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One Year Mortality after Hip Fracture: Development and Validation of a Prognostic Index

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Abstract

Objectives—To develop a prediction index for one year mortality after hip fracture in older adults that includes predictors from wide range of domains.

Design—Retrospective cohort study.

Settings—Health and Retirement Study (HRS)

Participants—857 HRS participants who experienced hip fracture between 1992 and 2010, as identified by Medicare claims data.

Measurements—Outcome measure was death within one year of hip fracture. Predictor measures were participants' demographics, socio-economic status, social support health, geriatrics symptoms and function. We identified variables independently associated with one year mortality and used best subsets regression to identify the final model. The selected variables were weighted

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to create a risk index. The index was internally validated by using bootstrapping to estimate model optimism.

Results—Mean age at time of hip fracture was 84, and 76% of the participants were women. There were 235 deaths (27%) during the one year follow up. Five predictors of mortality were included in the final model: age over 90 (2 points); male (2 points); CHF (2 points); difficulty preparing meals (2 points); and not being able to drive (1 point). The point scores of the index were associated with one year mortality, with 0 points predicting 10% risk and 7–9 points predicting 66% risk. The c-statistic for the final model was 0.73, with an estimated optimism penalty of 0.01 indicating very little evidence of overfitting.

Conclusion—The prognostic index combines variables about demographics, comorbidities and function, and can be used to differentiate between patients at low and high risk of one year mortality after hip fracture.

Keywords

Hip Fracture; Prediction; Mortality

INTRODUCTION

In the Unites States, over 250,000 patients were admitted to the hospital for a hip fracture in 2010[1]. While the age adjusted incidence rate of hip fracture has been decreasing in recent years[2], the US population is aging, and it is estimated that by year 2030 there will be 12% increase in hospital admissions due to hip fracture[3]. Previous studies have shown that between 20% and 30% of the hip fracture patients die in the subsequent year[4].

Having a good prognostic tool identifying patients with higher risk of mortality is important for both clinicians and patients. Anticipating that a patient has limited life expectancy can guide the clinicians to focus on palliative care needs, caregiver needs, and quality of life. In patients at high risk of poor outcomes, the focus on palliative concerns does not necessarily preclude care focused on life prolongation and rehabilitation. However, evidence of a limited life expectancy should prompt clinicians to discuss goals of care with patients and families, so that decisions about any limits on care are informed and consistent with individuals' values.

Additionally, serious events that impact life expectancy, such as hip fracture, should lead to reassessments of the management of comorbid conditions such as diabetes and hypertension. Prognostication is crucial to these reassessments because some treatments for chronic conditions have only long term benefits, but the harms of treatment are immediate[5]. After hip fracture, assessment of prognosis can help identify patients with limited life expectancy in whom the immediate harms of tight control of diabetes and hypertension exceed the benefits that are only likely to occur in patients with longer life expectancy. Considering life expectancy can protect patients from the unnecessary physical and emotional burdens associated with overtreatment of these conditions both during the initial hospitalization and afterwards.

Despite the need of such prognostic tool, there is no nationally representative risk stratification index based on wide range of predictors. Several studies identified individual risk factors for mortality among patients with hip fracture. Some of those studies examined mortality risk factors in the general population[6], while others focused on narrow subgroups[4,7–9]. However, no study has used demographic and socioeconomic characteristics, as well as pre-hip fracture health and functional status, to develop a broadly representative risk stratification index. The goal of our study is not only to identify individual mortality risk factors among hip fracture patients, but to use those risk factors to identify patients with low, intermediate or high risk of mortality in the one year following hip fracture.

METHODS

Participants

The Health and Retirement Study (HRS) was designed to examine changes in health and wealth as people age[10]. It is an ongoing nationally representative longitudinal study of participants age 50 and older. The study started in 1992 and follow up surveys are administered every two years. If a participant is not able to complete an interview, the interview is conducted with a proxy respondent.

We examined participants 65 years old and older who had a documented hip fracture while enrolled in HRS, ascertained by linking the HRS survey data to Medicare claims. A participant was identified as having a hip fracture event if one of the following two conditions was met[11–16]: (1) the participant was admitted to a hospital with an admitting diagnosis ICD9 code for hip fracture “820.xx”; or (2) a surgeon’s charge for operative hip repair (CPT code 27230 – 27248) supported with either (a) a second surgeon’s charge within 2 days or (b) a supporting ICD9 procedure code for hip fracture surgery (ICD9 7855, 7905, 7915, 7925). We excluded admissions which were considered late effects from a prior hip fracture, identified by ICD9 codes 733.81, 733.82, 905.3, V540–V549.

Out of 25,146 HRS participants age 65 or older at any point between 1992 and 2010, 19,006 (76%) agreed to have their HRS surveys linked to the Medicare claims. We identified 1124 hip fracture events among those participants. Since we used Medicare claims to identify the presence of comorbid conditions prior to hip fracture event, we excluded hip fracture events that were not preceded by one continuous year of Medicare fee-for-service enrollment (107, 9%). Of the remaining 1017 hip fracture events, 160 (16%) had no HRS interview within 2.5 years before hip fracture event and were therefore excluded. This resulted in sample of 857 participants with hip fracture.

Measures

The outcome of interest was death in one year following hip fracture. The exact date of death was determined by National Death Index.

We considered 34 variables from five domains of risk known to predict mortality, as potential predictors of one year mortality after hip fracture. The variables were chosen using clinical judgement, as well as the variables’ significance in previous studies[17,18]. Previous studies also showed that combination of health, functional and socio-economic predictors has better predictive power than any one domain by itself[19,20] The domains included demographic characteristics, socioeconomic status (SES), comorbid conditions, geriatric symptoms and function. Demographics domain included age, gender, race/ethnicity, marital status, proxy respondent and residence in nursing home which were reported by the participant in the HRS interview. Education, income and wealth were considered in the SES domain. For the comorbid conditions domain we considered all the conditions included in Charlson comorbidity index[21], but we only included the conditions that are present in at least 5% of the subjects in our cohort. Those 11 conditions are listed in Table 1 and were determined by presence of the corresponding ICD9 diagnosis codes in Medicare claims at any point in one year period before hip fracture. The geriatric symptoms domain included participants' reports in HRS survey of falls in the past year and incontinence. The functional domain included measures of functional status, which were assessed at the HRS interview preceding the hip fracture event. Functional status measures consisted of measurements of Activities of Daily Living (ADL) difficulty and dependence, Instrumental Activities of Daily Living (IADL) difficulty, and difficulty in other functional activities. The full list of functional measures considered is included in Table 1. Difficulty in any functional measure was assessed in HRS by asking, for example, "Because of health or memory problem do you have any difficulty with bathing or showering?". For participants that answered "Yes" to this question, dependence in ADL was assessed by a follow up question, for example, "Does anyone ever help you bathe?". We created a summary ADL variable with four levels for our analysis: No difficulty in any of the 6 ADLs; Difficulty in one or more ADLS but no dependence in any; Dependence in one ADL; Dependence in more than one ADL. Participants were also asked if they were currently able to drive. For some activities such as preparing meals or driving, some subjects reported that they do not do or never did the activity. We classified these subjects as unable to do the activity. We performed a sensitivity analysis, classifying the subjects that reported that they do not do or never doing the activity as being able to the activity. The results of the sensitivity analysis were similar, and we only report the results of the original analysis.

Statistical Analysis

Using mortality within one year of hip fracture as a dichotomous variable, we examined bivariate relationships between mortality and each of the 34 predictors at 0.2 significance level. In the next stage of model development, all the significant relationships were considered simultaneously in a series of models, with the final model selected using the best subsets regression method. Best subsets regression is a procedure that identifies models with different subsets of predictors, but similar statistical properties. Among models with equivalent accuracy, some models may be of more clinical use because variables are easier to obtain or because a model is simpler to use in a clinical setting. The best subsets approach makes it possible to apply both statistical and clinical considerations in choosing a model by allowing us to choose the most clinically sensible model among models of nearly equivalent statistical accuracy.[22].

Our best subsets approach ranked each possible model using the Bayesian Information Criterion (BIC). The BIC computes a score based on the fit (accuracy of the model) and then penalizes the accuracy score for each variable in the model. The rationale for using the BIC score is that among models of similar accuracy, a model with fewer variables is easier to use. The authors reviewed the 10 models with the highest BIC scores and chose as the final model the one containing variables that are easiest to obtain in a clinical setting, and with the most clinical sensibility.

Next, each variable in the final model was then assigned a point value. The point value for each variable was calculated by dividing its logistic regression coefficient by the smallest of the coefficients and rounding to the nearest integer. [23]

Model discrimination was assessed using the c-statistic. We validated the final model by bootstrapping the entire model selection process 100 times[23]. Bootstrapping allows one to assess the extent to which the model fitting process led to overfitting of the model and thus an overly optimistic estimate of model discrimination. We used Harrell's method to calculate over optimism of the c-statistic[24]. Our estimate of how well the model would perform in new data was obtained by subtracting the estimate of over-optimism from the c-statistic of our final model. Finally, we assessed the model's calibration by comparing observed and predicted mortality rates for each score. The predicted mortality rate for a given score is the average of predicted probabilities for one year mortality for each individual with that score.

RESULTS

Characteristics of the Participants

The mean age at the time of hip fracture was 84 and 76% were women (see Table 1). Median time between the baseline interview and hip fracture was 12.6 months (IQR 5.9 – 19.0 months). Twenty percent of the interviews were administered to proxy respondents. Forty-three percent had a Charlson comorbidity score greater than two; the two most common comorbid conditions were Chronic Obstructive Pulmonary Disease (COPD) (34%) and Congestive Heart Failure (CHF) (30%). Eighteen percent reported difficulty, but no dependence, in one or more ADLs, while 26% were dependent in one or more ADLs. Sixty five percent of the participants had difficulty walking several blocks. During one year follow up 235 participants (27%) died.

Bivariable and Multivariable Results

Twenty seven of the 34 proposed predictor variables were significant predictors of one year mortality in bivariable analysis (Table 2). To identify the most important predictors, the 27 significant predictors were entered into a multivariable logistic regression using best subsets selection. The final model included two predictors from the demographics domain (age and gender), one comorbid condition (CHF), one IADL variable (difficulty preparing hot meals) and one variable from the other functional activities domain (ability to drive). The c-statistic for the final model was 0.73. Based on bootstrap validation, we estimate that overfitting led to an over optimism penalty of 0.01, resulting in an adjusted c-statistic of 0.72.

Risk Stratification by Points

Points were assigned to each of the final predictors (Table 3a) and a risk score was calculated for each participant by adding the points for each predictor. For example, a 70 year old (0 points) man (2 points) with CHF (2 points), with no difficulty driving (0 points) but with difficulty preparing hot meals (2 points) is assigned 6 points. Each one point increase in the predictor score is associated with an increased risk of mortality in one year (Table 3b) and there is a close relationship between predicted and observed risk. The lowest risk category (0 points) predicts a 9.6% one year mortality rate, and the observed mortality rate among those participants with 0 point score is 9.3%. Similarly, the highest risk category (7–10 points) predicts a 66.1% one year mortality, which corresponds well to the 60.9% observed mortality rate in that group.

DISCUSSION

We developed a prognostic index that can be used to predict the risk of one year mortality for patients with hip fracture, and accurately differentiate between patients at low and high risk. Our final index included variables from demographics, comorbid conditions and functional status domains. While our risk factors encompass multiple domains of health and function, the ability to assess risk with only five items makes this an easy tool to administer. All of the risk factors can be obtained by interviewing a patient or caregiver without having to administer tests or order lab tests. The index had good discrimination, differentiating between groups with mortality risks ranging from 10% to 66% (c-statistic = 0.72) and minimal evidence of overoptimism in the bootstrap validation (0.01). The index is well calibrated, as shown by similar observed and predicted mortality rates.

Previous studies have identified risk factors associated with mortality, but our index is the first to combine the risk factors into a tool that assigns individuals to distinct risk groups. Many previous studies have identified some of the variables in our index as risk factors for mortality after hip fracture[4,6–9]. The goal of our study was not only to identify individual risk factors, but to combine them into a tool that risk stratifies the patients better than any individual risk factor alone.

It is important to note that our tool is not intended to be used to determine immediate treatment for hip fracture, such as hip repair surgery. Our index should be used to identify the best decisions following the initial treatment. A trial of rehabilitation is indicated for most patients following hip fracture repair, and will probably be indicated even for most patients at high risk of one year mortality. However, while palliative care has traditionally not been part of hip fracture management, simultaneous provision of palliative care might be particularly appropriate for patients at the highest risk of mortality. Components of palliative care that might be useful include establishing goals of care, aggressive symptom control, and attention to the substantial caregiver needs that will likely accrue following hip fracture. The focus on these palliative concerns can improve the care of patients with limited prognosis, even if full efforts at life prolonging and rehabilitative care are pursued.

Most patients with hip fracture have multiple chronic conditions, and will continue to receive care for those conditions in the months after hip fracture. An assessment of prognosis can help guide therapies for those conditions but avoid treatments that have substantial risk, with little benefit in persons with limited life expectancy. For example, recent recommendations, such as those from the AGS Choosing Wisely group, suggest tight control be avoided those with limited life expectancy[25]. Most patients who experience hip fracture are likely to be frail and are unlikely to benefit from tight glucose control. In practice, however, many of these patients continue to have aggressive management, and those identified by our index as having highest mortality risk are a group in whom the harms of tight control are likely to markedly exceed the benefits. [26,27]

In addition to clinical care decisions, patients and families can benefit from discussion about patient's life expectancy. This prognostic index is another tool that physicians can use to provide patients and families with information necessary for informed decision making. Discussing prognosis soon after hip fracture can help families prepare for the possibility that a family member may not do well, and may help families adjust expectations about treatment outcomes and reduce family conflicts. Discussions with families predicted to be at higher risk for mortality can still allow for hope that the patient will do well with rehabilitation, but lead to discussions that may avoid burdensome treatments if the patient follows a downward trajectory following a trial of rehabilitation. Our study used two novel methods that have been increasingly recognized as improving the accuracy of prognostic prediction. First, we used best subsets regression instead of stepwise regression. Best subsets regressions allowed us to consider several models with similar statistical properties, but different risk factors[22]. This made it possible to consider both statistical and clinical issues in model selection, as the best subsets approach allows us to select the most clinically useful model among multiple alternative models of similar statistical accuracy. Second, we used the bootstrapping validation method instead of split sample validation[23]. In split sample validation, one part of the sample is used for development and the other for validation. Experts in predictive modeling uniformly criticize split sampling methods because the smaller development sample leads to a greater risk of error in variable selection and markedly increases the chance the model will not be transportable when applied to new data[28,29]. This would be particularly problematic in our study, because of the relatively limited sample size. Bootstrapping uses replacement methods to generate new samples within the original data set, and allows one to estimate the extent to which our modeling strategies led to an overly optimistic estimate of discrimination[23]. The bootstrap validation of our model suggested only a minimal degree of overfitting with the small overoptimism penalty reducing the c-statistic from 0.73 to 0.72.

Our findings and index development must take into account has several limitations. First, the data collected was within two years prior to hip fracture and not immediately before the event. However, no significant effect modification was noted when we evaluated the time of the interview to the effect of the predictors on mortality. Second, Medicare claims are not captured for patients in Medicare Managed Care, and therefore our index may not be generalize to those patients. Finally, proxy respondents provided information for about 20% of our respondents. However, other studies have shown that proxy responses of subjective health and functional measures are concordant with direct responses[30].

In summary, we have developed a tool to stratify hip fracture patients into low and high mortality groups in the year following their hip fracture event. This valuable information will allow clinicians, patients, and caregivers to consider prognosis after hip fracture when making important care decisions.

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Table 1

Characteristics of Subjects

Domain	Characteristic	%
Demographics	Age (mean ± SD)	83.8 ± 7.7
	Female	76.0
	Race	
	White	86.8
	Black	6.9
	Hispanic or Other	6.3
SES	Education Less than Income	44.1
	Income (Median, IQR)	16K (9K–30K)
	Wealth (Median, IQR)	77K (6K–261K)
Social Support	Married or partnered	34.7
	Proxy interview	19.5
	Nursing Home	9.2
Charlson Comorbidities	Myocardial Infarction	12.1
	CHF	29.5
	Peripheral Vascular Disease	17.0
	Cerebrovascular Disease	25.4
	COPD	33.7
	Dementia	15.5
	Diabetes	26.4
	Diabetes with Sequelae	6.9
	Chronic Renal Failure	12.3
	Ulcers	5.8
	Any Malignancy	15.2
	Depression[a]	33.7
ADL Dependencies	Bathing	20.0
	Transferring	6.6
	Dressing	13.3
	Eating	6.7
	Toileting	4.6
	Walk across room	8.1
IADL Difficulties	Using the telephone	20.6
	Managing finances	35.7
	Managing medications	17.6
	Shopping for groceries	41.4
	Preparing meals	34.6
Other Functional Measures	Walking several blocks	64.5

Domain	Characteristic	%
	Climbing one flight of stairs	19.0
	Lifting or carrying 10 pounds	56.9
	Picking up a dime	13.9
	Pushing or pulling large objects	62.2
	Not Able to Drive	57.0

Abbreviation: CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; ADL, activities of daily living; IADL, instrumental activities of daily living

[a]Depression was assessed using CESD instrument during HRS interview.

Table 2

Predictors of One Year Mortality – Unadjusted Results

Domain	Characteristic	Mortality, %	p-value
Demographics	Age		
	65–85	21.9%	<0.001
	85–90	25.9%	
	≥90	44.1%	
	Gender		
	Female	24.0%	<0.001
	Male	38.3%	
	Race		
	White	27.8%	0.769
	Black	23.7%	
SES Measures	Education		
	≥ HS Education	27.1%	0.835
	< HS Education	27.8%	
	Income		
	≥ Median	25.5%	0.220
	< Median	29.3%	
	Net worth		
	≥ Median	23.2%	0.006
	< Median	31.6%	
Social Support	Married or partnered		
	No	27.9%	0.607
	Yes	26.3%	
	Proxy interview		
	No	24.1%	<0.001
	Yes	41.3%	
	Nursing Home		
	No	25.2%	<0.001
	Yes	49.4%	
Charlson Conditions	Myocardial Infarction		
	Absent	26.3%	0.047
	Present	35.6%	
	CHF		
	Absent	20.7%	<0.001
	Present	43.5%	
	Peripheral Vascular Disease		
	Absent	25.3%	0.002
	Present	37.7%	
	Cerebrovascular Disease		

Domain	Characteristic	Mortality, %	p-value
	Absent	26.0%	0.105
	Present	31.7%	
	COPD		
	Absent	25.0%	0.026
	Present	32.2%	
	Dementia		
	Absent	25.7%	0.008
	Present	36.8%	
	Diabetes		
	Absent	25.8%	0.081
	Present	31.9%	
	Diabetes with Sequelae		
	Absent	26.7%	0.078
	Present	37.3%	
	Chronic Renal Failure		
	Absent	24.9%	<0.001
	Present	45.7%	
	Ulcers		
	Absent	27.0%	0.283
	Present	34.0%	
	Any Malignancy		
	Absent	26.3%	0.075
	Present	33.8%	
ADLs	ADL Summary		<0.001
	No Difficulty	23.1%	
	Difficulty with one or more	24.8%	
	Dependency in one	35.7%	
	Dependency in two or more	41.7%	
Difficulty with IADLs	Using the telephone		
	No Difficulty	23.7%	<0.001
	Difficulty, can't, or don't	42.0%	
	Managing finances		
	No Difficulty	21.1%	<0.001
	Difficulty, can't, or don't	38.9%	
	Managing medications		
	No Difficulty	24.5%	<0.001
	Difficulty, can't, or don't	41.1%	
	Shopping for groceries		
	No Difficulty	21.3%	<0.001
	Difficulty, can't, or don't	36.2%	
	Preparing meals		

Domain	Characteristic	Mortality, %	p-value
	No Difficulty	20.2%	<0.001
	Difficulty, can't, or don't	41.2%	
Difficulty with Other Functional Measures	Walking several blocks		
	No Difficulty	19.4%	<0.001
	Difficulty, can't, or don't	31.8%	
	Climbing one flight of stairs		
	No Difficulty	23.6%	0.010
	Difficulty, can't, or don't	31.4%	
	Lift or carry 10 lbs.		
	No Difficulty	24.5%	0.094
	Difficulty, can't, or don't	29.7%	
	Picking up a dime		
	No Difficulty	26.5%	0.194
	Difficulty, can't, or don't	32.2%	
	Pushing or pulling large objects		
	No Difficulty	24.1%	0.100
	Difficulty, can't, or don't	29.3%	
	Able to Drive		
	Yes	19.2%	<0.001
	Not able, or never did	33.7%	

Abbreviation: CHF, congestive heart failure; COPD, chronic obstructive pulmonary disease; ADL, activities of daily living; IADL, instrumental activities of daily living

Table 3a

Multivariate Predictors of Mortality[a]

Risk Factor	Adjusted OR (95% CI)	Points
Male	2.36 (1.62,3.44)	2
Age ≥ 90	2.08 (1.37,3.15)	2
CHF	2.66 (1.91,3.73)	2
Difficulty Preparing Meals	1.94 (1.34,2.80)	2
Not Able to Drive	1.48 (0.99,2.22)	1

Abbreviation: OR, odds ratio; CI, confidence interval; CHF, congestive heart failure

[a]Each OR was adjusted for the other risk factors in the table.

Table 3b

Calibration of the Prognostic Index[a]

Points	N	Observed Mortality	Average Predicted Mortality
0	173	16 (9.3%)	9.6%
1	102	11 (10.8%)	14.2%
2	140	27 (19.3%)	20.4%
3	190	57 (30.0%)	26.8%
4	46	21 (45.6%)	37.2%
5	122	53 (43.4%)	44.5%
6	15	8 (53.3%)	55.5%
7–9	69	42 (60.9%)	66.1%

[a]For each score, observed mortality is the proportion of individuals that died within one year, and average predicted mortality is the average of predicted probabilities for each individual.