Chapter 5

The Prediction of Functional Decline in Older Hospitalized Patients

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Abstract

Context: 30% to 60% of older patients experience functional decline after hospitalization. This is associated with a decrease in quality of life and autonomy and an increase of readmission, nursing home placement and mortality. A 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 acute hospitalized older patients.

Design: Development study: a cohort study (n=492) with follow up three months after hospital admission (April 2006 to April 2008). Validation study: a secondary data analysis of a cohort study (n=484) in an independent population with follow up after three months (November 2002- April 2006).

Setting: Development study: the general internal medicine wards of two university teaching hospitals and one regional teaching hospital. Validation study: the general internal wards of a university teaching hospital

Participants: All consecutive patients of 65 years and older acutely admitted and hospitalized for at least 48 hours.

Main outcome measure: Functional decline was defined as a decline of at least one point on the Katz ADL index at follow-up compared to pre-admission status.

Results: 35% of all patients in the development cohort and 32% in the validation cohort suffered functional decline. The prediction model could accurately predict functional decline with only four items. The AUC was 0.71. At threshold 2 sensitivity, specificity, positive and negative predictive values were 87%, 39%, 43% and 85%, respectively. This positive outcome was supported by the results in the validation study which were respectively 0.68 89%, 41%, the 41% and 89%.
Conclusion: Pre-admission need for assistance in instrumental activities of daily living, use of a walking device, need for assistance in traveling, and no education after age 14, are the predictors in a model to identify older patients at risk for functional decline following hospital admission. This prediction model was translated into a scorecard: Identification of Seniors At Risk-Hospitalized Patients.
Background

Between 30% and 60% of older patients experience functional decline after hospitalization, resulting in a decline in health-related quality of life and autonomy\textsuperscript{1,2}. This is associated with increased risk of readmission, nursing home placement and mortality\textsuperscript{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\textsuperscript{6,7}. The first step in prevention is identifying the patients at risk\textsuperscript{8}. This can be followed by a comprehensive geriatric assessment (CGA) to guide preventive interventions throughout the hospital stay\textsuperscript{8-10}.

Some instruments to predict adverse health outcomes have been described in the literature\textsuperscript{11-15}. However, these were not specifically developed to predict functional decline or have not been validated in acutely hospitalized patients.

We compared the discriminative ability of three of these instruments in a population of older patients acutely admitted to internal wards: Identification of Seniors At Risk (ISAR), Hospital Admission Risk Profile (HARP) and Complexity Prediction Instrument (COMPRI)\textsuperscript{13-16}. None of these instruments showed good discriminative values in the targeted population. Therefore, the objective of this study is to develop and validate a prediction model to assess the risk of functional decline in acutely hospitalized older patients.
The prediction of functional decline in older hospitalized 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 who were acutely admitted to the internal medicine department of two university hospitals and one regional teaching hospital and who could be interviewed within 48 hours after admission were invited to participate in the study. Of 1031 eligible patients, 809 gave informed consent to participate. Patients were excluded for the following reasons: too ill to participate (n=20); transferred from another ward (n=36); transferred to the ICU within 48 hours after admission (n=28) and unable to speak or understand the language (n=86). After data collection, 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 (who could not decline further) and 128 patients (20%) who died within three 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 a university teaching hospital, using the same 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 three hospitals approved the studies.

Measurements

Development study: within 48 hours after admission and three months after admission, data were assessed by specially trained research nurses and geriatricians. Baseline data included the following: demographic data (age, sex, race, living and social situation, number of years of education), premorbid functional status (patients were asked to describe the situation two weeks before admission to eliminate possible effects of the illness causing hospital admission), Activities of Daily Living (ADL) and Instrumental ADL
(IADL) and potential predictors chosen from the literature including items of existing instruments as well as predictors suggested by experienced medical and nursing geriatric specialists. Potential predictors included cognitive status, previous delirium, nutritional status, use of devices, sensory impairments, continence, number of falls in the past three months and presence of a pressure ulcer. Medical data were obtained from the medical records.

The cognitive competence of the patient was verified at admission. In cases of severe cognitive problems (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 patient’s answers were verified with the proxy; if the answers were different, the proxy’s answers were used.

Three months after admission, functional status was recorded again by telephone interviews. The respondent was the same as the one interviewed at baseline (either the patient or the proxy).

Validation study: the measurements were equal to the development study. For the validation were used: demographic data (age, sex, race, living and social situation) data to compose the prediction model, functional status (pre admission and three months after admission) and cognitive status.

Functional decline was defined as a decline of at least one point on the Katz ADL index at three months after admission compared to premorbid ADL status.

**Measurement instruments**

Functional status was measured using the Katz ADL index (six items: bathing, dressing, toileting, transferring, eating and the use of incontinence materials) \(^\text{17}\). The Lawton scale was used to measure IADL: grooming, walking, making telephone calls, traveling, shopping, preparing meals, housekeeping, medication intake and organizing financial matters \(^\text{18}\). In both scales, each item was scored 0 (independent) or 1 (dependent).

Cognitive function was measured using the Mini Mental State Examination (MMSE) on a scale of 0 (poor) to 30 (excellent), where a score < 24 indicated cognitive
impairment. Nutritional status was measured using the validated Short Nutritional Assessment Questionnaire (SNAQ). This scale consists of four questions: >6 kg weight loss in the prior six months (3 points); >3 kg weight loss in the prior month (2 points); decreased appetite (1 point); and the use of supplemental food or tube feeding (1 point). Patients with a score of 3 points out of 7 were considered malnourished.

**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 dichotomized. Items of existing screening instruments, of the IADL index and of the SNAQ were analyzed as individual predictors. Next, a multivariate logistic regression was conducted (backward procedure, accepting P-values \(\leq 0.05\)) with predictors based on three criteria: the number of cases (per ten cases, one predictor), P-value \(\leq 0.15\) and suggestions of clinically relevant predictors mentioned by geriatric specialists. The four best models were compared and validated in a bootstrap procedure (1000 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. 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 dataset. 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 several patients had values missing for one or more of the variables and these were imputed per database separately using the single linear regression method\textsuperscript{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.

Table 1: Demographic and Clinical Characteristics of Older Patients Acutely Admitted to a General Internal Ward, Development and Validation Cohort

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

Baseline characteristics of both studies 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 also 78 years, 47% male and 32% of all patients 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: premorbid need of assistance in IADL on a regular basis, hearing impairment, visual impairment, use of a walking device, need of assistance for traveling and no education after age 14. With these six predictors, four models were compared using a bootstrap with 1000 samples. Because there were no relevant differences between the AUCs of these models (range between 0.71 – 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. The result was a prediction model with the following probability of risk for functional decline: 1/1+exp (-1.93 + 0.48 x “pre-admission need for assistance in IADL on a regular basis” + 0.81 x “use of a walking device” + 0.57 x “need for assistance in traveling” + 0.42 x “no education after age 14”).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Beta</th>
<th>Beta after shrinkage</th>
<th>P-value</th>
<th>OR (95%CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-admission need for assistance in IADL</td>
<td>.52</td>
<td>.48</td>
<td>0.03</td>
<td>1.7 (1.1-2.6)</td>
</tr>
<tr>
<td>Use of a walking device</td>
<td>.87</td>
<td>.81</td>
<td>&lt;0.01</td>
<td>2.4 (1.5-3.7)</td>
</tr>
<tr>
<td>Need for assistance in traveling</td>
<td>.61</td>
<td>.57</td>
<td>&lt;0.01</td>
<td>1.8 (1.2-2.9)</td>
</tr>
<tr>
<td>No education after age 14</td>
<td>.45</td>
<td>.42</td>
<td>0.03</td>
<td>1.6 (1.0-2.3)</td>
</tr>
</tbody>
</table>

The AUC of this model was 0.71 (95% CI 0.66 - 0.76) and the Hosmer Lemeshow test showed a P-value 0.95 which indicates a good fitting model, see also Figure 1. 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 2). 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. In total 70% of the patients were identified as patients at risk. Of this group 43% developed functional decline. Comparison of the true and false positives showed similarity in all aspects (predictors and IADL’s) except length of stay (LOS), which was similar for false positives and patients not at risk. For true positives LOS was nearly 1.5 times more.

Validation study: the AUC of the prediction model was 0.68 (95% CI 0.63-0.73), see also Figure 1. At the recommended threshold of 2 of the score card ISAR-HP sensitivity specificity, positive and negative predictive values were respectively 89%, 41%, the 41% and 89%.

Figure 1: Receiver Operating Characteristic Curve and Area Under the Receiving Operating Curve with 95% Confidence Interval

ROC of the prediction model in the development cohort: AUC 0.71 (0.66-0.76)
Discussion

Older patients acutely admitted to an internal ward who are at risk for functional decline after hospitalization 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 traveling and no education after age 14. This prediction model was internally validated and in a second step validated in an independent population to establish that it can be generalized to a different population of patients. Based on the beta’s of the prediction model a scorecard was developed, the Identification of Seniors At Risk - Hospitalized Patients (ISAR-HP).

To appreciate this study some aspects need to be addressed. In our study we missed some data (at random). Missing data will end up as missing cases in a multiple regression analysis. To decrease bias and increase statistical efficiency, it is better to impute missing values than to perform complete-case analysis. So we optimized the dataset by imputation.

To enhance internal validity, we cross-checked the outcome of the multiple regression model in two ways: a forward procedure (entry P-value ≤0.05, removal P-value ≥0.10) and a 1000-samples bootstrap procedure (drawn randomly with replacement, using a forward and backward procedure accepting a P-value ≤0.05 and a selection of >50% in the 1000 samples). 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 hospitalization. We also validated the best fitting model with a second 1000-samples bootstrap procedure. The bootstrap procedure is a method to see if the model is valid and not too optimistic in another population. This procedure has been shown to be superior to split-sample or cross-validation methods. 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 traveling, 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 in the discriminative values. All these positive measurements show that the prediction model can be generalized 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. The outcome of this study is relevant to patients at risk for functional decline rather than those at risk for 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% en 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 ADL’s. 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 relatively high percentage of false positives. A comparison of the false and true positives showed that the false positives
were very similar to the true positives, which indicates that all these patients were meeting the criteria of frailty.25 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 In studies of Marengoni, Dendukuri and Cigolle, a limited number of years of education was a strong predictor for functional decline and other adverse health outcomes.7,27,28 Functional status, measured in different ways and in different populations, was also a strong predictor for further functional decline in several studies.7,14,29,30 The predictors ‘need for assistance in activities of IADL on a regular basis’ and ‘need for assistance in traveling’ are both reflections of premorbid functional status.

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 ISAR population (patients in the emergency department in Canada) and our study population. The ISAR is a widely known instrument, and we thank the developer of the ISAR for permission to denominate our scorecard ISAR-HP. We believe this will enhance implementation in clinical practice.

**Figure 2: Scorecard: Identification of Seniors At Risk - Hospitalized Patients (ISAR-HP)**

<table>
<thead>
<tr>
<th>ISAR-HP</th>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Before hospital admission, did you need assistance for IADL (e.g., assistance in housekeeping, preparing meals, shopping, etc.) on a regular basis?</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2. Do you use a walking device (e.g., a cane, rollator, walking frame, crutches, etc.)?</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>3. Do you need assistance for traveling?</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>4. Did you follow education after age 14?</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Total score (circled figures)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total score 0 or 1 = not at risk
Total score ≥2 = patient is at risk for functional decline
Chapter 5

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 adequately predicted by a model with four variables. The results of the validation in an independent population support this conclusion. The scorecard of this model, the ISAR-HP, will be easy to use in clinical practice as it consists of only four questions which are easy to administer.
Reference List


The prediction of functional decline in older hospitalized patients
