

# Multidimensional Prognostic Index Predicts Mortality and Length of Stay During Hospitalization in the Older Patients: A Multicenter Prospective Study

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**Background.** The Multidimensional Prognostic Index (MPI) is a validated predictive tool for long-term mortality based on information collected in a standardized Comprehensive Geriatric Assessment. We investigated whether the MPI is an effective predictor of in-hospital mortality and length of hospital stay after admission to acute geriatric wards.

**Methods.** Prospective study of 1,178 older patients (702 women and 476 men, 85.0 ± 6.8 years) admitted to 20 geriatrics units. Within 48 hours from admission, the MPI, according to an earlier validated algorithm, was calculated. Subjects were divided into three groups of MPI score, low-risk (MPI-1 value ≤ 0.33), moderate-risk (MPI-2 value 0.34–0.66), and severe-risk of mortality (MPI-3 value ≥ 0.67), on the basis of earlier established cut-offs. Associations with in-hospital mortality and length of stay were examined using multivariable Cox regression models and adjusted Poisson linear mixed-effects models, respectively.

**Results.** At admission, 23.6% subjects had a MPI-1 score, 33.8% had a MPI-2 score, and 42.6% had a MPI-3 score. Subjects with higher MPI score at admission were older ( $p < .001$ ), more frequently women ( $p < .001$ ) and had higher prevalence of common chronic conditions. After adjustment for age, gender, and diseases, patients included in the MPI-2 and MPI-3 groups had a significantly higher risk for in-hospital mortality (hazard ratio: 3.48, 95% confidence intervals: 1.02–11.88,  $p = .047$ ; hazard ratio: 8.31, 95% confidence intervals: 2.54–27.19,  $p < .001$ ) than patients included in the MPI-1 group, respectively. In multivariable model, length of stay significantly increased across the three MPI groups (11.29 [0.5], 13.73 [1.3], and 15.30 [1.4] days, respectively [ $p < .0001$ ]).

**Conclusions.** In older acute care inpatients, MPI score assessed at hospital admission is an independent predictor of in-hospital mortality and the length of hospital stay.

**Key Words:** MPI—Prognosis—Hospital—Mortality—Aging.

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HOSPITALIZATION for an acute medical event represents a stressful and potentially hazardous event for older persons that often leads to important clinical complications, including functional decline, prolonged length of stay, and death, unrelated to the problem that caused admission or to its specific treatment (1). Very old frail patients and those with preadmission functional limitation are at higher risk of complications (2).

Identification of patients at high risk of in-hospital adverse events is of paramount importance for correct clinical decision and appropriate management, nevertheless the ability of medical diagnoses and traditional clinical assessment to discriminate high- and low-risk groups is limited. In this context, information on patient prognosis and

particularly on the risk of mortality should be a key information to consider to avoid unnecessary diagnostic procedures and inappropriate medical or surgical treatments in the older population (3).

Among several indices validated to assess the risk of mortality, the Multidimensional Prognostic Index (MPI) has been found to be one of the most accurate (4,5). The MPI is a derived index based on six commonly used geriatric assessment scales exploring cognitive, functional, nutritional and clinical status, as well as on information about drugs taken and patient's social support (6). Its long-term predictive value has been established in the overall hospitalized population (5) as well as in older subjects hospitalized for specific clinical conditions including pneumonia (7),

dementia (8), heart (9) and renal failure (10), and transient ischemic attack (11).

At present, however, it is not known whether the MPI may predict in-hospital mortality and length of hospital stay in older geriatric patients with different clinical diseases. The aim of this multicenter prospective study was to evaluate the efficacy of the MPI to predict in-hospital length of stay and mortality in older patients admitted to geriatrics units for an acute disease or a relapse of a chronic disease. We hypothesized that patients with higher MPI score at hospital admission would have higher mortality risk and longer hospital stay.

## METHODS

### *Study Population*

All patients with age  $\geq 65$  years consecutively admitted for acute illness or relapse of chronic disease to 20 acute geriatric wards located in the North-Eastern area of Italy from January 1, 2012 till March 31, 2012 were screened for inclusion. The study was conducted according to the principles of the Declaration of Helsinki. Information on demographics, including age and gender, housing status (ie, living with family or caregivers, institutionalized or living alone), medical history, and medication taken was collected using interview and/or medical records.

A Comprehensive Geriatric Assessment (CGA) was performed within 48 hours from admission to collect information on basic activities of daily living (ADL) and instrumental activities of daily living (IADL) according to the Katz (12) and the Lawton–Brody (13) scales, respectively. Cognitive status was evaluated using the Short Portable Mental Status Questionnaire (SPMSQ) (14). Comorbidity burden was summarized using the comorbidity subscale of the cumulative illness rating scale (CIRS) (15), and nutritional status was assessed through the Mini Nutritional Assessment (MNA) (16). The Exton–Smith scale (ESS) was used to evaluate the risk of developing pressure ulcers (17). The number of medications taken at home was recorded.

Vital status at discharge, number of hospitalization days, and the first five diagnoses reported in the discharge form and coded according to the International Classification of Diseases, Tenth Revision (ICD-10), were collected.

### *The Multidimensional Prognostic Index*

At admission the MPI was calculated using the CGA-based validated algorithm (6). Scores of each of the aforementioned multidimensional assessment scales (ADL, IADL, SPMSQ, CIRS, MNA, ESS), information on of housing status, and number of medications prescribed were recategorized based on a tripartite hierarchy and a new score was assigned (0 = no problems/low burden, 0.5 = minor problems/intermediate burden, and 1 = major problems/major burden).

The specific thresholds used to define the three hierarchic categories were reported elsewhere (11) and were based on either validated cut-offs (SPMSQ, MNA, EES, ADL, and IADL) or frequency of distribution in the earlier validation study (for CIRS and number of medications) (6). The newly adjudicated scores were summed and the result obtained was divided by eight (the total number of domains) to obtain an average value, namely the MPI score, ranging from 0 (= low mortality risk) to 1 (= high mortality risk). For clinical purposes, three grades of MPI were identified according to earlier validated cut-off: MPI-1 (low risk of mortality, MPI values from 0 to 0.33), MPI-2 (moderate risk of mortality, MPI values from 0.34 to 0.66), and MPI-3 (severe risk of mortality, MPI values from 0.67 to 1.0) (6). To calculate the MPI, software for Windows may be downloaded (available for free) from the following address: <http://www.operapadrepio.it/imp/impsetup.exe> (English version).

### *Statistical Methods*

Patients baseline characteristics were reported as mean  $\pm$  standard deviation (SD), median and interquartile range (Q1–Q3), or frequencies and percentage for continuous and categorical variables, respectively. In-hospital mortality rates for 100 person-months were also reported and compared using a Poisson model.

Univariable and multivariable Cox regression models with robust standard errors were performed to assess the prognostic effect of the MPI score at admission for in-hospital mortality, accounting for potential clustering due to study site (18). Results were reported as hazard ratios (HRs) and 95% confidence intervals (95% CI). Adjusted survival curves were drawn, for each MPI grade, from multivariable Cox model.

Predicted risk probabilities were derived from the estimated Cox regression models. Models' calibration, that is, the agreement between observed outcomes and predictions, was assessed using the survival-based Hosmer–Lemeshow goodness-of-fit test (19), a chi-squared test based on grouping observations into deciles of predicted risk and testing associations with observed outcomes. Models' discrimination, that is, the ability to distinguish subjects who will develop an event from those who will not, was assessed by computing the modified C-statistic for censored survival data (20,21). Comparison between C-statistics was carried out following Pencina and D'Agostino's approach (22). Reclassification improvement for the intrahospital mortality risk prediction offered by MPI at admission, was quantified using the survival-based net reclassification index (NRI), following the Kaplan–Meier approach with one-sided bootstrap-based *p* values (22–24). Because no established risk cut-offs were available for our high risk population, the continuous NRI (cNRI) was computed (24). Improvements in models' discriminatory power and risk reclassification were assessed within the median length of stay time horizon of 9 days.

Moreover, to evaluate the predictive role of the MPI at admission on patient's length of stay, adjusted Poisson linear mixed-effects model, accounting for clustering due to center random effect and different diagnoses at discharge, that is, heart failure, arrhythmia, pneumonia, chronic obstructive pulmonary disease (COPD), respiratory failure, dementia, acute or chronic kidney failure, was also assessed using the cohort of alive patients. Posthoc pairwise comparisons between the estimated means at different MPI grades were investigated through suitable contrasts and *p* values were adjusted for multiple comparisons, according to Hochberg's method (25).

A *p* value < .05 was considered for statistical significance. All analyses were performed using SAS Release 9.3 (SAS Institute, Cary, North Carolina).

## RESULTS

### Study Population

During the study period, 1,203 older patients were consecutively admitted to the study centers; of these 14 patients did not receive a CGA at admission and 11 did not give their consent to participate to the study and therefore they were excluded. Thus, 1,178 subjects, 702 (59.6%) women and 476 (40.4%) men, mean age 85.0 ± 6.8 years, who

agreed to participate and underwent a complete CGA at admission were included in the study. Patients' baseline characteristics, according to MPI score at admission, are reported in Table 1. At admission, 278 (23.60%) subjects had a MPI-1 score, 398 (33.79%) had a MPI-2 score, and 502 (42.61%) had a MPI-3 score. Subjects with higher MPI score at admission were older (*p* < .001), were more frequently women (*p* < .001) and had higher prevalence of heart failure, renal failure, pneumonia, and dementia when compared with subjects who were included in the lower MPI groups. Moreover, as expected, the functional, cognitive, nutritional, clinical, and social status, assessed using the MPI subscales, was worse in subjects with higher MPI score at admission (all *p* < .001).

### MPI and Mortality During Hospitalization

Among 1,178 patients, 68 (5.77%) died during the hospitalization. Specifically, 3 patients were in the MPI-1 group (1.08%), 17 patients were in the MPI-2 group (4.27%), and 48 patients were in the MPI-3 mortality risk group (9.56%). The overall in-hospital mortality rate was 15.41 per 100 persons-month: they were 3.39, 10.92, and 24.34 in the MPI-1, MPI-2 and MPI-3 groups, respectively (*p* value for trend < .001). Figure 1 displays adjusted Kaplan–Meier

Table 1. Patients Selected Baseline Clinical Characteristics According to MPI Grades at Admission

Variables	MPI-Low	MPI-Intermediate	MPI-High	<i>p</i> Value for Trend*
No. of patients ( <i>n</i> , %)	278 (23.60%)	398 (33.79%)	502 (42.61%)	
Age at admission (years, mean ± <i>SD</i> )	81.64 ± 6.77	84.87 ± 6.28	86.94 ± 6.50	<.001
Female ( <i>n</i> , %)	120 (43.16%)	234 (58.79%)	348 (69.32%)	<.001
BADL	5.54 ± 1.03	3.32 ± 2.06	0.42 ± 0.92	<.001
IADL	6.48 ± 1.71	2.84 ± 2.27	0.28 ± 0.75	<.001
SPMSQ (no. of errors)	1.39 ± 2.03	2.70 ± 2.57	7.57 ± 3.10	<.001
MNA	23.75 ± 4.52	19.39 ± 4.59	12.46 ± 5.22	<.001
ESS	18.61 ± 2.21	15.64 ± 2.82	9.65 ± 2.86	<.001
CIRS comorbidity	3.33 ± 1.96	4.18 ± 1.99	5.49 ± 2.10	<.001
Number of drugs	5.26 ± 3.05	6.43 ± 3.18	7.15 ± 3.19	<.001
Cohabit status ( <i>n</i> , %)				
Missing values	1 (0.36%)	1 (0.25%)	1 (0.2%)	.017
Living alone	225 (80.94%)	266 (66.83%)	291 (57.97%)	
Living in nursing home	2 (0.72%)	18 (4.52%)	149 (29.68%)	
Living in family	50 (17.99%)	113 (28.39%)	61 (12.15%)	
MPI at admission	0.23 ± 0.08	0.50 ± 0.09	0.80 ± 0.08	<.001
CHD ( <i>n</i> , %)	24 (8.63%)	54 (13.57%)	58 (11.55%)	.349
Heart failure ( <i>n</i> , %)	51 (18.35%)	99 (24.87%)	143 (28.49%)	.002
Arrhythmia ( <i>n</i> , %)	61 (21.94%)	68 (17.09%)	92 (18.33%)	.298
Ischemic stroke ( <i>n</i> , %)	25 (8.99%)	36 (9.05%)	53 (10.56%)	.431
Pneumonia ( <i>n</i> , %)	23 (8.27%)	54 (13.57%)	104 (20.72%)	<.001
COPD ( <i>n</i> , %)	40 (14.39%)	65 (16.33%)	50 (9.96%)	.034
Respiratory failure ( <i>n</i> , %)	13 (4.68%)	43 (10.80%)	41 (8.17%)	.201
Pulmonary embolism ( <i>n</i> , %)	4 (1.44%)	10 (2.51%)	11 (2.19%)	.566
Cancer ( <i>n</i> , %)	31 (11.15%)	53 (13.32%)	47 (9.36%)	.297
Dementia ( <i>n</i> , %)	15 (5.40%)	46 (11.56%)	134 (26.69%)	<.001
Acute or chronic kidney failure ( <i>n</i> , %)	23 (8.27%)	33 (8.29%)	70 (13.94%)	.006

Notes: CHD = coronary heart disease; CIRS = cumulative illness rating scale; ESS = Exton–Smith scale; BADL = basic activities of daily living; IADL = instrumental activities of daily living; MNA = Mini Nutritional Assessment; MPI = Multidimensional Prognostic Index; SPMSQ = Short Portable Mental Status Questionnaire.

\**p* values from ANOVA *F* test for trend on ranks and Mantel–Haenszel chi-square test for continuous and categorical variables, respectively.

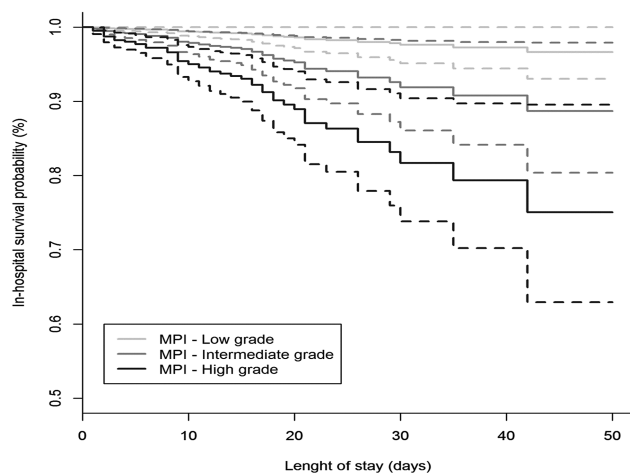


Figure 1. Adjusted (age, gender and disease) survival curves, with 95% confidence interval bands, according to baseline Multidimensional Prognostic Index group.

curves exploring the association between MPI score at baseline and in-hospital mortality. There was a proportional and graded and increased risk of death according to MPI group, with patients with highest MPI score (MPI-3 group) having the highest mortality. In multivariable Cox regression models (Table 2), after adjustment for age, gender and diseases (model 3), patients included in the MPI-2 and MPI-3 groups at admission were significantly at higher risk for intrahospital mortality about three times (HR: 3.48, 95% CI: 1.02–11.88,  $p = .047$ ) and eight times (HR: 8.31, 95% CI: 2.54–27.19,  $p < .001$ ) than patients included in the MPI-1 group, respectively.

The accuracy of the MPI as predictor of in-hospital mortality was very good: after adjustment for age, sex, and main diagnoses (heart failure, pneumonia, COPD, respiratory failure, dementia, acute and chronic kidney disease), the survival C-statistics of the MPI was 0.85 (95% CI: 0.79–0.91) and the calibration  $p$  value of .845. The addition of the MPI at admission into the Model 3, correctly reclassified the risk of in-hospital mortality in the 66.1% of events and in the 33.7% of nonevents ( $n = 1,057$ ), respectively, achieving a cNRI of 1.00 ( $p < .001$ ). Finally, to further investigate the prognostic utility of MPI, we compared the predictive ability for in-hospital mortality of a model including age, sex, diseases, ADL, and cognitive status (SPMSQ) with the predictive ability of a model with the same variables and the additional inclusion of MPI. The prognostic model was well calibrated and achieved a good prognostic accuracy (Supplementary Table 1); however, after the inclusion of the MPI into the basic model, the NRI and the IDI measures suggested an improvement of the prediction accuracy ( $p = .008$  and  $.052$ , respectively).

#### MPI and Length of Stay

After excluding patients who died during hospitalization ( $n = 68$ ), length of stay, according to the different MPI groups at admission, were 9.71 (95% CI: 8.7–10.6), 11.9

(95% CI: 10.9–12.9), and 12.0 (95% CI: 11.2–12.8) days, for MPI-1 low, MPI-2 intermediate, and MPI-3 high score, respectively. Adjustment for age, sex, and disease (heart failure, arrhythmia, pneumonia, COPD, respiratory failure, dementia, acute or chronic kidney failure) confirmed a significant difference in length of stay means, according to the different MPI groups at admission (11.29 [95% CI: 9.29–13.72], 13.73 [95% CI: 11.32–16.65], and 15.30 [95% CI: 12.61–18.55, respectively]). All adjusted means were significantly different as well as all pairwise comparisons (all  $p < .001$ ).

#### DISCUSSION

In this study, among acutely ill hospitalized patients aged  $\geq 65$  years, we demonstrated that the MPI derived from a CGA assessed at hospital admission was predictive of in-hospital mortality and length of hospital stay, independent of demographic characteristics and prevalence of chronic and acute conditions that are common cause of hospitalization in the elderly. The addition of MPI to a model built on demographics and diseases prevalence alone substantially and significantly increased model discrimination and risk reclassification, a more relevant criterion for guiding diagnostic and therapeutic decisions in clinical practice (26,27). Furthermore, these results were based on a large multicenter study without selective exclusion criteria, including patients with multiple different medical conditions and therefore providing a good external validity and generalizability of the findings.

Our findings are in agreement with the results of other studies that evaluated the risk of in-hospital mortality in older patients, reinforcing the predictive value of physical and cognitive function, nutrition, disease diagnosis, and selected biochemical parameters (28). Our study, however, provides a summary weighted index, incorporating all the different information obtained from the CGA and therefore supports the role of MPI as clinically useful risk stratification tool in the acute geriatric setting. The results of this work extend those of earlier studies of this group, providing new insight into the potential clinical application of MPI assessment. MPI has been consistently related to mid- and long-term mortality risk after hospital discharge in patients with a broad spectrum of specific diseases, including pneumonia, dementia, congestive heart failure, and kidney failure. Nevertheless, the utility and validity of MPI in predicting length of hospital stay and in-hospital mortality in unselected patients has never been formally investigated. It is widely recognized that to assess and address the health care needs of geriatric patients, clinicians need to incorporate multiple types of indicators including function, nutrition, cognitive, affective, and social status. Acutely ill older inpatients represent a highly heterogeneous subset of patients with complex clinical pictures and highly unstable health trajectories, for which a traditional clinical approach



Table 2. Univariable and Multivariable Marginal Cox Models With Robust Standard Errors to Assess the Prognostic Effect of the MPI Score at Admission for In-Hospital Mortality

Models*	MPI Groups	HR (95% CI) <sup>1</sup>	p Value	Survival C-Statistic (95% CI) <sup>2</sup>	HL-p Value <sup>3</sup>	Diff. Survival C-Statistic <sup>4</sup>	cNRI (95% CI) <sup>5</sup>	cNRI for Events	cNRI for Nonevents	p Value	IDI (95% CI) <sup>6</sup>
Model 1	—	—	—	0.500	—	<.001	—	—	—	—	—
Model 1 + MPI (at admission)	Intermediate vs. Low	3.10 (0.92–10.50)	.069	0.777 (0.715–0.839)	.589	<.001	0.792 (0.514–1.086)	0.425	0.367	<.001	0.043 (0.032–0.060)
	High vs. Low	6.79 (2.11–21.88)	.001								
Model 2	—	—	—	0.568 (0.456–0.682)	.290	<.001	—	—	—	—	—
Model 2 + MPI (at admission)	Intermediate vs. Low	3.09 (0.90–10.53)	.072	0.783 (0.720–0.845)	.656	<.001	0.931 (0.669–1.165)	0.604	0.326	<.001	0.045 (0.034–0.063)
	High vs. Low	6.67 (2.06–21.66)	.002								
Model 3	—	—	—	0.703 (0.625–0.782)	.257	<.001	—	—	—	—	—
Model 3 + MPI (at admission)	Intermediate vs. Low	3.48 (1.02–11.88)	.047	0.849 (0.791–0.906)	.845	<.001	0.999 (0.757–1.204)	0.661	0.337	<.001	0.084 (0.061–0.119)
	High vs. Low	8.31 (2.54–27.19)	<.001								

Notes: cNRI = continuous net reclassification index; HR = hazard ratio; IDI = Integrated Discrimination Improvement; MPI = Multidimensional Prognostic Index.

\*Model 1: unadjusted; Model 2: age, sex adjusted; Model 3: age, sex, and diseases (heart failure, arrhythmia, pneumonia, COPD, respiratory failure, dementia, acute or chronic kidney failure) adjusted.

<sup>1</sup>Discrimination and reclassification measures for in-hospital mortality risk prediction, adding the MPI at admission variable into the reference model (ie, Model 1–2–3), within a time horizon equal to the median length of stay of 9 days.

<sup>2</sup>p Value from Hosmer–Lemeshow (HL) test for calibration.

based on disease-specific guidelines is often imprecise and misleading with regard to prognosis. Indeed, failure to correctly consider prognosis in the context of clinical decision making can lead to poor quality of care and negative outcomes (29).

Most of the indices that predict mortality risk for hospitalized older patients estimate 1-year mortality. Nevertheless, in the acute setting, also accurate short-term prognosis can be the key to choose wisely between inappropriate treatments, realistic prioritization, and justifiably avoiding standard treatment on the basis of concerns about decreased benefit or increased harm. From this point of view, prognostic indices might offer a potential role for moving beyond arbitrary age-based cutoffs in clinical decision making for older adults. The MPI score, based on a standardized assessment of multiple determinants of the health status of older people, is likely to capture the integrated and synergistic negative effect of aging, comorbidity, disease severity, malnutrition, motivation, and cognition, therefore providing standardized and synthetic information that can be easily applied in everyday clinical practice.

The MPI score evaluated at hospital admission was linearly and directly associated with length of hospital stay, with the relationship remaining significant after adjustment for age, gender, and several common diseases. It has been suggested that roughly 30% of all hospital discharges are delayed, with an average increased length of 3 days (30), and that 63% of the unnecessary days might be due to non-medical reasons (31). From this point of view, a better individual discharge plan tailored on the basis of an early MPI assessment may reduce length of hospital stay and facilitate a more efficient continuity of care and posthospital discharge management (32).

This study has some limitations. First, because MPI assessment needs a complete CGA assessment in an acute setting, it is possible that it is a complex bedside index to use in elderly patients, especially in those with poor compliance and severe cognitive impairment. On the other hands, MPI evaluation might apply over the full spectrum of geriatric patients, whereas other assessment tools that have been recently suggested cannot be used in very sick or bedridden patients (33). Our analysis did not include sensible indicators of disease severity, including, but not limited to, ejection fraction, pneumonia severity score, clinical dementia rating scale, that might have allowed for a better disease characterization of the patients; nevertheless, earlier studies conducted in patients with selected disease suggested that MPI prognostic power is better when compared with disease-specific severity indexes (7,9). Finally, the results of this study should be confirmed and validated in a different and, possibly, more representative population.

In summary, this study presented robust evidence of the short-term prognostic utility of MPI assessed at hospital admission in the acute geriatric setting. Although the clinical impact of MPI should be formally investigated

in randomized clinical trials, taken together these results support the concept that if incorporated into the routine in-hospital assessment, MPI could help clinicians during decision making process leading to a better quality of care provided.

#### SUPPLEMENTARY MATERIAL

Supplementary material can be found at: <http://biomedgerontology.oxfordjournals.org/>

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