, %	39.1	32.8	26.9	19.5
Sensitivity, %	34.7	43.6	59.8	86.8
False-negative rate, %	65.3	56.4	40.2	13.2
Specificity, %	93.1	88.6	79.4	54.7
False-positive rate, %	6.9	11.4	20.6	45.3
Positive predictive value, %	39.1	32.8	26.9	19.5
Area under the curve	0.789			
Validation Sample				
Number of subjects	373	559	933	1866
Observed, %	33.2	29.9	26.4	19.2
Sensitivity, %	28.6	38.6	56.8	82.9
False-negative rate, %	71.4	61.4	43.2	17.1
Specificity, %	92.4	88.1	79.2	54.3
False-positive rate, %	7.6	11.9	20.8	45.7
Positive predictive value, %	33.2	29.9	26.4	19.2
Area under the curve	0.760			

There is growing consensus that targeting patients with the highest risk of nursing home placement through stringent preadmission screening is paramount for cost containment.^{6,36,45} As an alternative to traditional targeting, Weissert and colleagues⁴⁷ have argued for titration of care where resources are allocated based on risk measurement, attributable effectiveness of HCBS, and the monetary value of avoiding nursing home placement. Our model could be used as a risk-measurement tool to identify the highest-risk participants and develop targeted care management strategies to improve the effectiveness of HCBS programs. For example, some evidence points to the need for more intensive case management or multidisciplinary team models for high-maintenance participants, particularly those with behavioral issues related to dementia, depression, or mental illness.^{48,49} Annual assessment could be an ideal time for case managers to develop tailored interventions, including management of psychological and behavioral problems, to successfully maintain high-risk participants in the community. Furthermore, for participants who are severely frail or disabled, who incur higher levels of medical service and care than other participants, HCBS programs may be inadequate—nursing homes may be better suited to meeting their care needs.⁵⁰

Limitations

First, data on age were limited to 5-year categories and collected during the initial assessment. Although our models may not have fully adjusted for risk associated with greater age, we included multiple factors representing functional age. Second, we were unable to account for patient preferences and the availability of nursing home beds, which may be associated with nursing home placement. Third, although we adjusted for participant risk factors, the observed protective effect of the personal care assistant service may have been related to unmeasured differences between pilot and nonpilot participants.³⁸ Fourth, assessment of comorbidity severity was limited due to the nature of the data. Nonetheless, we obtained complementary data on medical costs and medications that likely offset this limitation. Finally, the analysis was restricted to CHCPE participants, so the results may not be generalizable to older adults in other regions or those who were not enrolled in a similar HCBS programs.

CONCLUSIONS

A model using information from an HCBS program had strong discrimination to predict the risk of long-term nursing home placement and can be implemented to iden-

tify high-risk participants for targeted interventions and tailored services. A consumer-driven personal care assistance service seemed to be effective in preventing nursing home placement. Future studies should explore the costs and effectiveness of targeting high-risk participants and tailoring services to prevent nursing home placement.

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eAppendix A. Service Category Descriptions

Service Type	Provider Category	Service	Service Description	Service Category Model
Social		Adult day care (medical model)	Adult day care is defined as a program of services provided in a congregate setting for a set number of hours per week. Elements are directed toward meeting supervision, health maintenance, socialization, and restoration needs. Includes transportation and meals. Additional services include the medical model are bathing, medication administration, and consultation in physical, occupational, and speech therapies.	Adult care/companion/supervision
Social	Formal	Adult day care (medical model)		Adult care/companion/supervision
Social	Formal	Assistive technology	Assistive technology is any item, piece of equipment, or product system that is used to increase, maintain, or improve functional capabilities (eg, lift chair, ceiling track lift systems, medication reminder devices).	Assistive technology
Social	Formal	Case management		Not applicable (everyone in program receives this service)
Social	Formal	Chore (highly skilled)	When an individual requires one-time only unique or specialized services to maintain a healthy and safe environment, the program shall pay for highly skilled chore services which include but are not limited to extraordinarily heavy cleaning where the work required is beyond the heavy cleaning normally performed by chore services; electrical repairs or installation; plumbing repairs; minor home repairs; and extermination.	Chores
Social	Formal	Chore (regular)	Chore services include the performance of heavy indoor or outdoor work or household tasks for individuals who are unable to do these tasks for themselves. Service includes installation/removal of air conditioning unit, heavy cleaning (refrigerator, stove, walls, shelving, carpet, etc), and yard work.	Chores
Social	Formal	Chronic disease self-management program	Chronic disease self-management programs are designed to help people gain self-confidence in their ability to control their symptoms and learn how their health problems affect their lives. Small-group workshops are given in community settings and are facilitated by 2 volunteer leaders/moderators.	Not applicable (will not show up in program files)

Service Type	Provider Category	Service	Service Description	Service Category Model
Social	Formal	Companion	Home-based supervision and monitoring activities. Hands-on personal care such as bathing, dressing, toileting, or assisting with ambulation is not permitted. This service includes, but is not limited to, escorting a client to recreational activities or to necessary medical/dental/business appointments, reminding a client to take self-administered medications, calls and written communications, supervising or monitoring a client during the self-performance of activities of daily living, such as meal preparation and consumption, dressing, personal hygiene, laundry and simple household chores, and reporting changes in a client's needs or condition.	Adult care/companion/supervision
Social	Formal	Companion (live-in)		Adult care/companion/supervision
Social	Formal	Companion (respite)		Respite care
Social	Formal	Congregate meal	The congregate meal program provides a place for older adults to gather for games (bingo, dominoes, cards, bridge, puzzles), physical activity (tai chi, qigong), conversation and a shared nutritious lunchtime meal. Congregate meal sites are free for anyone 60 years or older.	Home-delivered meals
Social	Formal	Counseling (home)	Mental health counseling services are professional counseling services provided to help resolve or enable the individual to cope with individual, family, and/or environmentally related problems or conditions.	Counseling
Social	Formal	Emergency response system (installation)	One-time only fee	Emergency response system
Social	Formal	Emergency response system (1-way)	The personal emergency response system is an in-home, 2-way, 24-hour electronic alarm system activated by a signal to a central switchboard. This system enables a high-risk individual to secure immediate help in the event of a medical, physical, emotional, or environmental emergency.	Emergency response system
Social	Formal	Emergency response system (2-way)		Emergency response system
Social	Formal	Emergency response system (wireless)		Emergency response system

Service Type	Provider Category	Service	Service Description	Service Category Model
Social	Formal	emergency response system with telephone enhancements		Emergency response system
Social	Formal	emergency response system (additional amulet, 1-way)	An additional amulet is provided when more than 1 person in the household is on the program.	Emergency response system
Social	Formal	emergency response system (additional amulet, 1-way, installation)		Emergency response system
Social	Formal	emergency response system (additional amulet, 2-way)		Emergency response system
Social	Formal	Emergency response system (additional amulet, 2-way, installation)		Emergency response system
Social	Formal	emergency response system with medication dispenser		Emergency response system
Social	Formal	Emergency response system with reminders		Emergency response system
Social	Formal	Emergency response system with reminders and fall detection		Emergency response system
Medical	Formal	Intermediate care facility (respite)	An individual requiring respite care for up to 30 days to provide relief for caregivers. Cost may not exceed an annualized care plan cost.	Respite care
Medical	Formal	skilled nursing facility (respite)		Respite care
Social	Informal	Financial management		Financial management and informal/in-kind service
Social	Formal	Financial management service	This service includes money management functions (check writing and balancing, bank deposit, bill paying, budgeting) by bonded personnel only (does not include financial planning or investing).	Financial management
Social	Formal	Friendly visit	Provides socialization, does not perform tasks.	Socialization
Social	Formal	Home-delivered meals	Home-delivered meals include the preparation and delivery of 1 (single) or 2 (double) meals for persons who are unable to prepare or obtain nourishing meals independently.	Home delivered meals
Social	Formal	Home-delivered meals (frozen)		Home-delivered meals
Social	Formal	Home-delivered meals (hot)		Home-delivered meals
Social	Formal	Home-delivered meals (kosher)		Home-delivered meals

Service Type	Provider Category	Service	Service Description	Service Category Model
Medical	Formal	Home health aide with supervision	Home health aide services provide assistance with personal care such as bathing and dressing, an established activity regimen such as range of motion exercises, nutritional needs such as feeding assistance, and simple maintenance of the person's environment. The rate includes a monthly supervisory visit made by a skilled nurse.	Home health aide
Medical	Formal	Home health aide (bath aide)		Home health aide
Social	Formal	Home health aide (respite)		Respite care
Social	Formal	Homemaker	Homemaker services are general household activities (limited to the client's living area). These services are provided on a part-time and intermittent basis. Hands-on personal care such as bathing, dressing, toileting, or assisting with ambulation is not permitted (eg, light housekeeping, laundry, changing linens, dishwashing, correspondence, meal planning and preparation, mending, shopping, communication of health or other problems)	Housekeeping/shopping
Social	Formal	Homemaker (respite)		Respite care
Social	Informal	Household care	Performed by an informal supporter and includes homemaker and laundry activities.	Housekeeping/shopping and informal/in-kind service
Medical	Formal	Medication administration (non-oral/injection, M/LPN)	An in-home nursing visit, provided by either an M or LPN for the administration of oral, intramuscular, and/or subcutaneous medication and also those procedures used to assess the client's medical/behavioral health status. Such procedures include glucometer readings, pulse rate checks, blood pressure checks, and/or brief mental health assessments, etc. Includes the administration of medication(s) while the nurse is present, the pre-pouring of additional doses (less than a 1-week supply) that the client will self-administer at a later time, and the teaching of self-administration of the medication that has been pre-poured.	Skilled nursing care/medication administration
Medical	Formal	Medication administration (non-oral/injection, M/LPN, subsequent client)	Subsequent client is a client in the same complex being seen within the same time frame and is a lower cost.	Skilled nursing care/medication administration

Service Type	Provider Category	Service	Service Description	Service Category Model
Medical	Formal	Medication administration (oral/injection, M/LPN)		Skilled nursing care/medication administration
Medical	Formal	Medication administration (oral/injection, M/LPN, subsequent client)		Skilled nursing care/medication administration
Social	Formal	Minor home modification	Minor home modifications provide physical adaptations to the home environment (such as a ramp), required by the client's plan of care. These modifications are necessary to ensure health and safety for the individual or which enable the individual to function with greater independence in the home, and without them, the client would require institutionalization.	Home modification/safety
Medical	Formal	Occupational therapy visit	Occupational therapy services provide an evaluation of functional disability and establishing and implementing a treatment regimen to restore functional ability.	Occupational/physical/speech therapy
Social	Informal	Personal care	Performed by an informal supporter and indicates hands on care.	Personal care and informal/in-kind service
Social	Formal	Personal care assistant	A personal care assistant is a person who assists a client with tasks that the individual would typically do for him/herself in the absence of a disability. Services may include physical or verbal assistance to the client with accomplishing any ADL or IADL. The client has "employer authority" and is responsible for hiring, training, terminating, and directing the activities of the personal care assistant. If a client does not need hands-on care, he/she is not eligible to receive these services.	Personal care assistant
Social	Formal	Personal care assistant (live-in)	Defines hours	Personal care assistant
Social	Formal	Personal care assistant (overnight)	Defines hours	Personal care assistant
Medical	Formal	Physical therapy visit	Physical therapy services provide an evaluation of movement dysfunction and establishing and/or implementing a treatment regimen to reassure physical ability. A physical therapist can also provide a safety-check of the client's home environment.	Occupational/physical/speech therapy
Social	Formal	Respite (in-home)		Respite care
Social	Formal	Respite (out of home)	An individual requiring respite care for up to 30 days to provide relief for caregivers. Cost may not exceed an annualized care plan cost.	Respite care

Service Type	Provider Category	Service	Service Description	Service Category Model
Social	Informal	Safety check	Informal supporter checks client at predetermined frequencies for 15 minutes per visit.	Adult care/companion/supervision and informal/in-kind services
Social	Informal	Shopping	Informal supporter shops for client.	Housekeeping/shopping and informal/in-kind services
Medical	Formal	Skilled nursing M visit (hour)	An in-home nurse visit, provided by either an M or LPN providing skilled and supportive care, health teaching, diagnosing responses to actual or potential health problems and the pre-pouring of medication(s) that the client will self-administer at a later time.	Skilled nursing care/medication administration
Medical	Formal	Skilled nursing M evaluation		Skilled nursing care/medication administration
Medical	Formal	Skilled nursing M extended shift (3-24 h) sub. client		Skilled nursing care/medication administration
Medical	Formal	Skilled nursing M extended shift (3-24 h)		Skilled nursing care/medication administration
Medical	Formal	Skilled nursing M visit (hour) sub. client		Skilled nursing care/medication administration
Medical	Formal	Skilled nursing LPN visit (hour)		Skilled nursing care/medication administration/medication administration
Medical	Formal	Skilled nursing LPN extended shift (3-24 h) sub. client		Skilled nursing care/medication administration
Medical	Formal	Skilled nursing LPN extended shift (3-24 h)		Skilled nursing care/medication administration
Medical	Formal	Skilled nursing LPN visit (hour) sub. client		Skilled nursing care/medication administration
Medical	Formal	Skilled nursing oasis visit (hour)		Skilled nursing care/medication administration
Social	Informal	Socialization	Provides socialization.	Socialization and informal/in-kind service
Medical	Formal	Speech therapy visit	Speech therapy services provide an evaluation of communication and swallowing disorders and establishing and implementing a treatment regime to reassure communication ability.	Occupational/physical/speech therapy
Social	Informal	Supervision (24 h)	Supervision provided by informal supporters.	Adult care/companion/supervision and informal/in-kind services

Service Type	Provider Category	Service	Service Description	Service Category Model
Social	Informal	Supervision (daytime)		Adult care/companion/supervision and informal/in-kind services
Social	Informal	Supervision (nighttime)		Adult care/companion/supervision and informal/in-kind services
Social	Informal	Transportation	Provided by informal supporters.	Transportation and informal/in-kind services
Social	Formal	Transportation (medical)		Transportation
Social	Formal	Transportation (social invalid coach)	Type of social transportation is dependent on client need.	Transportation
Social	Formal	Transportation (social livery)		Transportation
Social	Formal	Transportation (social taxi)		Transportation

ADL indicates activity of daily living; IADL, instrumental activity of daily living; LPN, licensed practical nurse.

eAppendix B. Supplemental Methods

Data Sources

We used clinical and administrative data from the Connecticut Home Care Program for Elders (CHCPE) provided by Connecticut Community Care, Inc (CCCI). CHCPE is a publicly funded care management program that provides preventive home care services to older Connecticut residents who are at risk for permanent nursing home placement. The program includes 1915(c) Home and Community-Based Medicaid waiver clients and state-funded clients. CCCI provided deidentified program files for 100% of clients from 2005 through 2011. Data included baseline eligibility evaluations and annual assessments for active participants conducted by CCCI primary care managers, which contain demographics, medical history, functional ability, social support, and financial assistance data elements in the “Modified Community Assessment Tool” published by the Connecticut Department of Social Services.²² Additional data included information on program status, funded and unpaid program services, hospital visits, short-term skilled nursing facility stays (Medicare funded, ≤ 90 days), and medications. Data reflects what is collected by the primary care manager during at-home visits and follow-up calls, including self-reporting from the client, family and home health nurse, as well as checking of medical records when they are available from physician, hospital, or nursing facility.

Study Population

The Connecticut Department of Social Services receives community referrals for at-risk residents, then refers qualified applicants to CCCI for further evaluation. Program service eligibility level is based on the number of critical needs, income, and total assets. The state

defines critical needs as functional dependencies in specific activities of daily living (ADLs) and instrumental activities of daily living (IADLs) (eg, bathing, toileting, medication administration) and/or cognitive impairment requiring supervision.²³ Clients may qualify under 3 service level categories: Level 1, state-funded for clients with 1-2 critical needs; Level 2, state-funded for clients with 3 or more critical needs; and Level 3, Medicaid waiver-funded for clients with 3 or more critical needs. After completion of the approval process for eligible residents, the primary care manager activates an initial service plan and follows up with annual assessments. Eligible Medicare and Medicaid beneficiaries may have also received additional physician and institutional services which are not reflected in these home-based care plans.

We included CHCPE participants 65 years and older who completed an annual assessment between January 1, 2005, and December 31, 2010. If a participant had multiple assessments, we used the earliest assessment for analysis. We chose to analyze this population separately from the broader group of initially evaluated residents because we hypothesized that their characteristics and risk factors would be different, and we were also interested in examining the effectiveness of services in preventing nursing home placement. We excluded participants younger than 65 years who qualified for program services on the basis of a degenerative neurologic diagnosis (n = 58).

Potential Predictors of Long-Term Nursing Home Placement

Potential predictors included demographics, clinical characteristics, social support, living arrangements, financial assistance and program-level variables. Demographic information included age, sex, race, marital status, and primary spoken language. With the exception of age, all characteristics were measured at the time of the assessment. To ensure that the data were

deidentified, we only captured age category at the time of the initial program assessment in 5-year increments (65-69, 70-74, 75-79, 80-84, 85-89, and ≥ 90 years). We categorized participants' race/ethnicity as black, Hispanic, white, or other. Clinical information included medical diagnoses, ADLs, IADLs, mental status quotient, behavioral and psychological issues, vision and hearing assessments, and medications. Medical diagnoses were coded as 0 (none), 1 (secondary diagnosis), or 2 (major diagnosis related to need for services). ADL and IADL measures were coded as 0 (independent), 1 (requires assistance), or 2 (total dependence). The mental status quotient was a cognition exam error count from 0 to 10. A dichotomous variable for "meets nursing home level of care" was based on 3 or more critical care needs as defined by the Connecticut Department of Social Services.²³ We calculated a depression score as the sum of the following mood variables: loss of interest, feeling depressed, and suicidal talk (each coded 0 for none, 1 for moderate, or 2 for serious or daily). We used National Drug Codes to identify insulin use and warfarin use and calculated total daily dose count of all medications. The data set also included information on participant's social support, living arrangements, and financial assistance. We calculated a support intensity score as the sum of distinct sources of support, including children, spouses, relatives, neighbors, landlords, and others.

Program-level variables included healthcare utilization, program services, and the patient's primary care manager and team. We assessed hospital admissions, emergency department visits, and short-term skilled nursing facility stays during the year prior to the assessment. We grouped services into categories (**Appendix A**), identified the services in place at the time of and in the 12 months before the assessment, and calculated mean monthly total costs, medical costs, and social service costs. The personal care assistant service pilot offered during the period of our study gave participants authority to hire a single person, including

family members, to perform services that might otherwise be provided by multiple persons. Care managers identified potential candidates for the pilot who needed hands-on assistance with bathing, dressing, eating, transferring or toileting and were capable of self-directing services. Variables for the assessment year, time since the initial assessment and the time since program activation were used to account for variation in subjects' program participation time.

Most variables had low rates of missingness (<2%). We imputed missing values as follows: "no" for dichotomous variables; the most frequent level or category for multichotomous variables; and median values for continuous variables.²⁴ Since missing values for the mental status quotient (3%) were likely attributable to pronounced cognitive or communication impairments, we imputed missing values to 11.

Outcomes

We followed participants for up to 1 year after the assessment. The primary outcome of interest was placement in a long-term nursing home. We calculated the days from assessment to nursing home placement based on a termination record in the program status file indicating that the client chose to enter a long-term nursing home or that a skilled nursing stay exceed 90 days. We flagged patients with nursing home placement within 180 days or 365 days of the assessment for analysis as binary outcomes. Time periods were selected based on practicality to allow sufficient time for a targeted service intervention to prevent nursing home placement.

Statistical Analysis

We present patient characteristics at the time of the annual assessment, using proportions for categorical variables and using means with SDs, medians with interquartile ranges, or

medians with ranges for continuous variables. We describe unadjusted observed nursing home placement as the frequency and Kaplan-Meier estimate of nursing home placement within 6 months and 1 year after the assessment.

Since the primary goal of this study was a prediction model that was useful in practice, we carefully preselected candidate variables on the basis of clinical judgment and previously published models,^{10,13,15,25,26} and we employed a rigorous model development process to minimize prediction error by identifying the most critical information while avoiding overfitting the model to idiosyncrasies in the current data.²⁷⁻³⁰ We calculated the maximum allowable number of variables in each model by requiring 10 events per examined variable. We explored variable interactions on the basis of clinical plausibility, including demographic factors, functional dependencies, depression, social network, Medicaid eligibility, and service costs. We employed factor analysis and the Spearman correlation matrix to narrow the list of potential candidates. We ran univariate and multivariable models to reduce highly correlated variables (eg, ADLs and IADLs). We included all remaining prespecified variables in the preliminary models, and we incrementally tested the value of additional variables using the Akaike information criterion, the C statistic, and Hosmer-Lemeshow tests. We examined quadratic variables when continuous variables failed the Box-Tidwell linearity test. Variables were coded to extract the most information for predictive power rather than for ease of interpretation (eg, ordinal vs dichotomous coding).

We used logistic regression models to estimate the unadjusted and multivariable relationships between study variables and 1-year and 6-month nursing home placement. Logistic regression was chosen to facilitate both internal and external model validation using well-established methods and practical implementation of the prediction model scoring mechanism in

our clients' electronic data systems. In all models, we incorporated random effects to account for variance in nursing home placement among primary care manager teams. As a sensitivity analysis, we used Cox proportional hazards models with robust standard errors to account for clustering of participants within primary care manager teams. For Kaplan-Meier and Cox survival analyses, we censored data for participants if they terminated the program and at the time of death.

Using simple random selection, we constructed a derivation sample consisting of 66% of the study cohort and a validation sample consisting of the remaining 34% of the study cohort. We initially developed the logistic regression models in the derivation sample, and then applied the results from these models to the validation sample. We evaluated the calibration and discrimination of all models in both samples and refit the models for the entire assessment study cohort.^{31,32} Using the derivation model estimates, we generated predicted probabilities of nursing home placement for participants in the derivation and validation samples. To assess the clinical usefulness of our prediction models, we considered patients who were in the top 10%, 15%, 25%, or 50% of the predicted probabilities to be those whom the model predicted would have nursing home placement.³³ At each threshold, we calculated the model's sensitivity (ie, the number of correctly predicted nursing home cases divided by the total number of actual nursing home cases), false-negative rate (ie, 1 minus sensitivity), specificity (ie, the number of correctly predicted non-nursing home cases divided by the total number of actual non-nursing home cases), false-positive rate (ie, 1 minus specificity), and positive predictive value (ie, the number of correctly predicted nursing home cases divided by the total number of predicted nursing home cases). We calculated the area under the curve (C statistic) to assess overall model discrimination. To assess model calibration in each sample, we plotted percent of predicted

nursing home placement vs percent of observed nursing home placement by decile of predicted probability and calculated E_{avg} (abs[percent observed nursing home placement–percent predicted nursing home placement]).³⁰

eAppendix C. Univariate and Multivariable Adjusted 6-Month Nursing Home Placement Refitted Model*

Variable	Unadjusted Model		Adjusted Model		
	OR (95% CI)	P Value	Adjusted Estimate	OR (95% CI)	P Value
Intercept			-6.7290	—	< .001
Age group	1.39 (1.32-1.46)	< .001	0.1728	1.19 (1.11-1.27)	< .001
Female	0.98 (0.82-1.17)	.85	-0.1505	0.86 (0.70-1.05)	.15
Race/ethnicity					
Black	0.60 (0.44-0.81)	< .001	-0.4458	0.64 (0.46-0.90)	.01
Hispanic	0.30 (0.22-0.42)	< .001	-0.1386	0.87 (0.53-1.42)	.58
White	1.00 [Reference]			1.00 [Reference]	
Other	0.52 (0.25-1.05)	.07	-0.3525	0.70 (0.32-1.54)	.38
Married	0.98 (0.80-1.19)	.82	0.002992	1.00 (0.77-1.30)	.98
English as primary language	2.79 (2.14-3.62)	< .001	0.8632	2.37 (1.60-3.51)	< .001
Medical history					
Alzheimer disease	1.93 (1.77-2.11)	< .001	0.2387	1.27 (1.12-1.44)	< .001
Cancer	1.22 (1.03-1.45)	.02	0.1295	1.14 (0.94-1.38)	.19
Cerebrovascular accident	1.03 (0.85-1.24)	.77	-0.1392	0.87 (0.71-1.06)	.18
Decubitus ulcers	1.28 (0.88-1.86)	.20	-0.07739	0.93 (0.61-1.40)	.72
Diabetes mellitus	0.81 (0.72-0.90)	< .001	-0.04129	0.96 (0.83-1.11)	.57
Hearing assessment	1.55 (1.36-1.76)	< .001	0.05996	1.06 (0.91-1.23)	.43
Hip fracture	1.94 (1.43-2.64)	< .001	0.2805	1.32 (0.94-1.87)	.11
Hypertension	0.88 (0.78-1.00)	.046	0.05548	1.06 (0.92-1.21)	.43
Mental illness	0.90 (0.76-1.07)	.22	-0.03120	0.97 (0.80-1.18)	.75
Vision assessment	1.11 (0.98-1.26)	.10	-0.07634	0.93 (0.80-1.07)	.29
Activities of daily living					
Laundry	2.29 (1.96-2.66)	< .001	0.09134	1.10 (0.91-1.32)	.33
Money management	2.46 (2.18-2.77)	< .001	0.2279	1.26 (1.06-1.49)	.008
Toileting	2.52 (2.24-2.82)	< .001	0.3269	1.39 (1.10-1.75)	.006
Summary score of additional measures	1.11 (1.10-1.12)	< .001	0.1843	1.20 (1.12-1.29)	< .001
Square of summary score of additional measures	1.00 (1.00-1.00)	< .001	-0.00479	1.00 (0.99-1.00)	< .001
Health, cognition, behavior, mood					
Perception of health	1.40 (1.23-1.59)	< .001	0.2092	1.23 (1.07-1.43)	.005
Meets nursing home level of care	4.03 (3.02-5.39)	< .001	0.2499	1.28 (0.93-1.78)	.13
Mental status quotient	1.18 (1.15-1.20)	< .001	0.1848	1.20 (1.10-1.32)	< .001
Square of mental status quotient	1.01 (1.01-1.02)	< .001	-0.01253	0.99 (0.98-1.00)	.004
Requires supervision	1.53 (1.44-1.62)	< .001	0.1259	1.13 (1.05-1.22)	.001
Depression score	1.23 (1.09-1.40)	.001	0.1743	1.19 (1.03-1.37)	.02
Living arrangements/support					
Lives alone	0.72 (0.62-0.84)	< .001	0.4596	1.58 (1.28-1.96)	< .001
Support intensity score	1.02 (0.91-1.15)	.68	-0.04766	0.95 (0.83-1.09)	.50
How often do you see supporters?	0.96 (0.83-1.10)	.55	-0.2746	0.76 (0.65-0.88)	< .001
Owns house or condominium	1.16 (0.94-1.43)	.16	-0.2193	0.80 (0.64-1.01)	.07
Financial factors					
Medicaid	0.97 (0.82-1.15)	.73	0.1950	1.22 (1.01-1.47)	.04
Supplemental Security Income	0.32 (0.23-0.45)	< .001	-0.3874	0.68 (0.47-0.99)	.04
Facility history \leq 12 months before assessment					
Prior or current hospital admission	2.22 (1.89-2.59)	< .001	0.1945	1.21 (0.98-1.50)	.07
Prior or current short-term skilled nursing facility stay	2.19 (2.00-2.41)	< .001	0.5264	1.69 (1.50-1.91)	< .001
Medications					

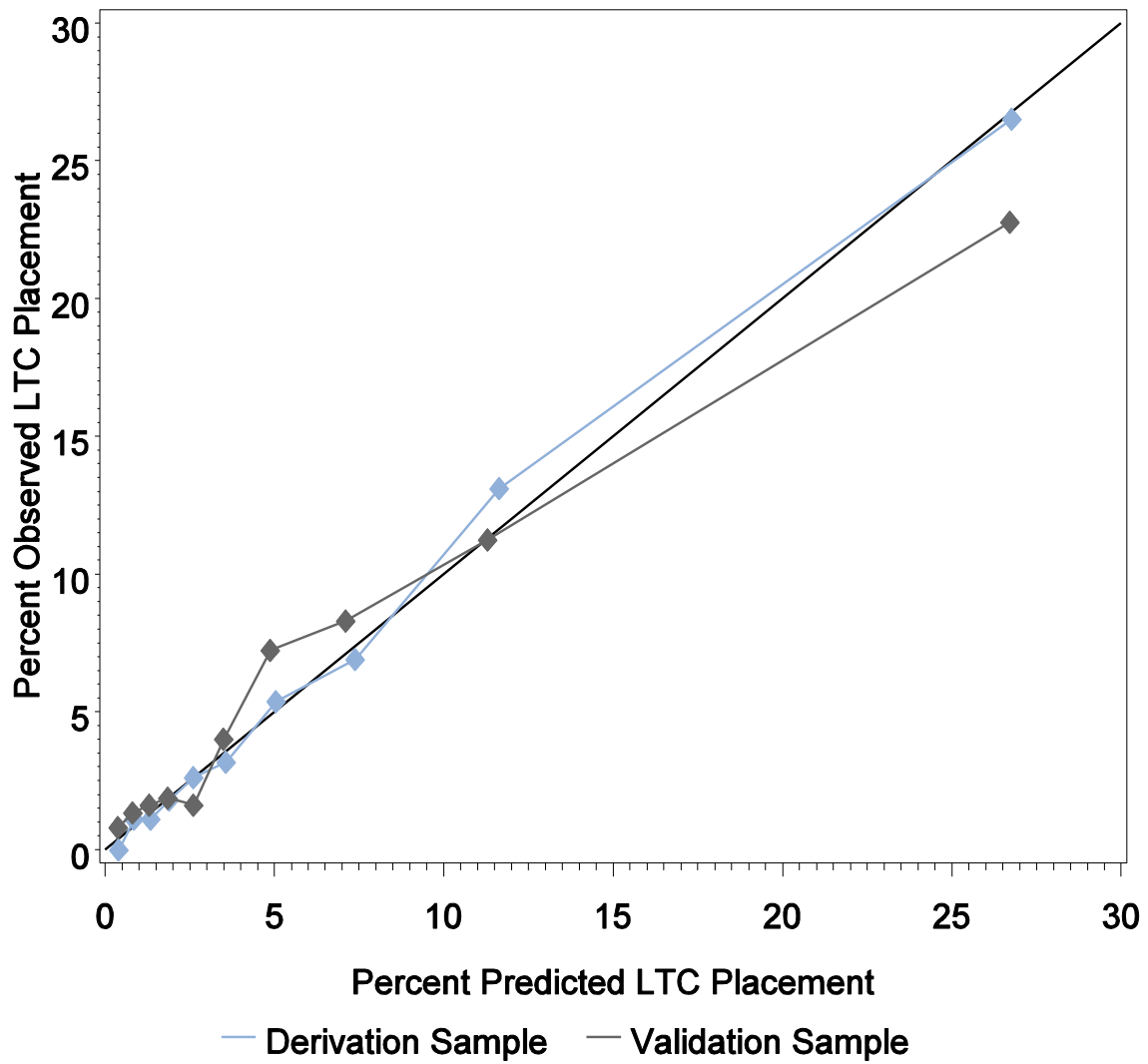
Variable	Unadjusted Model		Adjusted Model		
	OR (95% CI)	<i>P</i> Value	Adjusted Estimate	OR (95% CI)	<i>P</i> Value
Daily medication dose count	1.00 (0.99-1.01)	.89	-0.00487	1.00 (0.98-1.01)	.52
Insulin	0.86 (0.67-1.12)	.27	0.1413	1.15 (0.83-1.60)	.40
Warfarin	1.21 (0.96-1.51)	.10	0.07365	1.08 (0.84-1.38)	.56
Services ≤ 12 months before assessment		< .001			
Mean monthly medical cost per \$100	1.04 (1.02-1.05)	< .001	0.02595	1.03 (0.98-1.07)	.23
Square of mean monthly medical cost per \$100	1.00 (1.00-1.00)	< .001	-0.00160	1.00 (1.00-1.00)	.09
Personal care assistant (pilot)	1.34 (0.75-2.37)	.32	-0.5622	0.57 (0.31-1.04)	.07
Time from initial assessment per day	1.00 (1.00-1.00)	.11	0.000250	1.00 (1.00-1.00)	.07

* The multivariable model included all variables listed.

eAppendix D. Discrimination and Clinical Usefulness Measures of the 6-Month Nursing Home Placement Derivation Prediction Model

Measure	Long-Term Care Placement Prediction Threshold			
	Upper 10%	Upper 15%	Upper 25%	Upper 50%
Derivation Sample				
No. of subjects	724	1,086	1,811	3,622
Observed, %	26.5	22.7	17.1	11.0
Sensitivity, %	43.0	55.0	69.1	89.3
False-negative rate, %	57.0	45.0	30.9	10.7
Specificity, %	92.2	87.6	77.9	52.6
False-positive rate, %	7.8	12.4	22.1	47.4
Positive predictive value, %	26.5	22.7	17.1	11.0
Area under the curve			0.820	
Validation Sample				
No. of subjects	373	559	933	1,866
Observed, %	22.8	18.6	15.6	10.7
Sensitivity, %	37.4	45.8	64.3	88.1
False-negative rate, %	62.6	54.2	35.7	11.9
Specificity, %	91.8	87.0	77.5	52.5
False-positive rate, %	8.2	13.0	22.5	47.5
Positive predictive value, %	22.8	18.6	15.6	10.7
Area under the curve			0.785	

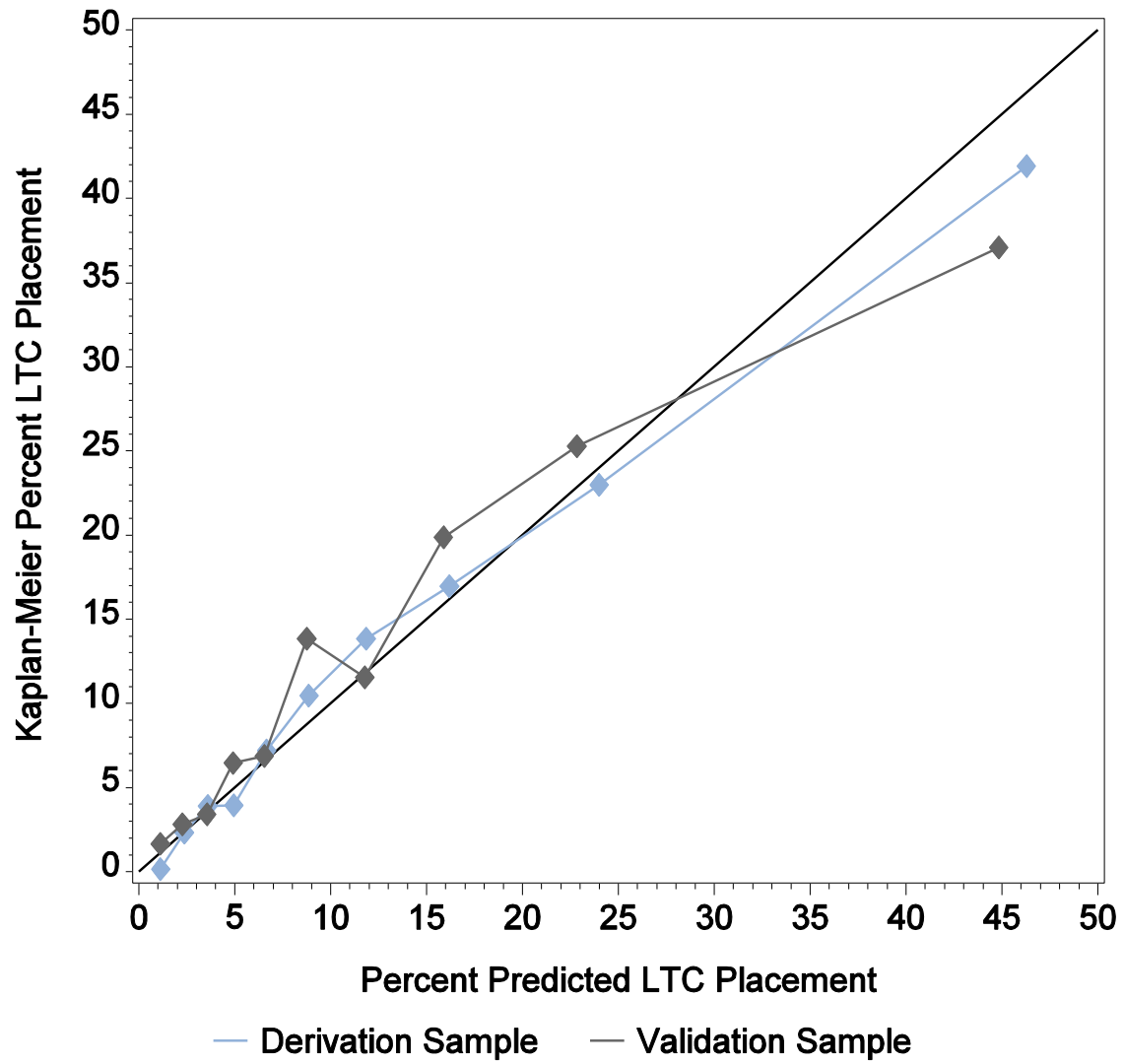
eAppendix E. Predicted Versus Observed Long-Term Care Placement Within 6 Months



eAppendix F. Cox Sensitivity Analysis: Discrimination and Clinical Usefulness Measures of the 1-Year Nursing Home Placement Derivation Prediction Model

Measure	Long-Term Care Placement Prediction Threshold			
	Upper 10%	Upper 15%	Upper 25%	Upper 50%
Derivation Sample				
No. of subjects	724	1,086	1,811	3,622
Sensitivity, %	32.7	43.5	59.3	85.3
False-negative rate, %	67.3	56.5	40.7	14.7
Specificity, %	92.9	88.6	79.4	54.5
False-positive rate, %	7.1	11.4	20.6	45.5
Positive predictive value, %	36.9	32.7	26.7	19.2
Area under the curve			0.782	
Harrell c-index			0.782	
Validation Sample				
No. of subjects	373	559	933	1,866
Sensitivity, %	28.2	39.7	56.6	82.9
False-negative rate, %	71.8	60.3	43.4	17.1
Specificity, %	92.4	88.3	79.1	54.3
False-positive rate, %	7.6	11.7	20.9	45.7
Positive predictive value, %	32.7	30.8	26.3	19.2
Area under the curve			0.754	
Harrell c-index			0.759	

eAppendix G. Cox Sensitivity Analysis: Predicted Versus Kaplan-Meier Nursing Home Placement Within 1 Year



eAppendix H. Cox Sensitivity Analysis: Discrimination and Clinical Usefulness Measures of the 6-Month Nursing Home Placement Derivation Prediction Model

Measure	Long-Term Care Placement Prediction Threshold			
	Upper 10%	Upper 15%	Upper 25%	Upper 50%
Derivation Sample				
No. of subjects	724	1,086	1,811	3,622
Sensitivity, %	42.1	53.5	69.4	88.6
False-negative rate, %	57.9	46.5	30.6	11.4
Specificity, %	92.1	87.5	77.9	52.5
False-positive rate, %	7.9	12.5	22.1	47.5
Positive predictive value, %	26.0	22.0	17.1	10.9
Area under the curve			0.811	
Harrell c-index			0.815	
Validation Sample				
No. of subjects	373	559	933	1,866
Sensitivity, %	37.9	48.0	63.4	85.9
False-negative rate, %	62.1	52.0	36.6	14.1
Specificity, %	91.8	87.2	77.5	52.3
False-positive rate, %	8.2	12.8	22.5	47.7
Positive predictive value, %	23.1	19.5	15.4	10.5
Area under the curve			0.781	
Harrell c-index			0.786	

eAppendix I. Cox Sensitivity Analysis: Predicted Versus Kaplan-Meier Long-Term Care Placement Within 6 Months

