Published in final edited form as:

Am J Phys Med Rehabil. 2018 October ; 97(10): 698–707. doi:10.1097/PHM.0000000000000942.

A Risk Scoring System for the Prediction of Functional Deterioration, Institutionalization, and Mortality among Medicare Beneficiaries

Heather F. McClintock, PhD, MSPH, MSW¹, Jibby E. Kurichi, MPH², Pui L. Kwong, MPH², Dawei Xie, PhD², Margaret G. Stineman, MD³, and Hillary R. Bogner, MD, MSCE^{2,4}

¹Department of Public Health, College of Health Sciences, Arcadia University, Glenside, Pennsylvania

²Center for Clinical Epidemiology and Biostatistics, Perelman School of Medicine, University of Pennsylvania, Philadelphia, Pennsylvania

³Department of Physical Medicine and Rehabilitation, Perelman School of Medicine, University of Pennsylvania, Philadelphia, Pennsylvania

⁴Department of Family Medicine and Community Health, Perelman School of Medicine, University of Pennsylvania, Philadelphia, Pennsylvania

Abstract

Objective—We sought to develop a risk scoring system for predicting functional deterioration, institutionalization, and mortality. Identifying predictors of poor health outcomes informs clinical decision-making, service provision, and policy development to address the needs of persons at greatest risk for poor health outcomes.

Design—Cohort study with 21,257 community-dwelling Medicare beneficiaries aged 65 years and older who participated in the 2001–2008 Medicare Current Beneficiary Survey.

Derivation of the model was conducted in 60% of the sample and validated in the remaining 40%. Multinomial logistic regression model generated β -coefficients which were utilized to create a risk scoring system. Our outcome was instrumental activity of daily living stage transitions (stable/improved function and functional deterioration), institutionalization, or mortality over two years of follow-up.

Results—A total of 18 factors were identified for functional deterioration ($p < 0.05$). In the derivation cohort, the likelihood of functional deterioration ranged from 6.27%–33.51%, risk of institutionalization from 0.07%–12.13%, and risk of mortality from 2.13%–31.83%, in comparison with stable/improved function.

Corresponding author: Heather F. McClintock PhD, MSPH, MSW, Department of Public Health, College of Health Sciences, Arcadia University, 450 S. Easton Road, Glenside, PA 19038, devriesmclintockh@arcadia.edu, Telephone: (215)-609-5841.

Disclosure of Interest: The authors have no financial or any other kind of conflicts of interest to declare.

Conclusion—A risk scoring system predicting Medicare beneficiaries' risk of functional deterioration, institutionalization, and mortality based on demographic and clinical indicators may feasibly be developed with implications for healthcare delivery.

Keywords

Disabled persons; Medicare; Functioning; Elderly

INTRODUCTION

According to the Institute on Medicine's report, 'The Future of Disability in America' the growth of the elderly population in the United States (U.S.) will result in substantial increases in the number of persons living with disabilities.¹ By 2060, approximately a quarter of the U.S. population will be aged 65 or older. Medical advances have reduced the occurrence of fatal infectious diseases and their accompanying morbidity and mortality during the 20th century. The greatest burden of disease is now attributable to chronic conditions, often characterized by disability and functional decline, for which risk dramatically increases with age. In all, 19% of non-institutionalized persons of all ages and approximately 38% of persons aged 65 and older were disabled in 2010.²

A key objective of care provision for aging persons is to prevent functional deterioration and promote independent living. Loss of the ability to carry out daily activities such as preparing food, managing finances, and telephone use is associated with increased care needs, reduced quality of life, morbidity, and mortality.³ These activities, called instrumental activities of daily living (IADLs), require personal autonomy, decision-making, and navigation of the environment. As a result, in contrast to the more basic activities of daily living (ADLs), IADLs are often the first to decline indicating a need for enhanced care.⁴ Conventionally, IADLs have been assessed by counts which provide an indication of disability severity but fail to identify which specific activities are impaired. Lack of identification of specific activities hampers assessment of the burden of illness as well as incorporation of adequate strategies for care management into clinical medicine and public health practice. In this study, we employ activity limitation stages in our evaluation of IADLs.⁵ Previous work has shown that higher IADL activity limitation stages, representing greater functional decline, are associated with greater risk for mortality,⁶ hospitalization,⁷ and admission to a long-term care (LTC) facility.⁸

Health care providers, public health practitioners, and policy makers struggle to meet the needs of aging populations with limited resources. As people age, they need additional care that ideally incorporates their preferences, personal characteristics, and their prognosis for functioning over their life course. Prediction models can identify risk and protective factors to inform resource allocation. Population-based public health or clinical programs can be developed and implemented to maintain functioning and prevent deterioration among older adults. Furthermore, knowledge of one's projected ability to function independently can help persons and their support networks plan and cope with impending life changes.⁹ The application of a risk scoring system can enhance the assessment of patient prognoses and may have particular application for legislation such as the Improving Medicare Post-Acute

Care Transformation Act (IMPACT) of 2014. This act requires reporting of standardized patient assessment data with regard to quality measures. With the projected availability of a greater level of detail regarding transitions in care, our predictive models may be able to yield more specified results pertaining to the types and frequency of institutionalization as well as community discharge. Furthermore, improved standardization may enhance the accuracy and precision of predictive model findings. The Affordable Care Act of 2010 (ACA) proposed broad reaching systemic changes. While findings related to the impact of this act are conflicting and inconclusive,¹⁰ some evidence suggests that Medicare beneficiaries may have experienced reduced inpatient costs and increased access to preventative care^{11,12} potentially reducing overall burden of morbidity, mortality, and delaying institutionalization. These overall changes make the application of predictive models for transitional and health outcomes even more important in understanding and addressing disparities in care provision that may persist.

This study aimed to identify risk and protective factors and create a scoring system predicting risk for functional deterioration as assessed by IADL stage transition, institutionalization, and mortality over two years of follow-up among Medicare beneficiaries. A risk scoring system was developed using IADL activity limitation stages, using the Medicare Current Beneficiary Survey (MCBS), for discrimination between 4 outcomes (stable or improved function combined, functional deterioration, institutionalization, and mortality) assessed over two years of follow-up. Prior work has examined factors associated with ADL and IADL activity limitation stages, which specify the type and severity of activity limitation.⁸ In addition, we have assessed a risk scoring system for functional deterioration using ADL activity limitation stages in prior work.¹³ No known work has examined and developed a risk scoring system for functional deterioration using IADL activity limitation stages. IADLs are more complex than ADLs and may be the first indication of decline. This predictive system for risk of functional decline in IADLs can help inform care provision, public health initiatives, and policy makers in supporting the healthy aging of older adults.

METHODS

Medicare Current Beneficiary Survey (MCBS)

The Centers for Medicare and Medicaid Services (CMS) conducts interviews (sample persons or proxy) among a sample of Medicare beneficiaries. Oversampling of people 80 years and older is conducted to ensure an adequate sample size of this age group. Participants are assessed beginning on January 1st (following the fall interview) and ending at two years of follow-up assessed by interviews with either sample persons or proxies. Proxies were used for many reasons including hospitalization, institutionalization, language barriers, lack of mental or physical capability, or unavailability of sample persons. Study design details are provided in prior work.¹⁴ The MCBS is a panel study in which a new group is enrolled every year.

Sample

The sample was drawn from participants in the 2001–2008 MCBS. In all, 30,356 community-dwelling adults aged 65 years and older were examined over two years by MCBS interviewers assessing their demographic characteristics and health status. Data utilized in this analysis was obtained from two time points (baseline and at 2 years after entry into the survey). Missing data was addressed by using list wise deletion. Beneficiaries lost to follow-up over two years of study observation were also excluded (n=6,882, 18.5%). As a result, our final analysis included 21,257 beneficiaries. The survey sampling weights were adjusted to remove the risk of nonresponse bias.¹⁵ Written informed consent was obtained. The Institutional Review Board of the University of Pennsylvania approved this study. This study conforms to all STROBE guidelines and reports the required information accordingly (see Supplementary Checklist).

Stage Transitions

Four stage transition categories were the primary outcomes: remained stable or improved in IADL stage, deteriorated to a higher IADL stage, was institutionalized, or died at 2 years of follow-up. IADL activity limitation stages were created to delineate clinically relevant patterns of greater difficulty with activities and to signify the severity and types of activity limitations. IADL activity limitation stages were constructed from question responses about IADLs including usage of the telephone, shopping, preparing food, housekeeping, doing laundry, and handling finances. In MCBS interviews, respondents were asked in relation to each IADL item, “Because of a health condition, do you (or does the person you are answering for) have difficulty with...?” In all, there are 5 categories: stage 0 (no limitation), stage I (mild limitation), stage II (moderate limitation), stage III (severe limitation), and stage IV (complete limitation). Greater reduction in functioning is associated with higher stage numbers. Stage III, a non-fitting stage, was constructed to account for limitation patterns that are atypical of the hierarchy. Higher activity limitation stages correspond to greater functional limitations. A person who was able to perform a complex activity but not a simple one would be atypical and be categorized in stage III. IADL activity limitation stages were assessed at baseline and at 2 years of follow-up. As in previous work,¹⁶ no change, a decrease to a lower stage of IADL limitation or an increase to a higher stage of IADL limitation comparing assessments at baseline and at two years were categorized as stable/improved or functional deterioration. Development of IADL activity limitation stages has been discussed in prior work.⁵ Beneficiaries were classified as institutionalized if the MCBS Key Record file indicated they were interviewed in a facility at two years of follow-up in the MCBS. The National Death Index was connected with MCBS data by study researchers to assess the outcome of mortality.

Covariates

Covariates were selected based on their known relationship with functional deterioration, institutionalization, and mortality. They were grouped into categories (sociodemographics, health conditions, impairments, perceived facilitators to receiving health care, perceived barriers to receiving health care, and function) based on prior work. Sociodemographic characteristics assessed were age groups (65–74, 75–84, or 85), gender (male, female), and

race (non-Hispanic white, non-Hispanic black, Hispanic, or other). Educational attainment was as assessed by graduation from high school or greater, or less than a high school education as in previous research. Living arrangement was categorized as lives with spouse, lives with children, lives with others, lives alone, or lives in a retirement community. Participants were asked to select the category that most accurately represented their living arrangement. Insurance coverage was evaluated based on dual eligibility (Medicare and Medicaid dual enrollee) or Medicare only. A measure of proxy use or self-respondent was recorded.

Medical conditions examined consisted of comorbidities or impairments that the respondent indicated had occurred within the past year and had been diagnosed by a physician. Medical conditions correspond to ICD-9 diagnosis codes. These medical conditions included emphysema/asthma/chronic obstructive pulmonary disease (COPD), hypertension, mental/psychiatric disorder, Alzheimer's disease/dementia, angina pectoris or coronary artery disease, complete or partial paralysis, diabetes type 1 or 2/high blood sugar (based on fasting glucose at two time points), myocardial infarction, other heart condition, Parkinson's disease, and stroke/brain hemorrhage. Impairments assessed were severe hearing impairment/deaf and severe vision impairment/no usable vision.

Barriers to and facilitators of receiving health care were also examined. Two questions measured the respondent's satisfaction with ease/convenience and out-of-pocket costs and three questions assessed respondent's satisfaction with care coordination and quality of overall care, information given, and care provider's concern for overall health. A Likert scale was used for responses to these questions with scores ranging from 1 to 4 (satisfied to very unsatisfied).¹⁷ Respondents were also asked if they had a usual source of care, such as a specific place where they usually obtained medical care.

Financial barriers to the receipt of health care were assessed through two questions. In the first question, respondents were first asked if they had trouble getting health care in the past year. If the respondent gave a positive response, then he/she was asked the reason for having trouble. If the reason given indicated financial difficulty (not enough money, cost too high, service/supplies not covered, or not eligible for public coverage) it was coded as a barrier because of financial reasons. The second question asked if medical care had been delayed in the previous year as a result of cost. If respondents indicated financial difficulties in getting health care or delays in getting health care due to cost, beneficiaries were coded as having trouble due to financial reasons. Transportation difficulties were recorded if the respondent indicated having experienced transportation barriers. Functioning was examined by the interviewer obtaining baseline IADL activity limitation stages as specified above in the stage transitions section. The MCBS Access to Care files were used to obtain all covariates.

Model development

The derivation cohort was derived by randomly selecting 60% of the Medicare beneficiary sample (n=12,758) in order to develop a prediction score system. The remaining 40% of the sample (n=8,506) served as the validation cohort. The following 5 steps generated a multinomial logistic regression model for activity limitation stage transition: (1) Identification and categorization of covariates based on previous findings showing an

association with stage transition¹⁸; (2) The use of chi-squared tests to examine the association of covariates to stage transition in the derivation cohort; (3) Estimation of a parsimonious model within the derivation cohort; (4) Creation of a point-scoring system in the derivation cohort; and (5) Validation of the model and development of a point scoring system in the validation cohort. The point scoring system was validated by using the R-square to validate the model fit of the validation cohort, and show the prediction probability of both derivation and validation cohorts. In step 3, potential predictors were entered into a multinomial logistic regression model if $p < 0.20$ for stage transition in step 2. After this, stepwise backward selection was employed to construct a final parsimonious model with all predictive variables achieving conventional levels of statistical significance at $p < 0.05$.

The scoring system was derived from regression results by assigning points to each predictor by dividing each β -coefficient in the final logistic regression models by the lowest significant β -coefficient, and then rounding up to the nearest integer. If individual β -coefficients for categorical variables were non-significant but the variable was significant overall a value of “0” was assigned. For each level of the outcome (functional deterioration, institutionalization, or mortality), a risk score was determined by adding up the points for all risk factors as indicated for each individual Medicare beneficiary. Based on these risk scores, beneficiaries were divided into quartiles. Quartiles were used because of their utility for the development of a clinical scoring system. They were obtained by dividing summed scores.

Goodness-of-fit of the model was assessed by R-square. Our analyses produced R-squares which can be interpreted as the amount of information gained when including the predictors in the model in comparison with the unadjusted model. We obtained derivation and validation cohorts by utilizing 6 pairwise c-statistics and the M-index (average of the 6 c-statistics). A pairwise c-statistic is defined as the probability of correctly discriminating between two cases from different categories that have been selected randomly. A sensitivity analysis was conducted by comparing models stratified by gender and proxy use as well as comparing baseline characteristics of persons who were lost to follow-up and those who were not. Statistical analyses were conducted using SAS 9.4 (SAS Institute, Inc.). P-values were two-sided and defined *a priori* with statistical significance defined at $p < 0.05$.

RESULTS

In all, 83.6% of Medicare beneficiaries were aged 65 years or older between 2001–2008, 43.2% were male, 82.7% were non-Hispanic white, 74.1% had a high school diploma or higher, 54.8% lived with a spouse, 10.6% were dual eligible for Medicare and Medicaid, and 5.7% used a proxy. Characteristics of Medicare beneficiaries in the derivation and validation cohorts were similar (Table 1). Missing data (7.3%) on covariates in the model included demographic characteristics (race, education), proxy usage, satisfaction with care, usual source of care, perceived financial barriers to the receipt of health care, and baseline IADL stage. At two years of follow-up in the derivation cohort, 75.1% of beneficiaries remained stable or had improved function in their IADL activity limitation stage, 15.0% had functional deterioration, 1.9% were institutionalized, and 8.0% had died.

In the unadjusted analysis, candidate variables with $p < 0.20$ were included in the preliminary regression model. These variables were included in an initial evaluation of the multinomial logistic regression model. Variables found to be predictive of all outcomes (functional deterioration, institutionalization, and mortality) were advanced age, gender, dual eligibility for Medicare and Medicaid, diabetes/high blood sugar, Alzheimer's/dementia, Parkinson's Disease, and IADL activity limitation stage I. Hispanic and non-Hispanic black, living alone, in a retirement community or with others, lack of satisfaction with information given, and stroke/brain hemorrhage were predictive of institutionalization and mortality. Less than a high school education, living with children, using a proxy respondent, lack of satisfaction with ease/convenience of access to care, myocardial infarction/heart attack, COPD, and IADL activity limitation stage II were predictive of functional deterioration and mortality (Table 2). Summed scores corresponded to the likelihood of adverse outcomes occurring. By adding points, a risk score can be obtained based on the likelihood of adverse outcomes (Table 3). In the derivation cohort, the likelihood of functional deterioration ranged from 6.27% to 33.51%, likelihood of institutionalization from 0.07% to 12.13%, and risk of mortality from 2.13% to 31.83%, in comparison with stable or improved function. Please see Table 4 for the rate prediction by sum score quartiles.

R-Squares generated from multinomial logistic regression were 0.2073 and 0.1912 in the derivation and validation cohorts, respectively. These indicated the prediction models demonstrated adequate fit. In the derivation cohort, 6 c-statistics were derived: 0.684, 0.862, 0.798, 0.729, 0.713, and 0.599. These statistics assessed 6 comparisons which evaluated discrimination between no change and functional deterioration, no change and institutionalization, no change and mortality, functional deterioration and institutionalization, functional deterioration and mortality, and institutionalization and mortality. The M-index calculated was 0.731. In the validation cohort c-statistics were 0.682, 0.848, 0.774, 0.745, 0.682, and 0.570 for the 6 comparisons described above. The M-index was 0.717. C-statistics and the M-index indicated discrimination between outcomes in the model. In evaluating sensitivity, our model was stratified by gender and coefficients within each gender stratum were similar. When stratified by proxy use or no proxy use, the models had similar coefficients. Baseline characteristics did not significantly differ between those who were lost to follow-up and those who were not.

DISCUSSION

In this work, MCBS data was used to identify predictors of functional deterioration, institutionalization, and mortality over 2 years of follow-up among elderly Medicare beneficiaries. The estimation of predictors and a clinically applicable scoring system for assessing risk was developed and validated using a large nationally representative sample of elderly Medicare beneficiaries. The identified demographic and clinical predictors in this study could be obtained through existing medical records and employed in clinical practice to inform care management and to promote the health and well-being of aging persons.

The examination of demographic characteristics in relation to functioning, institutionalization, and/or mortality has been the subject of many studies. Prior research shows that older age is linked with worse health and that women experience more chronic

illness and greater longevity than men.¹⁹ Higher proportions of persons from minority groups have been reported to have disabilities in comparison with non-minority groups.²⁰ Lower levels of education increase risk for worse health due to influences on individual, neighborhood, and macro- level factors such as resource availability, neighborhood environment and social policy.²¹ Persons needing home health care often experience greater disease burden and the presence of additional persons in the home may be indicative of both compromised health status as well as fewer resources.²² Beneficiaries who are dual eligible are generally older, have disabilities, lower income, have more chronic conditions, and account for more spending than non-dual eligible beneficiaries.²³ Use of a proxy is a risk factor for poor health outcomes, as it is often a surrogate for severe medical illness.²⁴ Thus, our findings that older age, males, Hispanics, non-Hispanic blacks, lower educational attainment, needing assistance in the home, dual eligibility, living with persons other than a spouse, and use of a proxy were associated with functional deterioration, institutionalization, and/or mortality is consistent with the literature. Based on these demographic characteristics, health care providers can employ preventive interventions to focus treatment accordingly, incorporating support systems and planning for projected life changes.

Some medical comorbidities were identified as risk factors for functional deterioration, institutionalization, or mortality in our prediction assessment. Our findings are consistent with prior investigations and assessments of the burden of disease. According to recent data from the Centers for Disease Control and Prevention, heart disease, chronic lower respiratory diseases, stroke (cerebrovascular disease), Alzheimer's disease, and diabetes are leading causes of mortality in the U.S.²⁵ In other work, Parkinson's disease has been found to be associated with functional deterioration and institutionalization.²⁶ The link between poor mental health and mortality has been documented in the literature with depression being an indicator of poor functional health and reduced longevity.²⁷ We found that hearing impairment and unusable vision/vision impairment separately were risk factors for functional deterioration. Both of these impairments have been linked to worse health outcomes in prior work.²⁸ These types of impairments may require additional assistance and inhibit independent living because of difficulty in caring for one's self.

Our findings build on prior work showing that demographic and clinical characteristics can predict functional decline as assessed by ADL activity limitation stage transitions.¹³ This is the first study to examine predictors of IADL stage transitions and to establish a corresponding risk scoring system for use in clinical practice. IADLs play an important role in independent community living as they assess an individual's ability to manage finances, go shopping, and carry out other important aspects of daily life. IADL stage transitions show a similar relationship to ADL stage transitions in relation to predictive factors,¹³ suggesting that these assessments of functioning may share common characteristics as well as prognostic purposes. However, there are several differences in the prognosis of IADL and ADL stage transition deterioration that are worthy of attention. For instance, persons experiencing a myocardial infarction/heart attack are at increased risk for functional deterioration as assessed in IADL stage transitions but not in ADL stage transitions. IADLs are considered to be more complex requiring greater environmental interaction than ADLs. Thus, for persons experiencing a heart attack particular attention should be focused on decline in IADL functioning. In addition, higher baseline IADL activity limitation stage was

a strong predictor for functional deterioration as assessed by IADL activity limitation stage. IADL stage decline may be an important marker for increased risk of nursing home admission and reduced survival over two years. Risk for poor outcomes should not only be evaluated by ADL activity limitation stage transitions but also by IADL activity limitation stage transitions. Providers should be aware of and alerted to care that can prevent deterioration as measured by IADL activity limitation stage transition. Persons identified at risk of poor outcomes may warrant advanced planning incorporating goals, values, and priorities for appropriate care management.

Scores can be assigned to patients to predict adverse outcomes based on demographic and clinical characteristics. A risk score can be obtained by adding points to obtain a likelihood of occurrence of each adverse outcome (Table 3). This risk score allows for the cumulative evaluation of risk based on a scoring system, facilitating ease of care provision. Risk scores can alert clinicians to patients at risk for functional deterioration, institutionalization, and mortality. Identifying factors that predict functional deterioration, institutionalization, and mortality over 2 years of follow-up can aid health care providers, patients, caregivers, and policy makers in targeting resources and care provision to prevent poor outcomes and foster healthy aging. Evaluating risk levels for beneficiaries will inform priorities to most effectively promote longer healthy living. Institutionalization, established as a critical indicator of functional decline,²⁹ may be a particularly important outcome to address through interventions incorporating risk scoring systems. Systemic constraints require further assessment and evaluation for feasible implementation of the proposed risk scoring system. Implementation of the risk scoring system would involve enhancing and potentially modifying current electronic medical record systems and data collection from patients. Such a system could incorporate calculations as to avoid additional burden on clinicians. The predictors evaluated in this study are easily extracted from existing data structures and can be used to predict functional deterioration, institutionalization, and mortality. Our findings are relevant and generalizable to community-dwelling Medicare recipients aged 65 years and older.

Study limitations are worth noting. Some IADL activity limitation stages were obtained from proxy responses and may have lacked accuracy in reflecting which activities the sample person experienced difficulty with. Recall bias may have occurred as survey questions asked the respondent to recall events that occurred within the past year. Proxies were included despite their potential to answer questions differently than beneficiaries themselves. However, bias may result if proxy responses are excluded.³⁰ Many respondents were lost to follow-up and the unknown outcomes of these individuals may have influenced the final results. Nevertheless, a sensitivity analysis by proxy respondents and losses to follow-up indicated that excluding proxy from the model had little effect on model coefficients. Baseline characteristics did not significantly differ between those who were lost to follow-up and those who were not. While we sought to examine all relevant factors in our analysis, some variables of potential significance were not measured in the MCBS and thus were not included in this work (e.g. self-advocacy, social cohesion, and capital). Our results are relevant to our selected sample, Medicare beneficiaries aged 65 and older, and may not be relevant to other populations. Lastly, our study was conducted using data from 2001–2008. Since this time, substantial systemic changes such as the modification of payment

systems, performance models, and quality measures in post-acute care have been proposed. Thus, interpretation and implications from our findings must be interpreted within the context of a healthcare system which continues to experience ongoing reform and transformation. More specifically, IMPACT of 2014 requires reporting of standardized patient assessment data with regard to quality measures. The Centers for Medicare and Medicaid Services (CMS) recently reported that they, with the RAND Corporation, have been contracted to develop standardized assessment-based data elements to meet the requirements of the act. The creation of standardized quality measures will facilitate improved accuracy for reporting and measurement of how predictors influence outcomes among Medicare beneficiaries. In addition, the ACA proposed broad reaching systemic changes with some evidence indicating it may have reduced inpatient costs and increased access to preventative care for Medicare beneficiaries.^{11,12} However, the little available evidence conclusively indicates that this act has or will differentially impact any predictors in our model. Thus, it is unlikely that the predictive value of our model would be influenced.

CONCLUSION

Our risk scoring system predicting functional deterioration, institutionalization, and mortality was validated in a population of elderly Medicare beneficiaries and may play an important role in shaping care provision and planning for this population. Future work is needed to validate this model and evaluate its efficacy in clinical settings. Public health practice, clinical care provision, and policy formulation can incorporate identified risk and protective factors to tailor and target services to most effectively promote healthy aging.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

Funding Source: Patient-Centered Outcomes Research Institute (PCORI) Project Program Award AD-12-11-4567.

References

1. Institute of Medicine. The Future of Disability in America. Washington, D.C.: 2007.
2. Population Reference Bureau. Aging in the United States. Population Bulletin. 2015; 70(2)
3. Reuben DB, Rubenstein LV, Hirsch SH, Hays RD. Value of functional status as a predictor of mortality: results of a prospective study. The American journal of medicine. Dec; 1992 93(6):663–669. [PubMed: 1466363]
4. Judge JO, Schechtman K, Cress E. The relationship between physical performance measures and independence in instrumental activities of daily living. The FICSIT Group. Frailty and Injury: Cooperative Studies of Intervention Trials. Journal of the American Geriatrics Society. Nov; 1996 44(11):1332–1341. [PubMed: 8909349]
5. Stineman MG, Streim JE, Pan Q, Kurichi JE, Schussler-Fiorenza Rose SM, Xie D. Activity Limitation Stages empirically derived for Activities of Daily Living (ADL) and Instrumental ADL in the U.S. Adult community-dwelling Medicare population. PM & R : the journal of injury, function, and rehabilitation. Nov; 2014 6(11):976–987. quiz 987.
6. Hennessy S, Kurichi JE, Pan Q, et al. Disability Stage is an Independent Risk Factor for Mortality in Medicare Beneficiaries Aged 65 Years and Older. PM & R : the journal of injury, function, and rehabilitation. Dec; 2015 7(12):1215–1225.

7. Na L, Pan Q, Xie D, et al. Activity Limitation Stages Are Associated With Risk of Hospitalization Among Medicare Beneficiaries. *PM & R : the journal of injury, function, and rehabilitation*. Sep 21.2016
8. Kurichi JE, Streim JE, Xie D, et al. The Association Between Activity Limitation Stages and Admission to Facilities Providing Long-term Care Among Older Medicare Beneficiaries. *Am J Phys Med Rehabil*. Nov 04.2016
9. de Vries McClintock HF, Barg FK, Katz SP, et al. Health care experiences and perceptions among people with and without disabilities. *Disability and health journal*. Jan; 2016 9(1):74–82. [PubMed: 26482010]
10. Obama B. United States Health Care Reform: Progress to Date and Next Steps. *Jama*. Aug 2; 2016 316(5):525–532. [PubMed: 27400401]
11. Henke R, Karaca Z, Gibson T, Cutler E, White C, Wong H. Medicare Advantage Penetration and Hospital Costs Before and After the Affordable Care Act. *Medical care*. 2018
12. Misra A, Lloyd JT, Strawbridge LM, Wensky SG. Use of Welcome to Medicare Visits Among Older Adults Following the Affordable Care Act. *American journal of preventive medicine*. Jan; 2018 54(1):37–43. [PubMed: 29132952]
13. Kurichi JE, Kwong PL, Xie D, Bogner HR. Predictive Indices for Functional Improvement and Deterioration, Institutionalization, and Death Among Elderly Medicare Beneficiaries. *PM & R : the journal of injury, function, and rehabilitation*. Apr 26.2017
14. US Department of Health & Human Services. [Accessed December 1, 2016] Medicare Current Beneficiary Survey (MCBS). 2010. <http://www.cms.hhs.gov/MCBS/>
15. Kautter J, Khatutsky G, Pope GC, Chromy JR, Adler GS. Impact of nonresponse on Medicare Current Beneficiary Survey estimates. *Health care financing review*. Summer;2006 27(4):71–93. [PubMed: 17290659]
16. Krueger AR, Giannoni P, Shah V, Casadio M, Scheidt RA. Supplemental vibrotactile feedback control of stabilization and reaching actions of the arm using limb state and position error encodings. *Journal of neuroengineering and rehabilitation*. May 02.2017 14(1):36. [PubMed: 28464891]
17. Lee Y, Kasper JD. Assessment of medical care by elderly people: general satisfaction and physician quality. *Health services research*. Feb; 1998 32(6):741–758. [PubMed: 9460484]
18. Bogner HR, de Vries McClintock HF, Hennessy S, et al. Patient Satisfaction and Perceived Quality of Care Among Older Adults According to Activity Limitation Stages. *Archives of physical medicine and rehabilitation*. Oct; 2015 96(10):1810–1819. [PubMed: 26119464]
19. Barford A, Dorling D, Davey Smith G, Shaw M. Life expectancy: women now on top everywhere. *Bmj*. Apr 08.2006 332(7545):808. [PubMed: 16601021]
20. O'Neil SS, Lake T, Merrill A, Wilson A, Mann DA, Bartnyska LM. Racial disparities in hospitalizations for ambulatory care-sensitive conditions. *American journal of preventive medicine*. Apr; 2010 38(4):381–388. [PubMed: 20307806]
21. Montez JK, Friedman EM. Educational attainment and adult health: under what conditions is the association causal? *Social science & medicine*. Feb.2015 127:1–7. [PubMed: 25557617]
22. Eum RS, Seel RT, Goldstein R, et al. Predicting institutionalization after traumatic brain injury inpatient rehabilitation. *J Neurotrauma*. Feb 15; 2015 32(4):280–286. [PubMed: 25203001]
23. Coughlin TA, Waidmann TA, Phadera L. Among dual eligibles, identifying the highest-cost individuals could help in crafting more targeted and effective responses. *Health affairs*. May; 2012 31(5):1083–1091. [PubMed: 22518821]
24. Neumann PJ, Araki SS, Gutterman EM. The use of proxy respondents in studies of older adults: lessons, challenges, and opportunities. *J Am Geriatr. Soc*. Dec; 2000 48(12):1646–1654. [PubMed: 11129756]
25. National Center for Health Statistics Center for Disease Control. *Health, United States, 2015*. Hyattsville, MD: 2016.
26. Bjornestad A, Tysnes OB, Larsen JP, Alves G. Loss of independence in early Parkinson disease: A 5-year population-based incident cohort study. *Neurology*. Oct 11; 2016 87(15):1599–1606. [PubMed: 27590290]

27. Wulsin LR, Vaillant GE, Wells VE. A systematic review of the mortality of depression. *Psychosomatic medicine*. Jan-Feb;1999 61(1):6–17. [PubMed: 10024062]
28. Genther DJ, Frick KD, Chen D, Betz J, Lin FR. Association of hearing loss with hospitalization and burden of disease in older adults. *JAMA*. Jun 12; 2013 309(22):2322–2324. [PubMed: 23757078]
29. Banaszak-Holl J, Liang J, Quinones A, Cigolle C, Lee IC, Verbrugge LM. Trajectories of functional change among long stayers in nursing homes: does baseline impairment matter? *Journal of aging and health*. Aug; 2011 23(5):862–882. [PubMed: 21436394]
30. Stineman MG, Ross RN, Maislin G. Functional status measures for integrating medical and social care. *Int J Integr Care*. 2005; 5:e07.

Table 1

Characteristics of Medicare Current Beneficiary Survey Sample Persons in Derivation and Validation Cohorts.

Characteristics	Total N (weighted %) N=21264	Derivation N (weighted %) N=12758 (60%)	Validation N (weighted %) N=8506 (40%)
Outcome of Activity of Daily Living stage transition			
Functional stable/improvement	15204 (75.1)	9113 (75.1)	6091 (75.1)
Functional deterioration	3516 (15.2)	2106 (15.0)	1410 (15.4)
Institutionalization	512 (1.9)	308 (1.9)	204 (1.9)
Mortality	2025 (7.8)	1228 (8.0)	797 (7.6)
Baseline characteristics			
Sociodemographics			
Age			
65–74	9529 (56.1)	5692 (55.8)	3837 (56.6)
75–84	8616 (34.2)	5200 (34.5)	3416 (33.7)
85	3112 (9.7)	1863 (9.7)	1249 (9.7)
Gender			
Male	9209 (43.6)	5469 (43.2)	3740 (44.2)
Female	12048 (56.4)	7286 (56.8)	4762 (55.8)
Race/Ethnicity			
Hispanic	1435 (6.8)	826 (6.5)	609 (7.4)
Non-Hispanic white	17528 (82.1)	10584 (82.7)	6944 (81.2)
Other	593 (3.1)	363 (3.2)	230 (2.9)
Non-Hispanic black	1701 (8.0)	982 (7.7)	719 (8.5)
Education			
High school diploma	15247 (74.1)	9155 (74.1)	6092 (74.1)
Below high school diploma	6010 (25.9)	3600 (25.9)	2410 (25.9)
Living arrangement			
Retirement community	1514 (6.1)	916 (6.1)	598 (6.1)
With spouse	10779 (54.2)	6511 (54.8)	4268 (53.5)
With children	2077 (8.9)	1207 (8.6)	870 (9.4)
With others	981 (4.7)	576 (4.5)	405 (5.0)
Alone	5906 (26.0)	3545 (26.0)	2361 (26.0)
Dual eligibility			
Medicare only	18726 (89.0)	11286 (89.4)	7440 (88.4)
Medicare and Medicaid	2531 (11.0)	1469 (10.6)	1062 (11.6)
Beneficiary or proxy interview			
Beneficiary	19846 (94.1)	11913 (94.3)	7933 (94.0)
Proxy	1411 (5.9)	842 (5.7)	569 (6.0)
Health conditions			
Alzheimer's disease/dementia	591 (2.2)	370 (2.3)	221 (2.0)

Characteristics	Total N (weighted %) N=21264	Derivation N (weighted %) N=12758 (60%)	Validation N (weighted %) N=8506 (40%)
Angina pectoris/coronary artery disease	2192 (9.8)	1321 (9.8)	871 (9.7)
Complete/partial paralysis	568 (2.5)	325 (2.3)	243 (2.7)
Diabetes/high blood sugar	4734 (22.5)	2840 (22.5)	1894 (22.5)
Emphysema/asthma/Chronic Obstructive Pulmonary Disease	2916 (13.6)	1760 (13.8)	1156 (13.2)
Hypertension	12969 (60.1)	7745 (59.6)	5224 (60.7)
Mental/psychiatric disorder	1251 (5.8)	743 (5.6)	508 (6.0)
Myocardial infarction/heart attack	3014 (13.0)	1818 (13.0)	1196 (12.9)
Other heart conditions	2954 (12.7)	1778 (12.8)	1176 (12.6)
Parkinson's disease	277 (1.1)	175 (1.2)	102 (1.1)
Stroke/brain hemorrhage	2415 (10.3)	1465 (10.3)	950 (10.2)
Impairments			
Severe hearing impairment/deaf	1602 (6.6)	932 (6.4)	670 (6.9)
Severe vision impairment/no usable vision	1622 (6.5)	977 (6.6)	645 (6.4)
Perceived facilitators to receiving health care			
Access to medical care			
Unsatisfied with ease/convenience	1046 (4.7)	644 (4.9)	402 (4.3)
Unsatisfied with out-of-pocket costs	3575 (17.3)	2149 (17.2)	1426 (17.5)
Care coordination and quality			
Usual source of care	20786 (97.7)	12469 (97.7)	8317 (97.7)
Unsatisfied with overall quality of care	721 (3.4)	443 (3.3)	278 (3.4)
Unsatisfied with information given	999 (4.6)	616 (4.7)	383 (4.4)
Unsatisfied with concern for overall health	997 (4.7)	594 (4.7)	403 (4.8)
Perceived barriers to receiving health care			
Has trouble getting health care or delayed health care because of financial reasons	1532 (7.8)	927 (7.8)	605 (7.7)
Has transportation difficulties	52 (0.2)	35 (0.3)	17 (0.2)
Function			
Instrumental Activity of Daily Living Stage			
0	13197 (65.8)	7851 (65.2)	5346 (66.6)
I	3698 (16.6)	2255 (16.9)	1443 (16.1)
II	1670 (7.1)	1008 (7.2)	662 (7.1)
III	2223 (8.8)	1351 (8.9)	872 (8.6)
IV	469 (1.7)	290 (1.8)	179 (1.6)

Table 2

Multinomial Logistic Regression Model for Functional Deterioration, Institutionalization, and Mortality in the Derivation Cohort (N= 12755)

Predictor	Functional deterioration				Institutionalization				Mortality			
	β Coefficient	Adjusted Odds Ratio (95% Confidence Interval)	P Value	Score*	β Coefficient	Adjusted Odds Ratio (95% Confidence Interval)	P Value	Score*	β Coefficient	Adjusted Odds Ratio (95% Confidence Interval)	P Value	Score*
Age (ref: 65–74)												
75–84	0.69	1.99 (1.78–2.23)	<.0001	4	1.33	3.77 (2.56–5.55)	<.0001	8	0.85	2.33 (1.97–2.75)	<.0001	5
85	1.33	3.80 (3.24–4.45)	<.0001	8	2.38	10.77 (7.11–16.29)	<.0001	14	1.94	6.94 (5.70–8.44)	<.0001	12
Sex (ref: female)												
Male	–0.37	0.69 (0.62–0.77)	<.0001	–2	–0.41	0.66 (0.49–0.89)	0.007	–3	0.55	1.73 (1.50–2.01)	<.0001	3
Race (ref: Non-Hispanic white)												
Hispanic	–0.09	0.92 (0.75–1.12)	0.396	0	1.56	4.78 (2.24–10.17)	<.0001	10	0.65	1.91 (1.41–2.59)	<.0001	4
Other	0.08	1.08 (0.77–1.51)	0.647	0	–0.02	0.98 (0.28–3.46)	0.976	0	0.06	1.06 (0.64–1.75)	0.827	0
Non-Hispanic black	0.17	1.18 (0.92–1.52)	0.196	0	1.10	3.01 (1.29–7.01)	0.011	7	0.73	2.08 (1.46–2.98)	<.0001	4
Education (ref: High school diploma)												
No high school diploma	0.21	1.24 (1.10–1.39)	0.000	1	0.20	1.23 (0.94–1.61)	0.142	0	0.29	1.34 (1.16–1.55)	<.0001	2
Insurance Coverage (ref: Dual eligibility)												
Medicare only	–0.32	0.73 (0.61–0.86)	0.000	–2	–0.95	0.39 (0.28–0.54)	<.0001	–6	–0.36	0.70 (0.57–0.85)	0.000	–2
Living arrangement (ref: With spouse)												
Alone	–0.06	0.94 (0.83–1.07)	0.349	0	0.99	2.69 (1.90–3.83)	<.0001	6	0.23	1.25 (1.06–1.48)	0.009	1
Retirement community	–0.02	0.98 (0.80–1.20)	0.865	0	1.61	5.00 (3.37–7.42)	<.0001	10	0.36	1.44 (1.13–1.83)	0.003	2
With children	0.19	1.21 (1.01–1.44)	0.038	1	0.30	1.35 (0.83–2.19)	0.231	0	0.35	1.42 (1.14–1.78)	0.002	2
With others	0.12	1.13 (0.88–1.43)	0.336	0	0.96	2.62 (1.48–4.62)	0.001	6	0.45	1.57 (1.17–2.11)	0.003	3
Proxy (ref: sample person responded)												
Proxy responded	0.47	1.60 (1.27–2.01)	<.0001	3	0.22	1.25 (0.82–1.92)	0.305	0	0.42	1.52 (1.21–1.92)	0.000	3
Comparators												

Predictor	Functional deterioration				Institutionalization				Mortality			
	β Coefficient	Adjusted Odds Ratio (95% Confidence Interval)	P Value	Score*	β Coefficient	Adjusted Odds Ratio (95% Confidence Interval)	P Value	Score*	β Coefficient	Adjusted Odds Ratio (95% Confidence Interval)	P Value	Score*
Very Satisfied with Information given	0.06	1.06 (0.83–1.35)	0.629	0	-0.57	0.57 (0.37–0.88)	0.010	-3	-0.33	0.72 (0.56–0.94)	0.015	-2
Very satisfied with ease/convenience of access to care	-0.29	0.75 (0.60–0.94)	0.012	-2	-0.17	0.84 (0.53–1.34)	0.474	0	-0.31	0.73 (0.57–0.94)	0.015	-2
Having Usual source of care	-0.09	0.91 (0.64–1.30)	0.606	0	-0.67	0.51 (0.26–1.01)	0.054	-4	-0.54	0.58 (0.39–0.86)	0.007	-3
Comorbidities (reference: no)												
Hypertension	0.16	1.18 (1.06–1.31)	0.002	1	-0.21	0.81 (0.63–1.05)	0.108	0	0.00	1.00 (0.87–1.15)	0.971	0
Myocardial infarction/heart attack	0.20	1.22 (1.05–1.41)	0.008	1	0.16	1.18 (0.83–1.67)	0.359	0	0.33	1.39 (1.17–1.65)	0.000	2
Angina pectoris/coronary artery disease	0.14	1.16 (0.98–1.36)	0.085	0	-0.53	0.59 (0.37–0.93)	0.023	-3	-0.07	0.93 (0.76–1.14)	0.482	0
Stroke/brain hemorrhage	0.36	1.43 (1.22–1.67)	<0.001	2	0.33	1.39 (1.00–1.94)	0.049	2	0.37	1.45 (1.21–1.74)	<0.001	2
Diabetes/high blood sugar	0.25	1.29 (1.14–1.45)	<0.001	2	0.47	1.60 (1.20–2.13)	0.001	3	0.36	1.43 (1.23–1.67)	<0.001	2
Alzheimer's/dementia	1.24	3.46 (2.41–4.98)	<0.001	8	1.94	6.93 (4.36–11.02)	<0.001	12	1.21	3.34 (2.44–4.56)	<0.001	7
Mental/psychiatric disorder	0.41	1.51 (1.23–1.85)	<0.001	2	0.40	1.49 (0.99–2.24)	0.058	0	0.05	1.05 (0.81–1.36)	0.722	0
Parkinson's disease	1.02	2.78 (1.82–4.25)	<0.001	6	0.92	2.52 (1.26–5.05)	0.009	6	1.05	2.86 (1.91–4.30)	<0.001	6
Chronic Obstructive Pulmonary Disease	0.43	1.54 (1.33–1.77)	<0.001	3	-0.07	0.93 (0.64–1.36)	0.705	0	0.76	2.15 (1.82–2.53)	<0.001	5
Complete/partial paralysis	0.31	1.36 (0.98–1.88)	0.067	0	0.68	1.98 (1.13–3.46)	0.017	4	0.33	1.39 (0.99–1.97)	0.059	0
Severe vision impairment/no usable vision	0.40	1.49 (1.24–1.80)	<0.001	2	-0.10	0.91 (0.62–1.32)	0.614	0	0.10	1.11 (0.90–1.36)	0.344	0
Severe hearing impairment/deaf	0.29	1.34 (1.10–1.65)	0.004	2	-0.31	0.73 (0.48–1.13)	0.156	0	-0.15	0.87 (0.70–1.08)	0.192	0
Instrumental Activity of Daily Living (ref: Stage I)												
Stage 0	0.19	1.21 (1.06–1.38)	0.004	1	-0.60	0.55 (0.39–0.78)	0.001	-4	-0.67	0.51 (0.42–0.62)	<0.001	-4
Stage II	-0.47	0.63 (0.51–0.78)	<0.001	-3	0.32	1.37 (0.91–2.07)	0.130	0	0.43	1.54 (1.23–1.92)	0.000	3
Stage III	-1.64	0.19 (0.15–0.25)	<0.001	-10	0.36	1.43 (0.98–2.10)	0.066	0	0.09	1.09 (0.88–1.36)	0.431	0
Stage IV	-15.39	omitted—floor effect		0	0.28	1.32 (0.71–2.45)	0.379	0	0.56	1.75 (1.23–2.50)	0.002	3

* Score was calculated by dividing each significant variable's β coefficient by the lowest β coefficient and then rounding to the nearest integer.

Table 3

Functional Deterioration, Institutionalization and Mortality Predictive Indices and Risk Groups* at 2 years of follow-up.

Predictor	Functional deterioration		Institutionalization		Mortality	
	Point	Score box	Point	Score box	Point	Score box
Instrumental activity of daily living						
Stage 0	1		-4		-4	
Stage I	0		0		0	
Stage II	-3		0		3	
Stage III	-10		0		0	
Stage IV	0		0		3	
Age						
65-74	0		0		0	
75-84	4		8		5	
85	8		14		12	
Gender						
Male	-2		-3		3	
Female	0		0		0	
Race						
Non-Hispanic white	0		0		0	
Hispanic	0		10		4	
Other	0		0		0	
Non-Hispanic black	0		7		4	
Education						
High school diploma	0		0		0	
No high school diploma	1		0		2	
Dual eligibility						
Medicare only	-2		-6		-2	
Medicare plus Medicaid	0		0		0	
Living arrangement						

Predictor	Functional deterioration		Institutionalization		Mortality	
	Point	Score box	Point	Score box	Point	Score box
With spouse	0		0		0	
Alone	0		6		1	
Retirement community	0		10		2	
With children	1		0		2	
With others	0		6		3	
Proxy Interviewed						
Sample person responded	0		0		0	
Proxy responded	3		0		3	
Comorbidities						
Hypertension	1		0		0	
Myocardial infarction/heart attack	1		0		2	
Angina pectoris/coronary artery disease	0		-3		0	
Stroke/brain hemorrhage	2		2		2	
Diabetes/high blood sugar	2		3		2	
Alzheimer's/dementia	8		12		7	
Mental/psychiatric disorder	2		0		0	
Parkinson's disease	6		6		6	
Chronic Obstructive Pulmonary Disease	3		0		5	
Complete/partial paralysis	0		4		0	
Severe vision impairment/no usable vision	2		0		0	
Severe hearing impairment/deaf	2		0		0	
Comparators						
Very Satisfied with Information given	0		-3		-2	
Very satisfied with ease/convenience of access to care	-2		0		-2	
Having Usual source of care	0		-4		-3	

*** Instructions**

1. The 2-year functional deterioration, institutionalization, and mortality predictions involve 3 different scoring systems.
2. Score the person associated with the presence of each predictor. Enter the associated points in its score box.
3. Add the points associated with each predictor to obtain a sum score for the relevant scoring system.
4. In the sum score box in Table 4, circle the sum scores to determine the person's risk group and the average likelihood of functional deterioration, institutionalization, and mortality.

Table 4

Rate Prediction by Sum Score Quartiles

Sum point scores	Derivation cohort		Validation cohort	
Functional deterioration				
	Outcome achieved, n /Total, n	Probability, %	Outcome achieved, n /Total, n	Probability, %
−3	179 / 2854	6.27	122 / 1841	6.63
−2 − 0	472 / 3036	15.55	295 / 2072	14.24
1 − 3	637 / 2888	22.06	425 / 1912	22.23
4	818 / 2441	33.51	568 / 1676	33.89
Institutionalization				
−3	2 / 2802	0.07	5 / 1868	0.27
−2 − 4	14 / 2640	0.53	9 / 1760	0.51
5 − 11	61 / 2074	2.94	49 / 1433	3.42
12	231 / 1905	12.13	141 / 1234	11.43
Mortality				
−4	69 / 3232	2.13	50 / 2126	2.35
−3 − 0	116 / 2245	5.17	84 / 1591	5.28
1 − 5	229 / 2307	9.93	163 / 1500	10.87
6	814 / 2557	31.83	500 / 1671	29.92