A Clinical Index to Stratify Hospitalized Older Adults According to Risk for New-Onset Disability

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BACKGROUND: Many older adults who are independent prior to hospitalization develop a new disability by hospital discharge. Early risk stratification for new-onset disability may improve care. Thus, this study's objective was to develop and validate a clinical index to determine, at admission, risk for new-onset disability among older, hospitalized adults at discharge.

DESIGN: Data analyses derived from two prospective studies.

SETTING: Two teaching hospitals in Ohio.

PARTICIPANTS: Eight hundred eighty-five patients aged 70 years and older were discharged from a general medical service at a tertiary care hospital (mean age 78, 59% female) and 753 patients discharged from a separate community teaching hospital (mean age 79, 63% female). All participants reported being independent in five activities of daily living (ADLs: bathing, dressing, transferring, toileting, and eating) 2 weeks before admission.

MEASUREMENTS: New-onset disability, defined as a new need for personal assistance in one or more ADLs at discharge in participants who were independent 2 weeks before hospital admission.

RESULTS: Seven independent risk factors known on admission were identified and weighted using logistic regression: age (80–89, 1 point; ≥90, 2 points); dependence in three or more instrumental ADLs at baseline (2 points); impaired mobility at baseline (unable to run, 1 point; unable to climb stairs, 2 points); dependence in ADLs at admission (2–3 ADLs, 1 point; 4–5 ADLs, 3 points); acute stroke or metastatic cancer (2 points); severe cognitive impairment (1 point); and albumin less than 3.0 g/dL (2 points). New-onset disability occurred in 6%, 13%, 18%, 34%, 35%, 45%, 50%, and 87% of participants with 0, 1, 2, 3, 4, 5, 6, and 7 or more points, respectively, in the derivation cohort (area under the receiver operating characteristic curve (AUC) = 0.784), and in 8%, 10%, 27%, 38%, 44%, 45%, 58%, and 83%, respectively, in the validation cohort (AUC = 0.784). The risk score also predicted ($P < .001$) disability severity, nursing home placement, and long-term survival.

CONCLUSION: This clinical index determines risk for new-onset disability in hospitalized older adults and may inform clinical care. **J Am Geriatr Soc 2011.**

Key words: hospitalization; prognosis; disability; activities of daily living

Acute illness and hospitalization often lead to disability in older adults,[1–4] increasing the odds of disability 60 times and accounting for nearly half of all new cases of disability.[3] New-onset disability is defined as a recent transition from independence to dependence on another person to perform basic activities of daily living (ADLs), such as bathing, dressing, transferring from a chair, or using a toilet. This new-onset disability at hospital discharge often heralds long-term institutionalization, repeated hospitalizations, and death.[5,6] However, acute illness and hospitalization do not lead uniformly to functional decline, and disability after hospitalization and is sometimes preventable or reversible.[3,7–9]

The accurate stratification of hospitalized older adults according to their disability risk would allow the targeting of interventions to those at high risk. Although previous efforts have identified risk factors for functional decline[10] and developed screening tools in various clinical populations,[11–15] none has focused specifically on new-onset disability (new ADL dependence in hospitalized older adults who were independent

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before hospitalization—those for whom preventive and restorative measures may have the greatest effect).

Therefore, a clinical index was developed and validated to predict new-onset disability at hospital discharge in adults aged 70 and older who were independent in all ADLs 2 weeks before hospitalization. Based on conceptual models of disablement[16] and studies of its risk factors,[1–3,17,18] it was hypothesized that predisposing factors that indicate proximity to the threshold of disability (e.g., poor mobility), the effect of acute illness on function at admission, and inhibitors of recovery (e.g., cognitive impairment, malnutrition, or very old age) would predict new-onset disability. Potential predictors that are easily determined on admission, including sociodemographic, clinical, and functional characteristics, were considered. The goal was to develop a prognostic index that can be used to inform clinical decisions.

METHODS

Participants

Participants were drawn from two prospective studies of an intervention to improve functional outcomes of hospitalized older adults in two teaching hospitals in Ohio.[19,20] Participants aged 70 and older who had emergency admissions to the general medical services between 1993 and 1998 were eligible. Exclusion criteria were admission to an intensive care unit or oncology ward, elective admission, or length of stay less than 2 days. Of 11,475 patients meeting eligibility criteria, 3,163 were randomly selected and enrolled in the original studies. The demographic, clinical, and functional characteristics of study participants enrolled were similar to those of people not enrolled.[20] The original prospective studies included 1,632 participants at one site and 1,531 at the second site. Participants were randomized at admission to an intervention unit or a usual care unit using a block design that was determined a priori. Computer-generated random numbers were put in opaque envelopes that the admitting desk clerk opened sequentially. Seventy-nine participants were not admitted to the unit of randomization. The intervention was a multicomponent intervention including a special environment, patient-centered care, discharge planning, and review of medical care to reduce functional disability. ADL decline from baseline to discharge did not differ in the intervention (30%) and usual care (34%) groups ($P = .11$).[20] These results were similar when analyzed using intention-to-treat or per-protocol analysis. In addition, the intervention and usual care groups did not differ significantly in their admission characteristics or self-reported measures of function at discharge.[19,20]

Of the 3,163 participants in the original studies, 1,656 reported that they did not require personal assistance 2 weeks before admission in any of five ADLs: bathing, dressing, transferring from bed to chair, using a toilet, and eating. For 18 participants, ADL information was missing at hospital discharge, leaving an analytical sample of 1,638. The clinical index was developed in a community teaching hospital (n = 885) and then validated in a university teaching hospital (n = 753) to test its transportability and accuracy.

Data Collection and Measurements

Trained interviewers obtained data from participants and surrogates, and trained chart abstractors obtained data from medical records. Standardized interviews were completed at hospital admission and discharge. On admission, participants were asked about sociodemographic characteristics, their health, and ADL and instrumental ADL (IADL) function at two time points: 2 weeks before admission and at admission. On discharge, participants were asked about ADL and IADL function. IADLs were using the telephone, transportation, shopping, preparing meals, doing housework, taking medicines and handling money.[21] Prior work has demonstrated the validity of self-report of function.[22] Surrogates were interviewed if the participant had more than five errors on the Short Portable Mental Status Questionnaire[23] (SPMSQ) or if the participant was too ill to communicate.

Outcomes

The outcome of main interest was disability at hospital discharge, which was defined as need for personal assistance in performing one or more ADLs as reported to a trained interviewer by the participant or the surrogate, who was generally the participant's primary nurse. ADL function was measured using a modified version of the Katz index of five ADLs: bathing, dressing, transferring from bed to chair, using a toilet, and eating.[24] Because too few participants died in the hospital to identify separate predictors of death, the primary outcome for this study was the composite outcome disability at hospital discharge or death in hospital. Secondary outcomes included catastrophic disability (defined as dependence in three or more ADLs), nursing home placement at discharge, and long-term survival through December 31, 2009, confirmed by review of the National Death Index and a search of Ohio state death records.

Predictor Variables

Sociodemographic, clinical, and functional characteristics were considered as potential predictors of disability as conceptualized in the disablement model.[16] Sociodemographic characteristics included age, sex, marital status, self-identified race, educational level, and current living situation. Clinical characteristics included the reason for admission, comorbid illnesses (Charlson Comorbidity Index),[25] and acute severity of illness as indicated by the acute physiology component of the Acute Physiology and Chronic Health Evaluation (APACHE) II;[26] Charlson and APACHE scores were then divided into tertiles. For laboratory values, the University Hospitals of Cleveland clinical chemistry laboratory measured creatinine, hematocrit, and albumin. Creatinine and hematocrit were evaluated using tertiles and albumin using an a priori defined clinically relevant cut point. Severe cognitive impairment was defined according to medical record documentation of dementia, five or more errors on the SPMSQ, or inability to complete the SPMSQ.[23] Depressive symptoms were evaluated using the 10-item modified version of the Center for Epidemiologic Study Depression Scale (CES-D) and evaluated using a cut point of four or more symptoms.[27] Self-rated general health was reported as excellent, very good, good, fair, or poor.[28]

Potential predictors included ADL function on admission (but not 2 weeks before admission, when all participants were independent in ADLs) and instrumental ADL (IADL) function, walking, and gait, at two time points (2

weeks before admission and on admission). IADLs were assessed as 1 point per dependency in using the telephone, transportation, shopping, preparing meals, doing housework, taking medicines, and handling money.[29] Dependence was defined as needing the help of another person. IADLs were then evaluated in three groups, participants who were independent in all IADLs, dependent in one or two IADLs, and dependent in three or more IADLs. Walking ability was determined using a hierarchical scale based on participant reports of inability to run a short distance, walk up stairs or a hill, walk a block or more, or none of these.[30] Gait was classified as steady or unsteady according to participant reports.[31]

Missing Data

For most variables, data were missing for fewer than 2% of participants. To avoid dropping participants with missing data, a multiple imputation strategy was used incorporating the Imputation for Chained Equations (ICE) library and the multiply imputed missing (mim) library[32] in Stata version 10 (Stata Corp., College Station, TX). Analyses were calculated twice—with imputation and by dropping cases with missing values. Because the results did not vary substantially, the multiple imputation results were reported as the primary findings.

Analytical Strategy

This study sought to develop separate models to predict new-onset disability and death in the derivation cohort and to test the models in the validation cohort. Because too few participants died to allow the development of separate models, a model to predict the composite outcome disability or death at discharge was constructed; this composite outcome is referred to as "new-onset disability."[33] A secondary analysis was also performed excluding participants who died that gave results similar to those of the primary analysis, which are reported.

Bivariate associations between each characteristic and the composite outcome of disability or death at hospital discharge were assessed using single-predictor logistic regression analysis in the derivation cohort. To build a risk index for new-onset disability, multivariate logistic regression analyses were conducted using the best subsets methodology, as recommended, to incorporate biological plausibility and clinical utility in the selection of prognostic models.[34] The score selection option of Proc Logistic in SAS 9.2 (SAS Institute, Inc., Cary, NC) was used. Best subsets regression produces a number of models with an increasing set of predictors. In this instance, a range of models with 1 to 20 predictors was evaluated. Several models of similar predictive power, reflected in statistically indistinguishable score statistics between many pairs of models, were then compared. The clinical relevance and practicality of potential predictors were then considered to select the final model from this larger set. In contrast, stepwise selection methods, which are extremely common in the literature, calculate only a single model; the natural tendency is to accord special status to this single model even though it is nearly always statistically indistinguishable from an extraordinarily large number of alternative models and it is not guaranteed to be the optimal model according to any known statistical criterion. To construct a clinical index, points were assigned to each predictor by dividing the β coefficient in the logistic model by the lowest β coefficient and rounding to the nearest integer.[35] A risk score was calculated for each participant by summing the points assigned for each risk factor. The frequency of new-onset disability for each risk score was determined.

The clinical index was tested at a different site because this form of prospective validation testing assesses the generalizability of the model, as well as its accuracy.[36,37] The predictive validity of the logistic model and the clinical index were assessed by comparing the frequency of new-onset disability observed in the validation cohort with the predicted frequency using the Hosmer-Lemeshow test (calibration) and by calculating the area under the receiver operating characteristic curve (AUC) in the derivation and validation cohorts (discrimination).[38]

To provide further information about the index's potential clinical significance,[39] the relationship between risk score and three other outcomes at discharge were examined: the number of ADL dependencies that participants were dependent in, catastrophic disability, and nursing home placement. The index's performance was then examined in specific subgroups defined according to age, sex, cognitive status, and ADL function at admission. To determine whether the clinical index had similar discrimination in the intervention and usual care groups, its performance in all participants in the intervention group was compared with its performance in all participants in the usual care group. Finally, the relationship between risk score and survival from hospital discharge through 2009 was tested.

RESULTS

Characteristics of Participants

The mean age ± standard deviation of participants in the derivation cohort (n = 885) was 78 ± 6; 59% were women, and 89% were white (Table 1). On admission, medical conditions included chronic lung disease (27%), congestive heart failure (24%), diabetes mellitus (23%), and severe cognitive impairment (17%), and 346 participants (39%) were dependent in one or more ADLs. At discharge, 242 (27%) were dependent in one or more ADLs, and 633 (72%) were independent in all ADLs; 10 participants (1%) had died.

The mean age of participants in the validation cohort (n = 753) was 79 ± 7; 63% were women, and 66% were white (Table 1). On admission, medical conditions included chronic lung disease (18%), congestive heart failure (22%), diabetes mellitus (14%), and severe cognitive impairment (19%), and 279 participants (37%) were dependent in one or more ADLs. At discharge, 231 (31%) were dependent in one or more ADLs and 507 (67%) were independent in all ADL; 15 participants (2%) had died.

Bivariable Associations

In the derivation cohort, new-onset disability was associated with three demographic characteristics (age, sex, and marital status), two measures of functional status 2 weeks before admission (mobility and IADL function), and several admission characteristics (e.g., ADL function, unsteady gait, specific clinical diagnoses (e.g., stroke, severe cognitive

Table 1. Characteristics of Patients in the Derivation and Validation Cohorts

Characteristic	Derivation Cohort (n = 885)	Validation Cohort (n = 753)
Sociodemographic		
Age, mean ± SD	78 ± 6	79 ± 7
Female, n (%)	520 (59)	472 (63)
Marital status, n (%)		
Married	398 (45)	300 (40)
Widowed	405 (46)	306 (41)
Other	82 (9)	145 (19)
Self-identified race, n (%)		
White	786 (89)	499 (66)
Black	99 (11)	254 (34)
Education, years, n (%)		
<12	337 (41)	241 (34)
12	262 (32)	177 (25)
>12	216 (27)	288 (41)
Lived alone, n (%)	338 (38)	327 (44)
Functional status 2 weeks before admission, n (%)		
Mobility		
Able to run a short distance	264 (30)	191 (25)
Able to walk uphill or stairs but unable to run a short distance	478 (54)	373 (50)
Unable to walk uphill or stairs	139 (16)	189 (25)
IADLs, n (%)		
Independent in all	595 (67)	428 (57)
Dependent in 1–2	206 (23)	181 (24)
Dependent in ≥3	82 (9)	143 (19)
Clinical characteristics on admission, n (%)		
Global health, patient assessment		
Poor to fair	221 (31)	195 (35)
Good, very good, or excellent	483 (69)	367 (65)
ADLs		
Independent in all	532 (61)	471 (63)
Dependent in 1	120 (14)	84 (11)
Dependent in 2	89 (10)	59 (8)
Dependent in 3	58 (7)	44 (6)
Dependent in 4 or 5	79 (9)	92 (12)
Number of depressive symptoms (Center for Epidemiologic Studies Depression Scale), n (%)		
0–3	443 (65)	375 (65)
≥4	242 (35)	206 (35)
Unsteady gait	362 (55)	308 (52)
Clinical conditions, n (%)		
Stroke	56 (6)	11 (2)
Severe cognitive impairment	151 (17)	143 (19)
Congestive heart failure	215 (24)	160 (22)
Peripheral vascular disease	221 (25)	47 (6)
Pneumonia	114 (13)	80 (11)
Chronic lung disease	234 (27)	132 (18)
Gastrointestinal bleeding	56 (6)	75 (10)
Diabetes mellitus	202 (23)	105 (14)
Metastatic cancer	53 (6)	25 (3)
Charlson comorbidity score, mean ± SD	2.3 ± 2.0	1.5 ± 1.7
APACHE II Acute Physiology Score, mean ± SD	9.3 ± 3.1	10.7 ± 3.5
Laboratory values on admission, mean ± SD		
Creatinine, mg/dL	1.2 ± 0.9	1.7 ± 1.8
Hematocrit, %	36.4 ± 7.1	35.5 ± 7.1
Serum albumin, g/dL	3.5 ± 0.5	3.8 ± 0.5

Some percents do not add to 100% due to missing data or rounding. Data were missing for the following characteristics in the derivation cohort: education (n = 70), income (n = 328), clinical conditions (n = 1), Charlson comorbidity score (n = 1), Acute Physiology and Chronic Health Evaluation (APACHE) (n = 1), renal insufficiency (n = 19), anemia (n = 20), albumin (n = 51), gait (n = 229), walk at baseline (n = 48), walk at admission (n = 197), instrumental activities of daily living (IADLs) (n = 2), activities of daily living (ADLs) at admission (n = 7), global health (n = 181), living alone (n = 4), depressive symptoms (n = 200). Data were missing for the following characteristics in the validation cohort: marital status (n = 2), education (n = 47), income (n = 247), clinical conditions (n = 13), Charlson comorbidity score (n = 3), APACHE (n = 3), renal insufficiency (n = 10), anemia (n = 16), albumin (n = 110), gait (n = 164), walk at baseline (n = 13), walk at admission (n = 167), IADLs (n = 1), ADLs at admission (n = 3), global health (n = 191), living alone (n = 1), depressive symptoms (n = 172). SD = standard deviation.

impairment, congestive heart failure, pneumonia, chronic lung disease, and metastatic cancer)), Charlson comorbidity score, APACHE score, and albumin level of less than 3.0 mg/dL (Table 2).

Multivariable Results

Seven risk factors were independently associated with new-onset disability in the logistic model identified using best subsets regression, including one demographic characteristic (age), two indicators of functional status 2 weeks before admission (mobility and IADL function), and four admission characteristics (dependency in ≥2 ADLs, diagnosis of acute stroke or metastatic cancer, severe cognitive impairment, and albumin <3.0 mg/dL) (Table 3). After controlling for these independent risk factors, other characteristics and diagnoses were not associated with new-onset disability. Thus some predictors associated with new-onset disability on bivariable analyses were not included in the clinical index: sex, marital status, gait unsteadiness, congestive heart failure, pneumonia, chronic lung disease, Charlson comorbidity score, and APACHE acute physiology score.

Risk Scoring System

The points assigned to each of the seven independent risk factors are listed in Table 3. A risk score was calculated for each participant by summing the points of each risk factor present. For example, an 86-year old woman (1 point) who was independent in IADLs and ADLs 2 weeks before admission but was unable to climb stairs (2 points) and was dependent in two ADLs (1 point) on admission for treatment of urosepsis would have a risk score of 4 points.

According to quintiles of predicted risk, the frequency of new-onset disability ranged from 8% in the lowest-risk

Table 2. Bivariable Associations Between Risk Factors and New–Onset Disability at Discharge in the Derivation Cohort

Risk Factor	New–Onset Disability at Discharge* n (%)	Odds Ratio (95% Confidence Interval)	*P*-Value†
Sociodemographic risk factor			
Age			<.001
70–79	114 (21)	1.0 (ref)	
80–89	108 (37)	2.2 (1.6–3.1)	
≥90	30 (60)	5.7 (3.1–10.4)	
Sex			<.01
Male	86 (24)	1	
Female	166 (32)	1.5 (1.1–2.1)	
Marital status			<.001
Other	27 (33)	1	
Married	83 (21)	0.5 (0.3–0.9)	
Widowed	142 (35)	1.1 (0. 7–1.8)	
Self-identified race			.45
Black	25 (25)	1	
White	227 (29)	1.2 (0.8–1.9)	
Education, years			.08
<12	100 (30)	1	
12	58 (22)	0.7 (0.5–1.0)	
>12	64 (30)	1.0 (0.7–1.5)	
Lives alone			.18
No	146 (27)	1	
Yes	105 (31)	1.2 (0.9–1.7)	
Functional status 2 weeks before admission			
Mobility			<0.001
Able to run a short distance	38 (14)	1	
Able to walk uphill or stairs but unable to run a short distance	145 (30)	2.6 (1.7–3.8)	
Unable to walk uphill or stairs	67 (48)	5.5 (3.4–8.9)	
Instrumental ADLs			<.001
Independent in all	125 (21)	1	
Dependent in 1–2	72 (35)	2.0 (1.4–2.9)	
Dependent in ≥3	55 (67)	7.7 (4.6–12.6)	
Characteristics on admission			
Patient assessment of global health			.40
Poor to fair	63 (29)	1	
Good, very good, or excellent	123 (25)	0.9 (0.6–1.2)	
ADLs			<.001
Independent in all	99 (19)	1	
Dependent in 1	32 (27)	1.6 (1.0–2.5)	
Dependent in 2	39 (44)	3.4 (2.1–5.5)	
Dependent in 3	27 (47)	3.8 (2.2–6.7)	
Dependent in 4 or 5	52 (66)	8.4 (5.0–14.1)	
Number of depressive symptoms (Center for Epidemiologic Studies Depression Scale), n (%)			.75
0–3	185 (29)	1	
≥4	67 (28)	1.0 (0.7–1.3)	
Gait			<.01
Steady	47 (16)	1	
Unsteady	93 (26)	1.8 (1.2–2.7)	
Clinical conditions			
Stroke			<.001
Absent	217 (26)	1	

(*Continued*)

Table 2. (Contd.)

Risk Factor	New–Onset Disability at Discharge* n (%)	Odds Ratio (95% Confidence Interval)	*P*-Value†
Present	35 (63)	4.7 (2.7–8.3)	
Severe cognitive impairment			<.001
Absent	162 (22)	1	
Present	90 (60)	5.2 (3.6–7.5)	
Congestive heart failure			.04
Absent	179 (27)	1	
Present	73 (34)	1.4 (1.0–2.0)	
Peripheral vascular disease			.09
Absent	179 (27)	1	
Present	73 (33)	1.3 (1.0–1.9)	
Pneumonia			.04
Absent	229 (30)	1	
Present	23 (20)	0.6 (0.4–1.0)	
Chronic lung disease			.03
Absent	198 (30)	1	
Present	54 (23)	0.7 (0.5–1.0)	
Gastrointestinal bleeding			.77
Absent	237 (29)	1	
Present	15 (27)	0.9 (0.5–1.7)	
Diabetes mellitus			.53
Absent	198 (29)	1	
Present	54 (27)	0.9 (0.6–1.3)	
Metastatic cancer			.03
Absent	230 (28)	1	
Present	22 (42)	1.9 (1.1–3.3)	
Acute Physiology and Chronic Health Evaluation Acute Physiology Score (tertiles)			<.001
≤8	100 (24)	1	
9–11	78 (26)	1.1 (0.8–1.5)	
>11	74 (43)	2.4 (1.6–3.5)	
Charlson comorbidity score (tertiles)			.02
0–1	93 (25)	1	
2–3	93 (29)	1.2 (0.9–1.7)	
≥4	66 (36)	1.7 (1.2–2.5)	
Laboratory values			
Creatinine, mg/dL (tertiles)			.59
<1.5	194 (28)	1	
1.5–2.9	44 (31)	1.1 (0.8–1.7)	
≥3	11 (36)	1.4 (0.7–3.0)	
Hematocrit, % (tertiles)			.1
<30	45 (33)	1	
30–35	75 (32)	0.9 (0.6–1.5)	
≥36	127 (26)	0.7 (0.5–1.0)	
Serum albumin, g/dL			<.001
≥3.0	178 (26)	1	
<3.0	64 (50)	3.0 (2.0–4.4)	

* The composite outcome of disabled at discharge includes participants with activity of daily living (ADL) disability and those who died during hospitalization, as described in the Methods section.

† *P*-value from global likelihood ratio tests for each single predictor logistic regression model.

Table 3. Characteristics Associated with New–Onset Disability at Discharge in the Derivation Cohort (Multivariable Analyses)

Characteristic	Adjusted Odds Ratio (95% Confidence Interval)	*P*-Value	Point Score
Age			
80–89	1.8 (1.2–2.5)	.002	1
≥90	2.8 (1.4–5.8)	.004	2
Dependent in three or more IADLs* 2 weeks before admission	2.6 (1.4–4.7)	.001	2
Mobility 2 weeks before admission			
Able to walk uphill or stairs but unable to run a short distance	2.0 (1.3–3.1)	.001	1
Unable to walk uphill or stairs	3.1 (1.8–5.3)	<.001	2
Number of ADL dependencies on admission†			
2–3	2.1 (1.4–3.2)	.001	1
4–5	4.0 (2.2–7.0)	<.001	3
Metastatic cancer or stroke	2.9 (1.8–4.6)	<.001	2
Severe cognitive impairment‡	2.3 (1.5–3.6)	<.001	1
Albumin <3.0 g/dL	2.7 (1.7–4.1)	<.001	2

* Instrumental activities of daily living (IADLs) included using the telephone, transportation, shopping, preparing meals, doing housework, taking medicines, and handling money.[28]

† A modified version of the Katz index of activities of daily living[23] (ADLs), included bathing, dressing, transferring from bed to chair, using a toilet, and eating.

‡ A diagnosis of dementia, five or more errors on the Short Portable Mental Status Questionnaire (SPMSQ), or inability to perform the SPMSQ.[22]

quintile to 66% in the highest-risk quintile in the derivation group and from 7% to 65% in the validation group (Table 4). The discrimination of the final model was similar in the derivation and validation cohorts (AUC = 0.787 and 0.791, respectively). Risk scores ranged from 0 to 14 points in the derivation cohort (mean 2.8 ± 2.5) and were directly

Table 4. Validation of the Clinical Index: New–Onset Disability at Discharge in Derivation and Validation Cohorts According to Risk Stratum

	Derivation Cohort		Validation Cohort	
Risk Stratum	Patients Disabled at Discharge/All Patients	% (95% CI)	Patients Disabled at Discharge/All Patients	% (95% CI)
Quintile of risk* (logistic regression model)				
1	13/167	8 (4–13)	10/139	7 (4–13)
2	23/172	13 (9–19)	19/144	13 (8–20)
3	36/182	20 (14–26)	36/128	28 (21–37)
4	59/182	32 (26–40)	63/161	39 (32–47)
5	121/182	66 (59–73)	118/181	65 (58–72)
AUC	0.787		0.791	
Risk group points (risk scoring system)				
0	7/125	6 (2–11)	8/100	8 (4–15)
1	27/207	13 (9–18)	18/175	10 (6–16)
2	30/167	18 (12–24)	34/126	27 (19–36)
3	42/125	34 (25–43)	30/80	38 (27–49)
4	30/85	35 (25–46)	43/98	44 (34–54)
5	21/47	45 (30–60)	27/60	45 (32–58)
6	23/46	50 (35–65)	21/36	58 (41–74)
7	21/28	75 (55–89)	23/31	74 (55–88)
8	16/18	89 (65–99)	11/13	85 (55–98)
9	13/15	87 (60–98)	10/12	83 (52–98)
≥10	22/22	100 (85–100)	21/22	95 (77–100)
AUC	0.784		0.784	
Hosmer-Lemeshow test *P*-value	.40		.54	

The composite outcome of disabled at discharge includes patients with activity of daily living (ADL) disability and patients who died during hospitalization, as described in Methods.

* Quintiles of risk were defined in the derivation cohort by picking cut points in the distribution of the predicted probabilities calculated using the logistic model derived in the derivation group; the cut points of that gave five groups of approximately equal size were the predicted probabilities of 11%, 15%, 24%, and 44%. The same cut points were applied to the validation cohort.

CI = confidence interval; AUC = area under the receiver operating characteristic curve.

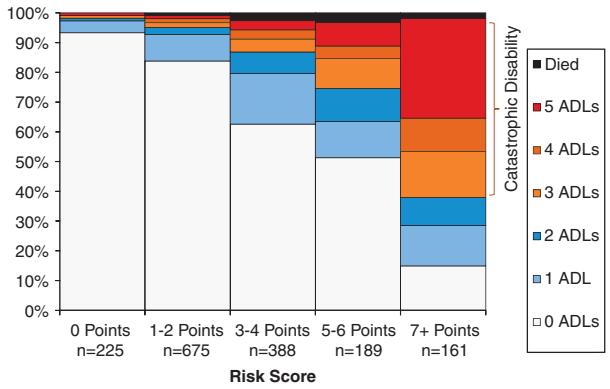

Figure 1. Proportion of participants with different numbers of activity of daily living (ADL) dependencies at discharge, according to the risk score. The number of ADLs participants were dependent in is shown in different colors, according to the key. Catastrophic disability is indicated by dependence in three or more ADLs. In this figure, the derivation and validation cohorts are combined. Areas under the receiver operating characteristic curve were 0.760 for participants aged 70 to 79 and 0.763 for participants aged 80 and older; 0.781 for women and 0.786 for men; 0.787 for participants with severe cognitive impairment and 0.725 for those without severe cognitive impairment; and 0.723 for participants independent in zero to one ADLs at admission and 0.767 for those dependent in two to five ADLS at admission.

related to the frequency of new-onset disability in the derivation and validation cohorts. The risk scoring system had acceptable calibration and good discrimination in the derivation and validation cohorts (AUC = 0.784 in each).

The risk score was associated with disability severity, as indicated by the number of ADL dependencies participants were dependent in at discharge (Figure 1, $P < .001$). In participants with 0, 1 to 2, 3 to 4, 5 to 6, and 7 or more points, catastrophic disability, defined as dependent in three or more ADLs, occurred in 0%, 4%, 19%, 37%, and 65%, respectively, and discharge to a nursing home occurred in 0%, 1%, 4%, 6%, and 15%, respectively. The risk score was also associated with long-term survival. In participants with 0, 1 to 2, 3 to 4, 5 to 6, and 7 or more points, 5-year survival was 71%, 52%, 36%, 28%, and 19%, respectively, and 10-year survival was 41%, 24%, 16%, 11%, and 5%, respectively.

The risk scoring system performed well in several subgroups of the development and validation cohort combined (Appendix 1) (AUC = 0.786 for men, AUC = 0.781 for women; AUC = 0.760 for participants aged 70–79, AUC = 0.763 for participants aged ≥80; AUC = 0.725 for participants with normal cognition, AUC = 0.787 for participants with severe cognitive impairment; AUC = 0.744 for participants independent in all ADLs at admission, AUC = 0.764 for participants dependent in one or more ADLs; AUC = 0.774 for participants in the intervention arm, AUC = 0.796 for participants who received usual treatment in the original trial).

DISCUSSION

A clinical index that uses information on hospital admission to stratify previously independent older adults according to their risk for new-onset disability was developed. The index identified groups of people with frequencies of disability that ranged from less than 10% to more than 90%, with excellent discrimination and calibration in prospective validation testing. Moreover, higher scores also identified people who had greater disability, more-frequent nursing home placement, and higher 10-year mortality rates after discharge.

This clinical index includes seven independent risk factors that are consistent with the disablement model[16] and are identifiable within 24 hours of hospital admission. Some risk factors, such as impaired mobility and dependence in IADLs 2 weeks before hospitalization, probably indicate loss of functional reserve, physical frailty, and proximity to the threshold of ADL disability before a person became acutely ill. Dependence in two or more ADLs on admission reflects the magnitude of the effect of the acute illness on function; dependence in four or five ADLs at admission was the greatest risk factor for disability at discharge. Other risk factors, including aged 80 and older, severe cognitive impairment, hypoalbuminemia, and a diagnosis of stroke or metastatic cancer, are factors that may slow recovery of independence in ADLs, indicating low resilience. The congruence of the risk factors with the conceptual framework supports the "biological plausibility" of the clinical index and increases confidence that it is likely to be robust in different settings.

These findings extend previous studies in several ways. First, the clinical index demonstrated better discrimination, calibration, and validation than earlier indices, with AUCs of 0.784 in derivation and validation testing, compared with AUCs of 0.64 to 0.73 for previous indices.[11,12] This better performance probably resulted from a theoretically based conceptual framework, a focus on adults at risk for new-onset disability, and the large size of the cohorts.

Second, this clinical index predicts new-onset disability in hospitalized people who had been independent in ADLs at baseline; prior studies predicted worsening ADL function in heterogeneous groups, some disabled before hospitalization and some not.[11,12] Focusing on new-onset disability in previously independent adults may help target preventive and rehabilitative interventions.[40]

Finally, the findings extend the understanding of risk factors for disability. Risk factors for disability have been extensively studied in community-dwelling populations[41] but have been studied less often in relation to acute illness and hospitalization,[10] even though hospitalization accounts for half of all new-onset disability.[3] This study confirms the importance of age (≥80), cognitive impairment, difficulty with IADLs, and signs of malnutrition as risk factors for disability in hospitalized older people, and the findings quantify the independent prognostic significance of each risk factor. The findings also provide quantitative estimates of the importance of difficulty walking, stroke, and advanced cancer as prognostic factors in hospitalized older adults. Measures of acute severity of illness and of comorbid illness were not independent prognostic risk factors, consistent with prior reports.[15]

This study has several implications. First, the findings provide a rationale for routine assessment on admission of the risk factors for new-onset disability. The clinical index may facilitate early planning for posthospital care,

which is central in interventions to improve transitions in care.[18,42,43] For example, patients at low risk for new-onset disability can plan to return home with little additional support. High-risk patients may need personal assistance, new equipment, or even rehabilitation to return home; these patients may also be at higher risk for unplanned readmission. Risk stratification can also identify patients who may benefit most from interventions aiming to prevent or ameliorate disability.[18,20,44,45] Although the current study found similar performance of the index in the Acute Care for Elders intervention and usual care group, future studies could evaluate interventions that promote mobility[46] and improve nutrition[47] for patients at risk for new-onset disability. Second, prehospital interventions in the community may enhance modifiable risk factors and thereby reduce new-onset disability. For example, programs that enhance mobility and nutrition could increase an individual's distance from the ADL disability threshold and promote resilience, preventing new-onset disability. Third, the clinical index may also be useful in comparing outcomes achieved by different large-scale providers. If two hospitals had different rates of new-onset disability in their older patients, it would be important to determine whether this difference was attributable to differences in admission characteristics (as in this index).

Several methodological considerations support the validity of these findings, including the large size of the cohort, the measurement of potential prognostic factors in conceptual domains, systematic use of a valid measure of disability, near-complete ascertainment of outcomes, and the reproducible accuracy of the clinical index when tested in a second site.

This study is the first to describe a clinical index for new-onset disability, and it had important limitations. First, measures of function were based on participant and surrogate reports, although these reports have demonstrated validity[48] and are strongly associated with health outcomes such as mortality, nursing home placement, and resource use.[1,19,49] Second, although many potential risk factors were evaluated, it cannot be excluded that other potentially important risk factors such as delirium, physical activity, and specific medications may add to predictive ability if evaluated. Delirium has been shown to contribute to disability in previously independent older adults,[13,50] but it was not systematically assessed in the current study. Third, participants were enrolled in the 1990s, and the accuracy of the index should be tested in current patients. Although the frequency and predictors of new-onset disability may change over time, these changes may be small, as supported by the small fall in the average length of hospital stay in the United States for adults aged 65 and older from 4.8 days in 1998 to 4.6 days in 2007.[51] In addition, the topic of new-onset disability may be of particular interest now, because the future prospective "bundling" of payment for hospital and posthospital costs may necessitate ways to identify and intervene upon disability in the peri-hospitalization period as a way to reduce overall costs. Finally, the generalizability of the findings to surgical and intensive care patients has not been determined.

In summary, a clinical index predicted new-onset disability at discharge in hospitalized older adults. It uses seven admission risk factors, most of which indicate loss of functional reserve and resilience, to calculate a simple point scoring system. The index had good discrimination and calibration and generalized well in testing at a different site. These features suggest that this index may be clinically useful.

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Conflict of Interest: The editor in chief has reviewed the conflict of interest checklist provided by the authors and has determined that the authors have no financial or any other kind of personal conflicts with this paper.

Author Contributions: Dr. Mehta had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis. Drs. Landefeld, Chren, Palmer, and Counsell contributed to original acquisition of data. Drs. Pierluissi and Walter acquired data from the National Death Index. Drs. Mehta and Landefeld contributed to study design and concept, data analysis and interpretation of data, drafting of the manuscript, and study supervision. Drs. Pierluissi and Boscardin and Ms. Kirby contributed to the data analysis, interpretation of data, and drafting of the manuscript. All authors contributed to the critical revision of the manuscript for important intellectual content, helped conceptualize ideas, interpreted findings, and reviewed drafts of the manuscript.

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Appendix 1. Disability or Death at Discharge, According to Risk Score in Patient Subgroups