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The prediction of functional decline in older hospitalised patients

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Abstract

Background: thirty to sixty per cent of older patients experience functional decline after hospitalisation, associated with an increase in dependence, readmission, nursing home placement and mortality. First step in prevention is the identification of patients at risk.

Objective: to develop and validate a prediction model to assess the risk of functional decline in older hospitalised patients.

Design: development study: cohort study ($n = 492$). Validation study: secondary data analysis of a cohort study ($n = 484$) in an independent population. Both with follow-up after 3 months. Functional decline was defined as a decline of at least one point on the Katz ADL index at follow-up compared with pre-admission status.

Setting: development study: general internal medicine wards of two university hospitals and one regional hospital. Validation study: general internal wards of an university hospital.

Subjects: patients ≥ 65 years acutely admitted and hospitalised for at least 48 h.

Results: thirty-five per cent of all patients in the development cohort and 32% in the validation cohort developed functional decline. A four-item model could accurately predict functional decline with an AUC of 0.71. At threshold 2 sensitivity, specificity, positive and negative predictive values were 87, 39, 43 and 85%, respectively. In the validation study, this was, respectively, 0.68, 89, 41, 41 and 89%.

Conclusion: pre-admission need for assistance in instrumental activities of daily living, use of a walking device, need for assistance in travelling and no education after age 14, are the items of a prediction model to identify older patients at risk for functional decline following hospital admission. The strength of the model is that it relies on four simple questions and this makes it easy to use in clinical practice and easy to administer.

Keywords: *prediction, functional decline, older hospitalised patients, elderly*

Background

Between 30 and 60% of older patients experience functional decline after hospitalisation, resulting in a decline in health-related quality of life and autonomy [1, 2]. This is associated with increased risk of readmission, nursing home placement and mortality [3–5]. Several factors play a role in the high occurrence of functional decline, such as the physical and cognitive condition of the patient before hospital admission, multimorbidity and iatrogenic complications [6, 7]. The first step in prevention is identifying the patients at risk [8]. This can be followed by a comprehensive geriatric assessment (CGA) to guide preventive interventions throughout the hospital stay [8–10].

Some instruments to predict adverse health outcomes have been described in the literature [11–15]. However, these were not specifically developed to predict functional decline or did not show good discriminative values in the targeted population [16].

Therefore, the objective of this study is to develop and validate a prediction model to assess the risk of functional decline in acutely hospitalised older patients.

Methods

Participants

First a cohort study was conducted between April 2006 and April 2008 to develop and internally validate a prediction model. Patients aged 65 years and older, acutely admitted to the internal medicine department of two university

and one regional teaching hospital, were invited to participate in the study. Of 1,031 eligible patients, 809 consented to participate. Reasons for exclusion: too ill to participate ($n = 20$); transferred from another ward ($n = 36$); transfer to ICU within 48 h after admission ($n = 28$), unable to speak or understand the language ($n = 86$). Also 147 patients were excluded who were not able to demonstrate functional decline: 19 patients (3%) with a maximum score on the Katz index at baseline and 128 patients (20%) who died within 3 months after admission. Finally, 492 patients were included in the analysis.

Second, an external validation study was conducted: a secondary data analysis of a cohort study in an independent population (November 2002–April 2006) of 484 patients admitted to the internal medicine wards of an university teaching hospital, using equal inclusion and exclusion criteria as in the development study.

For both studies, written informed consent was obtained before inclusion. The medical ethics committee of the hospitals approved the studies.

Measurements

Development study: within 48 h after admission and 3 months after admission, data were collected by trained research nurses and geriatricians. Baseline data included: demographic data (age, sex, race, living and social situation, number of years of education), functional status of 2 weeks before admission (to eliminate possible effects of the illness causing hospital admission) and potential predictors:

cognitive status, previous delirium, Instrumental Activities of Daily Living (IADL), nutritional status, use of devices, sensory impairments, number of falls in the past 3 months and the presence of a pressure ulcer. These predictors were chosen from the literature including items of instruments used in an earlier comparative study [16], including the original ISAR and predictors suggested by geriatricians and geriatric nurse specialists.

The cognitive competence of the patient was verified at admission. In cases of severe cognitive problems (Mini-Mental State Examination (MMSE)-score <16 points), patient information was gathered from the patient's proxy. In patients with mild cognitive problems (MMSE-score 16–20 points), the answers were verified with the proxy; if answers differed, the proxy's answers were used.

Three months after admission, functional status was recorded again by telephone interviewing the same respondent as at baseline.

Validation study: the relevant measurements were equal to the development study.

Functional decline was defined as a decline of at least one point on the Katz ADL index at 3 months after admission compared with pre-morbid ADL status [17].

Measurement instruments

Functional status was measured using the Katz ADL index (six items: bathing, dressing, toileting, transferring, eating and the use of incontinence materials) [17]. Each item was scored 0 (independent) or 1 (dependent).

Cognitive function was measured using the MMSE on a scale of 0 (poor) to 30 (excellent), where a score <24 indicated cognitive impairment [18]. IADL was measured by the Lawton scale (grooming, walking, making telephone calls, travelling, shopping, preparing meals, housekeeping, medication intake and organising financial matters) [19].

For nutritional status the short nutritional assessment questionnaire (SNAQ) was used. This scale consists of questions regarding weight loss, appetite and use of supplements [20]. All other predictors were measured as present or absent.

Data analysis

Percentages, means and standard deviations were calculated to describe both study cohorts. Student's *t*-test (continuous variables) and Chi-square test (dichotomous variables) were used to test differences between groups of patients.

In the development study, potential predictors associated with functional decline were identified using univariate logistic regression. Categorical and continuous variables were dichotomised. Items of existing screening instruments, of the IADL index and of the SNAQ were analysed as individual predictors. Next, a multivariate logistic regression was conducted (backward procedure, accepting *P*-values ≤0.05) with predictors based on three criteria: the number of cases (per 10 cases, 1 predictor), *P*-value ≤0.15 [21] and

suggestions of clinically relevant predictors mentioned by geriatric specialists. The four best models were compared and validated in a bootstrap procedure (1,000 samples drawn randomly with replacement) using the AUC with 95% CI to determine the discriminative value. The best model was recalibrated by shrinkage of the betas to prevent over-fitting using the formula of van Houwelingen and Le [22]. This was followed by recalculating the intercept in such a way that the total prediction of all cases of the recalibrated model was equal to the incidence of functional decline in the data set. Finally, the prediction model was transferred into a scorecard by dividing the beta coefficients by the smallest predictor beta and rounding. Sensitivity, specificity and positive and negative predictive values were calculated. These were also measured in the external validation cohort as well as the AUC to determine the discriminative value.

In both databases, random missing values were found and these were imputed per database separately using the single linear regression method [23].

The analyses were performed using SPSS, version 15 (Statistic Package for Social Studies, Inc. Chicago, IL, USA) and the statistical package R version 2.8.1 for bootstrap procedures.

Results

Baseline characteristics are shown in Table 1. In the development cohort mean age was 78 years, 44% were male and 35% experienced functional decline. In the validation cohort, this was, respectively, 78 years, 47% male and 32% suffered a functional decline of at least 1 point measured on the Katz index.

Development study: 35 variables were used in the univariate regression. Overall, 12 variables showed significant predictive values in the univariate analysis. Based on the 170 patients that showed functional decline, 17 predictors were selected for multiple logistic regression analysis; 15 predictors with *P*-values <0.15 and two clinically relevant predictors (previous delirium and visual impairment) with *P*-values >0.15. The multiple logistic regression resulted in a model with six predictors independently associated with functional decline: pre-morbid need of assistance in IADL on a regular basis, hearing impairment, visual impairment, use of a walking device, need of assistance for travelling and no education after age 14. With these six predictors, four models were compared using a 1,000 samples bootstrap. Because there were no relevant differences between the AUCs of these models (range between 0.71 and 0.72), we preferred the model that was easiest to use in clinical practice with only four predictors. After shrinkage of the beta coefficients (factor 0.936), the intercept was recalculated resulting in a prediction model with the following probability of risk for functional decline:

$1/1 + \exp(-(-1.93 + 0.48 \times \text{'pre-admission need for assistance in IADL on a regular base'} + 0.81 \times \text{'use of a$

Table 1. Demographic and clinical characteristics of older patients acutely admitted to a general internal ward, baseline and follow-up, development and validation cohort

	Development cohort (n = 492)	Validation cohort (n = 484)
Age, mean (SD)	78 (8)	78 (8)
Male, % (n)	44 (218)	47 (226)
Caucasian, % (n)	92 (452)	
Living situation, % (n)		
Dependent	24 (116)	30 (147)
Social situation, % (n)		
Living alone	49 (241)	54 (259)
MMSE at admission, mean (SD)	24 (7)	23 (6)
<24 points (cognitive impaired)	34 (166)	43 (207)
% (n)		
Admission reason, % (n)		
Infectious disease	43 (189)	54 (260)
Diseases of the digestive system	21 (92)	33 (159)
Malignancy	6 (26)	17 (81)
Cardiovascular diseases	6 (24)	9 (45)
Other	24 (104)	17 (81)
Functional status 2 weeks before admission		
Independent, % (n)	54 (267)	51 (249)
Functional status 3 months after admission		
Independent, % (n)	44 (216)	47 (228)
Difference in functional status pre-admission/3 months later, % (n)		
-4 to -1 (improved function)	11 (53)	15 (73)
0 no difference	55 (269)	53 (257)
≥1 point decline (functional decline)	35 (170)	32 (154)

walking device' + 0.57 × 'need for assistance in travelling' + 0.42 × 'no education after age 14') (see also Table 2).

The AUC of this model was 0.71 (95% CI: 0.66–0.76), the Hosmer–Lemeshow test showed a P-value 0.95 indicating a good fitting model.

A scorecard, Identification of Seniors At Risk–Hospitalized Patients (ISAR-HP), was developed based on this prediction model by dividing the beta coefficients by the smallest predictor beta and rounding (Figure 1). At threshold 2 (score ≥2 indicating high risk for functional decline) the sensitivity, specificity and positive and negative predictive values were 87, 39, 43 and 85%, respectively. Supplementary data available in *Age and Ageing* online, Appendix 1, Table S3 shows predictive values in subgroups

Table 2. Independent predictors of functional decline (n = 492)

Variable	Beta	Beta after shrinkage	P-value	OR (95%CI)
Pre-admission need for assistance in IADL	0.52	0.48	0.03	1.7 (1.1–2.6)
Use of a walking device	0.87	0.81	<0.01	2.4 (1.5–3.7)
Need for assistance in travelling	0.61	0.57	<0.01	1.8 (1.2–2.9)
No education after age 14	0.45	0.42	0.03	1.6 (1.0–2.3)

including patients who died and patients of 70 or 75 years and older.

In total 70% of the patients were identified as patients at risk. Of this group 43% developed functional decline. The mean functional decline of patients at risk was 0.68 and of patients not at risk 0.19, showing a significant difference (P < 0.000). Comparison of the true and false positives showed similarity in most aspects (Supplementary data are available in *Age and Ageing* online Appendix 2, Table S4).

Validation study: the AUC of the prediction model was 0.68 (95% CI: 0.63–0.73). At the recommended threshold of 2 of the score card ISAR-HP sensitivity, specificity, positive and negative predictive values were, respectively, 89, 41, 41 and 89%.

Discussion

Older patients acutely admitted to an internal ward who are at risk for functional decline after hospitalisation can be identified with only four predictors: pre-admission need for assistance in IADL on a regular basis, use of a walking device, need for assistance in travelling and no education after age 14. This prediction model was internally validated and validated in an independent population to establish generalisability to a different population of patients. Based on the betas of the prediction model, a scorecard was developed, the ISAR-HP.

To appreciate this study, some aspects need to be addressed. We optimised the data set by imputation as some data were missing (at random). Missing data will end up as missing cases in multiple regression analysis. To decrease bias and increase statistical efficiency, it is better to impute missing values than to perform complete case analysis [23, 24].

To enhance internal validity, we cross-checked the outcome of the multiple regression model in two ways: a forward procedure and a 1,000-samples bootstrap procedure (drawn randomly with replacement). In these analyses, the results were equal, supporting the idea that the predictors used in the final model are the strongest for predicting functional decline after hospitalisation. We also validated the best fitting model with a second 1,000-samples bootstrap procedure. This procedure has been shown to be superior to split-sample or cross-validation methods [24]. The AUC in the bootstrap samples was higher than in the prediction model, thus supporting the validity of the model. The general applicability of the prediction model is also supported by the differences in the population of the development study: the populations of the three hospitals in our development study were significantly different with respect to age, years of education, need for assistance in travelling, and functional decline. Finally, we applied a secondary data analysis in an independent cohort study to externally validate the model. The prediction model and the score card showed a good performance with only slightly differences

ISAR-HP		
	YES	NO
1. Before hospital admission, did you need assistance for IADL (e.g., assistance in housekeeping, preparing meals, shopping, etc.) on a regular basis?	1	0
2. Do you use a walking device (e.g., a cane, rollator, walking frame, crutches, etc.)?	2	0
3. Do you need assistance for travelling?	1	0
4. Did you continue education after age 14?	0	1
Total score (circled figures)		
Total score 0 or 1 = not at risk		
Total score ≥ 2 = patient is at risk for functional decline		

Figure 1. Scorecard: Identification of Seniors At Risk–Hospitalised Patients (ISAR-HP).

in the discriminative values. All these positive measurements show that the prediction model can be generalised to a different population.

We excluded the deceased patients from the analysis ($n = 128$ in the development cohort and $n = 148$ in the validation cohort) because we did not want to confuse the predictors of functional decline with those of mortality. Patients with a maximum score on the Katz index at baseline ($n = 19$ for the development and $n = 12$ for the validation cohort) were also excluded. Our aim was to prevent functional decline by identifying those at risk at hospital admission; it is open to discussion whether these vulnerable groups of patients should have been included as well. Therefore, we also measured the predictive value of the ISAR-HP in these groups of patients. In the development study for predicting mortality sensitivity was 81%; for identifying patients with a maximum Katz index score at baseline as at risk sensitivity was 100% and for the combined group including the deceased and patients with a maximum score at baseline sensitivity was 85%. Also in the validation cohort the ISAR-HP showed good results for the combined group: sensitivity, specificity, positive and negative predictive values were 85, 41, 56% and 57%, respectively.

Thus, in both cohorts the ISAR-HP can identify patients that are vulnerable at admission, including those who will die and those who are already dependent in six ADLs.

In translating the prediction model to the scorecard, the choice of a threshold was based on the balance between the acceptable proportion of missed cases (false negatives) and reducing the number of patients unnecessarily qualified as at-risk (false positives). In general, a higher cut-off point leads to fewer subjects in the at-risk group. Because risk assessment can be seen as the first step in prevention that should be followed by a CGA, we preferred a high sensitivity (87%). This results in a significant percentage of false positives. A comparison of the false and true positives showed that false positives were very similar to true positives, which indicates that all these patients were meeting the criteria of frailty [25] and need further geriatric assessment. Although the ISAR-HP generates false positives, it enhances efficiency given that 30% of older patients who are assessed do not need further geriatric attention.

The predictors identified in our model were also relevant in previous studies, thereby supporting the face validity of the prediction model. Mahoney *et al.* concluded that using a cane or walker was the best predictor of adverse health outcomes [26]. The predictor ‘no education after age 14’ is an indicator of the socio-economic status of a person, which is also a described predictor of functional decline [27, 28]. The predictors ‘need for assistance in activities of IADL on a regular basis’ and ‘need for assistance in travelling’ are both reflections of pre-morbid functional

status and strong predictors for functional decline in several studies [7, 14, 29–31].

Finally, all items of existing screening instruments were included as potential predictors. Only one item of the ISAR was a valid predictor in this study. This might be explained by the major differences between the original ISAR population (patients in the emergency department in Canada) and our study population. To enhance implementation in clinical practice, with consent of McCusker who developed the ISAR, the choice was made to denominate the scorecard ISAR-Hospitalized Patients.

Conclusion

Based on this study in 492 older patients acutely admitted to the internal wards of three hospitals, functional decline after hospital admission can be predicted by a model with four variables. Validation in an independent population in 484 patients supports this conclusion. Next step is to further validate the ISAR-HP in different inpatient groups and different countries. The strength of the model is that it relies on four simple questions to predict functional decline. The scorecard of this model, the ISAR-HP, will be easy to use in clinical practice and will be easy to administer.

Key points

- Thirty to sixty per cent of all hospitalised older patients are suffering functional decline after hospitalisation.
- Prevention of this functional decline is an important target for all health care workers.
- Identifying high-risk patients is the first step in prevention of functional decline.
- The ISAR-HP is a validated and easy to use instrument to predict functional decline in older hospitalised patients.

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Supplementary data

Supplementary data mentioned in the text is available to subscribers in *Age and Ageing* online.

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