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CLINICAL RESEARCH STUDY

A Prognostic Model for 1-Year Mortality in Older Adults after Hospital Discharge

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ABSTRACT

PURPOSE: To develop and validate a prognostic index for 1-year mortality of hospitalized older adults using standard administrative data readily available after discharge.

SUBJECTS AND METHODS: The prognostic index was developed and validated retrospectively in 6382 older adults discharged from general medicine services at an urban teaching hospital over a 4-year period. Potential risk factors for 1-year mortality were obtained from administrative data and examined using logistic regression models. Each risk factor associated independently with mortality was assigned a weight based on the odds ratios, and risk scores were calculated for each patient by adding the points of each independent risk factor present. Patients in the development cohort were divided into quartiles of risk based on their final risk score. A similar analysis was performed on the validation cohort to confirm the original results.

RESULTS: Risk factors independently associated with 1-year mortality included: aged 70 to 74 years (1 point); aged 75 years and greater (2 points); length of stay at least 5 days (1 point); discharge to nursing home (1 point); metastatic cancer (2 points); and other comorbidities (congestive heart failure, peripheral vascular disease, renal disease, hematologic or solid, nonmetastatic malignancy, and dementia, each 1 point). In the derivation cohort, 1-year mortality was 11% in the lowest-risk group (0 or 1 point) and 48% in the highest-risk group (4 or greater points). Similarly, in the validation cohort, 1-year mortality was 11% in the lowest risk group and 45% in the highest-risk group. The area under the receiver operating characteristic curve was 0.70 for the derivation cohort and 0.68 for the validation cohort.

CONCLUSION: Reasonable prognostic information for 1-year mortality in older patients discharged from general medicine services can be derived from administrative data to identify high-risk groups of persons.

KEYWORDS: Prognosis; Geriatrics; Prediction; Mortality

Modern medicine and public health advancements have led to greater numbers of older persons living with chronic, debilitating illnesses for which there are limited or no curative therapies. Health care systems are facing increasing responsibility for addressing the need for supportive services throughout the continuum of illness and during end-of-life care.[1,2] Unfortunately, many clinicians do not discuss palliative care and hospice options until very late in the disease course when patients and families are unable to benefit fully from these resources.[3] An important barrier to palliative care is the ability to identify patients at higher risk for mortality earlier in the illness trajectory.[4] Identifying persons at greatest risk for death could prompt health care providers to reassess goals of care, redefine medically necessary therapies, focus on symptom control, assess other physical, psychosocial, and spiritual problems, and consider earlier palliative care consultation and hospice referral.[5]

Prognostication has been recognized as an important but often neglected part of patient management, especially for discussions of goals of care, treatment preferences, advance planning, and clinical therapeutic options.[4,6] There are a few prognostic indices available for predicting mortality in hospitalized older adults, but their use has not been incorpo-

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rated into routine medical practice. Some existing models are applicable only to specific patient populations and disease states[7-9] or require subjective assessments of risk by clinicians.[10] Others require use of lengthy formulas[11] or knowledge of certain laboratory data and functional status,[12,13] which are not always available in a patient's chart.[14] Persons with chronic, progressive, and disabling illnesses often require hospitalization in the last year of life, leading to further functional decline and morbidity.[15,16] Hospitalization therefore may present a key trigger point for identifying persons at greatest risk for mortality in the ensuing year.

The goal of this study was to develop an easy-to-use prognostic index for older patients on general medical wards using information readily available from standard administrative data shortly after hospital discharge.

CLINICAL SIGNIFICANCE

- More than a quarter of patients aged 65 years and older were deceased within a year after hospital discharge.
- A point system created from administrative data can provide reasonable prognostic information to sort patients into groups of risk for mortality.
- Mortality risk stratification can help physicians and family members plan for the care of patients who may be at increased risk of death in the coming year.

METHODS

Participants

The data used in these analyses were collected on individuals enrolled in a prospective cohort study comparing costs and outcomes of care by hospitalist and non-hospitalist physicians. It was conducted on an academic general medicine service at the University of Chicago Hospitals in Chicago, Ill from July 1, 1997 through June 30, 2001. The study included 14,661 patients admitted to the general medicine service either directly or transferred from nonmedical services or intensive care. Details of the study are published elsewhere.[17] This study involved an analysis of the subset of patients who were aged 65 years and older. Because it focused on survival of patients after discharge, those who died in the hospital were excluded. Patients admitted July 1997 through June 1999 were used as the derivation cohort, and those admitted from July 1999 through June 2001 were used to validate the model. Of the 6534 patients in the derivation cohort, 2839 (44%) were aged 65 years and older, and of these, 100 (4%) died in the hospital and were excluded. Of the 8127 patients in the validation cohort, 3780 (47%) were aged 65 years and older, of which 137 (4%) died in the hospital and were excluded. This study was approved by the Institutional Review Board at the University of Chicago.

Data Collection and Measurements

Administrative data were accessed using software from Transitions Systems, Inc., which contains all of the ICD-9 codes required for billing for Medicare and other payers. All primary and secondary code diagnoses in ICD-9 codes of all outpatient and inpatient encounters in the year before the index hospital admission were extracted. These ICD-9 codes were then used to create indicator variables for 14 co-morbid conditions defined by Romano et al that extended earlier work by Deyo et al constructing a claims-based measure of comorbidity based on the Charlson Index.[18,19] Comorbid conditions were coded as present or absent with the exception of cancer, which was coded as either absent, solitary malignancy, or metastatic solid tumor. Hematologic malignancies were included with solitary tumors.

Other risk factors for 1-year mortality were chosen based on clinical relevance, prevalence in the sample, and ease of abstraction from data (Table 1). Age was divided into 5-year intervals. Length of hospital stay was categorized as <5 days or ≥5 days, based on the mean length of stay in the derivation cohort.

Outcome

The outcome of interest was death within 1 year after hospital discharge. Mortality was assessed 365 days from the day of discharge by linking patients with the Social Security Death Index.[20] Survival status and date of death were matched to the patient according to social security number, name, and date of birth. Data on survival status were obtained on 99.8% of the subjects.

Prognostic Index Derivation

Bivariate relationships between potential risk factors and mortality were assessed in the derivation cohort using logistic regression models. Significant variables ($P < .05$) were entered into a multiple logistic regression model. Risk factors that remained significant after adjustment ($P < .05$) were used to create the predictive model.

The accuracy of this model was evaluated using methods similar to those employed by Walter et al.[12] Risk of death for each subject was estimated based on the final logistic regression model in the development cohort. The subjects were divided into quartiles of risk. The predictive accuracy of the logistic regression model was determined by comparing predicted and observed mortality in the validation cohort.

A 1-year mortality risk scoring system was created by assigning points to each risk factor by dividing each beta coefficient in the model by the lowest beta coefficient (congestive heart failure) and rounding to the nearest integer.[12,21] A risk score was determined for each subject by adding up the points for each risk factor present. Subjects in the derivation and validation cohorts were divided into

Table 1 Characteristics of Patients in Derivation and Validation Cohorts

Characteristic	Derivation (n = 2739) n (%)	Validation (n = 3643) n (%)	*P* Value
Age, years			
Mean (SD)	78 (8.3)	78 (8.1)	.15
65-69	533 (19)	624 (17)	.05
70-74	566 (21)	723 (20)	
75-79	581 (21)	825 (23)	
80-84	451 (16)	676 (19)	
85-89	336 (12)	456 (12)	
≥90	272 (10)	339 (9)	
Women	1733 (63)	2372 (65)	.13
Discharge to nursing home or skilled nursing facility	415 (15)	602 (17)	.16
Length of stay ≥5 days	967 (35)	1116 (31)	<.001
Dead at 1 year	722 (26)	950 (26)	
Comorbid conditions			
Myocardial infarction	344 (13)	512 (14)	.08
Congestive heart failure	635 (23)	879 (24)	.38
PVD	441 (16)	611 (17)	.47
Cerebrovascular disease	367 (13)	501 (14)	.68
Dementia	322 (12)	422 (12)	.83
COPD	743 (27)	881 (24)	.008
Rheumatologic disease	162 (6)	189 (5)	.21
Peptic ulcer disease	107 (4)	75 (2)	<.001
Diabetes	916 (31)	1382 (38)	<.001
Renal disease	323 (13)	452 (12)	.46
Liver disease	50 (2)	84 (2)	.19
Hematologic and solid malignancy	468 (17)	504 (14)	<.001
Metastatic cancer	206 (8)	156 (4)	<.001
Acquired immune deficiency syndrome	9 (0.3)	3 (0.08)	.03

PVD = peripheral vascular disease; COPD = chronic obstructive pulmonary disease.

quartiles based on their risk scores. The prognostic accuracy of the predicted mortality was determined by comparing predicted and observed mortality across these quartiles of predicted mortality in both cohorts.[21] Kaplan-Meier curves were used to examine the performance of the prognostic index.

Finally, the area under the receiver operating characteristic (ROC) curves was calculated for the logistic regression model for the development and validation cohorts.

RESULTS

Study Populations

Characteristics of the derivation and validation cohorts are listed in Table 1. The mean (SD) age of the patients in the derivation cohort was 78 (8.3) years. Sixty-three percent were female, 81% were African American, and 15% were discharged to a nursing home or skilled nursing facility. Thirty-five percent had a length of stay of at least 5 days in the hospital before discharge. During 1-year of follow-up, 722 patients (26%) died.

The mean (SD) age of the patients in the validation cohort was 78 (8.1) years. Sixty-five percent were female, 80% were African American, and 17% were discharged to a nursing home or skilled nursing facility. Thirty-one percent had a length of stay at least 5 days in the hospital before discharge. During 1-year of follow-up, 950 patients (26%) died.

Derivation of the Prognostic Index

Risk factors with significant bivariate associations with 1-year mortality are listed in Table 2. Of these, age >70 years, length of stay at least 5 days, discharge to nursing home, congestive heart failure, peripheral vascular disease, dementia, hematologic and solid malignancy, and metastatic cancer remained significantly associated after adjustment (Table 3). By quartiles of risk, 1-year mortality ranged from 11% in the lowest-risk quartile to 48% in the highest risk quartile in the derivation cohort and from 11% to 45% in the validation cohort (Table 4, top panel). There was good calibration of the model, with close agreement between observed and predicted mortality across the risk quartiles.

Table 2 Bivariate Associations of Risk Factors and 1-Year Mortality in Derivation Cohort

Characteristic	Odds Ratio (CI)	*P* Value
Age, years		
70-74	1.6 (1.2-2.2)	<.001
75-79	2.1 (1.6-2.9)	
80-84	1.9 (1.4-2.6)	
85-89	2.8 (2.0-3.9)	
≥90	3.0 (2.1-4.2)	
Women	0.9 (0.7-1.0)	.06
Discharge to nursing home or skilled nursing facility	2.0 (1.6-2.5)	<.001
Length of stay ≥5 days	1.7 (1.5-2.1)	<.001
Comorbid conditions		
Myocardial infarction	1.0 (0.8-1.3)	.86
Congestive heart failure	1.4 (1.2-1.7)	<.001
Peripheral vascular disease	1.9 (1.5-2.3)	<.001
Cerebrovascular disease	1.4 (1.1-1.8)	.002
Dementia	2.0 (1.6-2.6)	<.001
Chronic obstructive pulmonary disease	1.0 (0.8-1.2)	.71
Rheumatologic disease	0.9 (0.6-1.2)	.39
Peptic ulcer disease	1.8 (1.2-2.7)	.005
Diabetes	0.8 (0.7-0.9)	.02
Renal disease	1.8 (1.4-2.3)	<.001
Liver disease	1.2 (0.7-2.2)	.56
Hematologic and solid malignancy	2.3 (1.9-2.8)	<.001
Metastatic cancer	3.8 (2.9-5.1)	<.001
Acquired immune deficiency syndrome	2.2 (0.6-8.4)	.23

CI = 95% confidence interval.

Table 3 Risk Factors Associated with 1-Year Mortality in Derivation Cohort in Multivariate Analyses

Characteristic	Odds Ratio (CI)	*P* Value	Points
Age, years			
70-74	1.6 (1.2-2.2)	.003	1
75-79	2.2 (1.6-3)	<.001	2
80-84	2 (1.4-2.8)	<.002	2
85-89	2.9 (2.1-4.1)	<.003	2
≥90	3 (2.1-4.4)	<.004	2
Discharge to nursing home or skilled nursing facility	1.7 (1.4-2.2)	<.005	1
Length of stay ≥5 days	1.5 (1.3-1.8)	<.006	1
Comorbid conditions			
Congestive heart failure	1.3 (1.1-1.7)	.005	1
PVD	1.8 (1.4-2.3)	<.001	1
Dementia	1.6 (1.2-2.1)	<.001	1
Renal disease	1.7 (1.3-2.2)	<.001	1
Hematologic and solid malignancy	1.7 (1.3-2.1)	<.001	1
Metastatic cancer	3.1 (2.2-4.4)	<.001	2

CI = 95% confidence interval; PVD = peripheral vascular disease.

The ROC curve area was also similar between the derivation and validation cohorts, 0.70 and 0.68, respectively.

Prognostic Risk Scoring System

The points assigned to each of the 9 final risk factors in the prognostic scoring system are listed in Table 3. A final risk score was calculated by adding the points designated for each risk factor. For example, a 90-year-old patient (2 points) with congestive heart failure (1 point) and who is discharged to a nursing home (1 point) will have a final risk score of 4 points.

Patients were divided into risk groups of roughly equal size based on their risk scores (Table 4, bottom panel). In the derivation cohort, mortality ranged from 14% in the lowest-risk group (0 to 1 point) to 46% in the highest risk group (at least 4 points). Similar results were found in the validation cohort with the low-risk group and highest risk groups having a 1-year mortality of 14% and 42%, respectively. The ROC curve areas for the derivation and validation cohorts were similar, 0.67 and 0.65, respectively.

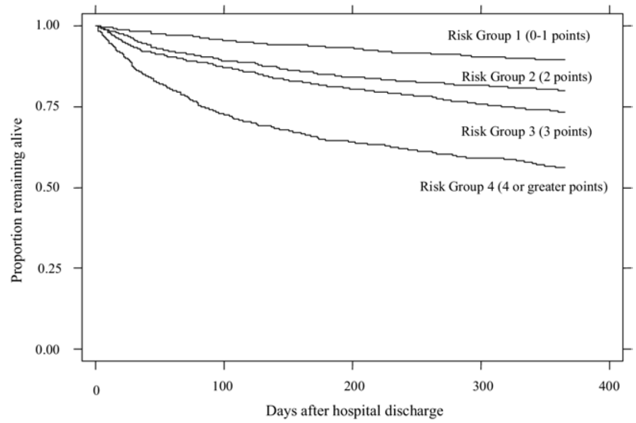

Figure Kaplan-Meier survival curve for the validation cohort, stratified by risk groups.

Kaplan-Meier survival curves for both the derivation and validation cohorts were nearly identical (data on all subjects not shown). The survival curve for the validation cohort demonstrates that the 4 risk groups have survival trajectories that diverge early after hospital discharge (Figure 1). For example, 3 months after discharge, approximately 25% of the high risk patients (group 4) were already deceased, compared with <5% in the lowest quartile (group 1).

DISCUSSION

We have created a relatively simple prognostic index for older adults discharged from a general medicine service that stratifies patients at risk for 1-year mortality using information readily available from standard administrative data.

Table 4 Validation of Prognostic Index: 1-Year Mortality in Derivation and Validation Cohorts by Risk Strata

	Derivation Cohort		Validation Cohort	
Risk Strata	n = Died/At Risk*	% (CI)	n = Died/At Risk	% (CI)
Quartile of risk				
1	68/636	11 (8-13)	90/853	11 (8-13)
2	119/698	17 (14-20)	199/959	21 (18-23)
3	207/711	29 (26-32)	249/910	27 (24-31)
4	325/683	48 (44-51)	412/921	45 (42-48)
ROC curve area	0.7		0.68	
Risk group by points				
0-1	110/799	14 (11-16)	155/1104	14 (12-16)
2	130/719	18 (15-21)	233/953	24 (22-27)
3	180/563	32 (28-36)	242/818	30 (26-33)
≥4	299/647	46 (42-50)	320/768	42 (38-45)
ROC curve area	0.67		0.65	

ROC = receiver operating characteristic; CI = 95% confidence interval.
*Data on mortality missing on 11 subjects.

Because many Medicare beneficiaries are hospitalized at least once in the year before death,[22] the hospital admission becomes an important window of opportunity for recognizing persons at risk for further decline and mortality. As medical records are becoming more electronically based, this prognostic data can be generated from a computerized support system using standard Medicare billing forms shortly after a patient is discharged from the hospital and made available to primary care physicians. Indeed, ICD-9 code data are currently readily available in hospitals and other health care systems and can be easily accessed by trained personnel. Future validation work may lead to development of a pocket-sized card or program for personalized digital assistants that clinicians can apply routinely using ICD-9 code data that are readily available from discharge summaries or online records once a patient is discharged. This information can, in turn, prompt clinicians to initiate discussions on advance care planning and goals of care in their patients who may be at an increased risk of dying in the ensuing year.

As the number of older persons living with serious chronic diseases grows, more persons will be in need of palliative care support. Optimal care involves advance planning and evaluating goals of care over the course of the illness with attention to symptom management, caregiver support, and thoughtful use of resources. One might argue that all older adults admitted to the hospital are at risk for further decline, and this should prompt discussions of goals of care and advance care planning in everyone. Although physicians commonly encounter situations requiring the use of prognostication, they often feel poorly prepared for it.[23] They find it stressful, and often avoid delivering prognostic information even if the patient requests it.[24,25] They may refrain from hospice discussions because of the constraints of hospice eligibility requirements and the difficulty in predicting death within 6 months.[26] This prognostic tool may help overcome these barriers by providing objective information that distinguishes high-risk groups of patients who may benefit from palliative care resources. Lynn has suggested that "comprehensive end-of-life services are best triggered by recognition that the patient is sick enough that 'dying this year would not be a surprise'. Rather than targeting patients who 'will die'. . . programs for end-of-life care should target those who 'reasonably might die'."[5] Indeed, identifying patients further "upstream" from hospice eligibility and imminent death fits with the broader movement within palliative care to offer aggressive symptom management and supportive care to anyone suffering from advanced illness, even if they are pursuing active disease-specific treatment or cure of the underlying condition.[27] For example, recently hospitalized patients found to be at increased risk of death in 1 year may be referred to an outpatient palliative care program that provides services to patients facing serious illnesses.[28,29]

This model's performance is modest compared with other sophisticated tools such as SUPPORT (ROC = 0.79) and APACHE (ROC = 0.90), but this model does not require additional data collection and complex calculations of these other tools.[7,11] It is most useful in sorting patients into groups of risk; therefore, clinical decisions on individual patients should not be based on the risk strata alone.

There are several additional reasons to suspect that the ready delivery of prognostic information may be of value for patients and the health care system. First, widespread media attention to end-of-life care has increased public awareness of the importance of these issues.[30] Second, efforts to control rising health care costs have provided hospitals, managed care organizations, and payers increasing incentives to more efficiently allocate expenditures for patients likely to be close to the end of life. Third, independent of cost considerations, better identification of patients at high risk of death may lead to earlier hospice referral, redefining the usefulness of medical therapies, and enhanced provision of comfort measures. Finally, prognostic estimates allow comparison of outcomes between health care providers or health care delivery systems in order to improve future medical care.[4] Another potential use for this prognostic model may be in risk-adjusting postdischarge outcomes (eg, comparing home care providers) when only administrative data are available.

This study has several limitations. First, it was developed and validated at a single site in a university hospital setting. Second, the demographics of our population include predominantly African American persons, which may not represent hospital settings with other ethnic and racial populations. Third, length of stay and nursing home placement vary regionally, which may alter the performance of the model in other sites. As with other prognostic indices, the validity and generalizability of this model needs to be tested in other locations with different groups of patients.[31-33] Also, with the exception of coding for malignancy, this index does not account for severity of comorbid conditions, which is often not available in administrative data sets. Lack of severity rating could potentially weaken the model's predictability. In addition, this prognostic model does not include laboratory data or functional status that might have improved its performance. However, although the prognostic importance of functional decline has been well documented in the literature,[13,34,35] the clinical reality is that accurate documentation of Activities of Daily Living is lacking in up to 98% of medical charts.[14] Additional variables might improve the model's precision but at the cost of requiring other information often lacking in administrative data, thus making it less likely to be used in routine clinical practice. Lastly, because this model was derived from data in patients aged 65 years and older, it may not be applicable to a younger population.

In summary, this prognostic index provides a reasonable method for identifying older persons at high risk for 1-year mortality after surviving a hospital stay. Hospital discharge may be the window of opportunity for identifying prognostic issues and initiating future discussions on advance directives, patient preferences, and future goals of care. Although many advocate discussing advance directives with all patients, use of this prognostic index may at least encourage clinicians who do not universally discuss advance directives to have discussions with individuals at greatest risk of death. This prognostic information may be most useful to the primary care provider once the patient has left the hospital and is recovering from an acute illness. In addition, hospitals and other health care systems may use this prognostic information for quality improvement efforts in increasing advance directives and hospice referrals in high-risk patients.

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