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Development and Validation of a Multidimensional Prognostic Index for Mortality Based on a Standardized Multidimensional Assessment Schedule (MPI-SVaMA) in Community-Dwelling Older Subjects

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Abstract

Objectives: To develop and validate a Multidimensional Prognostic Index (MPI) for mortality based on information collected by the Multidimensional Assessment Schedule (SVaMA), the recommended standard tool for multidimensional assessment of community-dwelling older subjects in seven Italian regions.

Design: Prospective cohort study.

Participants: Community-dwelling subjects older than 65 years who underwent an SVaMA evaluation from 2004 to 2010 in Padova Health District, Veneto, Italy.

Measurements: The MPI-SVaMA was calculated as a weighted (weights were derived from multivariate Cox regressions) linear combination of the following nine domains: age, sex, main diagnosis, and six scores, ie, the Short Portable Mental Status Questionnaire, the Barthel index (contains two domains: activities of daily living and mobility), the Extton-Smith scale, the Nursing Care Needs, and the Social Network Support by a structured interview. Subjects were followed for a median of 2 years; those who had not died were followed for at least 1 year. The MPI-SVaMA

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score ranged from 0 to 1 and 3 grades of severity of the MPI-SVaMA were calculated on the basis of estimated cutoffs. Discriminatory power and calibration were further assessed.

Results: A total of 12,020 subjects (mean age 81.84 ± 7.97 years) were included. Two random cohorts were selected: (1) a development cohort, ie, 7876 subjects (mean age 81.79 ± 8.05 , %females: 63.1) and (2) a validation cohort, ie, 4144 subjects (mean age: 81.95 ± 7.83 , %females: 63.7).

The discriminatory power for mortality of MPI-SVaMA was 0.828 (95% CI 0.817–0.838) and 0.832 (95% CI 0.818–0.845) at 1 month and 0.791 (95% CI 0.784–0.798) and 0.792 (95% CI 0.783–0.802) at 1 year in development and validation cohorts, respectively. MPI-SVaMA results were well calibrated showing lower than 10% differences between predicted and observed mortality, both in development and validation cohorts.

Conclusions: The MPI-SVaMA is an accurate and well-calibrated prognostic tool for mortality in community-dwelling older subjects, and can be used in clinical decision making.

Keywords

Comprehensive geriatric assessment; prognosis; mortality; elderly

Mortality prediction in community-dwelling older subjects is useful for clinicians and researchers to identify the appropriate management of subjects (ie, to decide whether to administer a potentially harmful intervention to patients with limited life expectancy or establish eligibility to home-care programs and institutionalization). A recent study underlined the usefulness of predictive tools for mortality in clinical practice,¹ specifically in older adults.² Among several tools validated in different settings and populations to predict mortality, the Multidimensional Prognostic Index (MPI), developed and validated in two independent cohorts of older patients hospitalized for acute disease or relapse of a chronic disease,³ was well calibrated, and demonstrated good discrimination,^{1,2} with the accuracy maintained when the index was tested over 1 month or 1 year of follow-up.⁴ Interestingly, the MPI was based on multidimensional information, collected from a standardized Comprehensive Geriatric Assessment (CGA), that is, functional, cognitive, nutritional, comorbidity, medication, and social network data, usually available at admission to an acute ward in most older patients, suggesting that the multidimensional approach is effective for evaluating prognosis in older patients. Different settings (ie, hospital, nursing home, and the community), however, may require different and specific predictive tools. With this in mind, we developed and validated an MPI-SVaMA (Standardized Multidimensional Assessment Schedule [Scheda per la Valutazione Multidimensionale delle persone adulte e Anziane]) predictive of mortality at 1-month and 1-year follow-up using information from the SVaMA, the standard assessment tool to establish access to the National Health System resources in the Veneto Region of Italy.

Material and Methods

Study Population

The present was a cohort prospective study conducted according to the Declaration of Helsinki, the guidelines for Good Clinical Practice, and the Strengthening the Reporting of

Observational Studies in Epidemiology (STROBE) guidelines (available at www.strobe-statement.org/).

All consecutive subjects aged 65 years and older who required a public health care intervention or support by the Public Local Health Care System (ie, institutionalization or home-care services), and that for this reason were evaluated at their home from the January 1, 2004, to December 31, 2010, by the multidisciplinary team of the Local Health Care System (Azienda ULSS 16 Padova, Italy), were screened for inclusion in the study. Inclusion criteria were (1) age 65 years or older; (2) ability to provide an informed consent or availability of a proxy for informed consent; and (3) a complete SVaMA. Because the Public Health Care System in Italy is addressed to all residents without limits as regards age, sex, race, religion, and income, the cohort may be considered as representative of community-dwelling older subjects who need health care assistance, mainly for having access to homecare services or institutionalization. All patients were followed for a median period of 2 years; patients who had not died were followed for at least 1 year. Vital status at a least 1 year from the evaluation was assessed by consulting the Registry Offices of the cities in which the patients were residents at the time of the evaluation. Dates of death were identified from death certificates.

Two cohorts of random older patients living at home were identified. The first cohort (the development cohort) was identified by randomly selecting about 66% of the total sample data and was used for developing the MPI-SVaMA; the second cohort (the validation cohort) was identified by using the remaining total sample data and was used to validate the prognostic accuracy of MPI-SVaMA. Two distinct MPI-SVaMAs were defined as predictors of mortality at 1 month and 1 year of follow-up, respectively.

The SVaMA

The SVaMA is the officially recommended assessment schedule used by the health personnel of the National Health Care System to perform a multidimensional assessment in community-dwelling older persons or nursing home residents introduced by the Veneto Regional Health System since 2000 to establish accessibility to some health care resources. When a resident citizen requires support by the Public Local Health System (ie, home-care services or institutionalization), a specific commission has the task to perform a multidimensional assessment of the subject to develop a project of care tailored to the needs of the individual. The commission consists of a multidisciplinary team that includes a physician of the public Health Care District, a general practitioner (GP), a nurse, a social worker, and a geriatrician as a consultant specialist that through the SVaMA may collect information on health, functional, social, and economic domains. Reliability, accuracy, and calibration of the SVaMA have been previously tested and validated.⁵ At present, the SVaMA is the officially recommended multidimensional assessment instrument used in most regions in Italy (ie, Veneto, Trentino, Puglia, Molise, Sicilia, Campania, Basilicata, and Valle D'Aosta), comprising a total population area of about 21,700,000 inhabitants. The SVaMA instrument is available online at <http://www.regione.veneto.it/NR/rdonlyres/2A86F528-22A4-4603-86D6-D22F79858006/0/>

[Deliberazione della Giunta Regionale n. 1133 del 6 maggio 2008.pdf](#) (Italian version) and at <http://www.operapadrepio.it/it/content/view/2152/1082/> (English version).

The MPI Based on the SVaMA

To develop the MPI-SVaMA, the following nine domains, including 55 items, were considered: (1) age, (2) sex, (3) main diagnosis, (4) nursing care needs (VIP), evaluated according to a validated numeric scale including 11 items that estimated the nursing care needs of the older subject based on the presence of (a) insulin-dependent diabetes mellitus; (b) heart failure in 3–4 New York Heart Association class that needs frequent monitoring of pulse, blood pressure, heart rate, and liquid balance; (c) liver failure with ascites; (d) tracheostomy; (e) oxygen therapy for more than 3 hours per day; (f) feeding gastrostomy and/or nasogastric tube; (g) central venous catheter; (h) bladder catheter; (i) ureterostomy; (j) nephrostomy; (k) pressure sores at the limbs or other sites that need medications; (5) cognitive status (VCOG), evaluated by the Short Portable Mental Status Questionnaire (SPMSQ), a 10-item questionnaire that assesses orientation, memory, attention, calculation, and language⁶; (6) pressure sores risk (VPIA), evaluated by the Exton-Smith Scale, a 5-item questionnaire that determines physical and mental condition, activity, mobility, and incontinence⁷; (7) activities of daily living (VADL) and (8) mobility (VMOB) evaluated by the Barthel Index, which defines the level of dependence/independence in seven daily care activities, including feeding, bathing, grooming, dressing, bowel and bladder continence and toilet use, as well as the capacities for moving from bed to wheelchair and back, walking on level surface, and going up and down stairs^{8,9}; and (9) social support (VSOC), evaluated by a numeric scale of 16 items that explores the presence of a support network for preparing meals, cleaning house, washing clothes, buying something, feeding, taking a bath, personal hygiene, dressing, going to the toilet, taking medications, transferring, walking, money management, psycho-affective support, and supervision during the day and the night.

To calculate the MPI-SVaMA indices, a weighted sum of each individual domain (D_i) was computed (raw formula). Weights (S_i) were estimated from 2 distinct multivariate Cox proportional hazard models, one for 1-month and one for 1-year mortality prediction, respectively (Table 1).

Each weighted sum $[R = \sum (S_i \cdot D_i)]$ was then normalized into a range that varies from 0 (lowest risk) to 1 (highest risk), subtracting the observed raw minimum value and then dividing such difference by the observed range (minimum to maximum span). Specifically, for 1-month MPI-SVaMA, the raw formula can be normalized by subtracting the minimum value of 0.276 and dividing the obtained difference by 6.564 (ie, $\frac{(R - 0.276)}{6.564}$). Similarly, for 1-year MPI-SVaMA, the raw formula can be normalized by subtracting the minimum value of 0.673 and dividing the obtained difference by 5.476 (ie, $\frac{(R - 0.673)}{5.476}$).

The RECURSIVE Partition and AMalgamation (RECPAM) algorithm¹⁰ was used to identify subgroups of patients at different risks for mortality, as previously reported.¹¹ At each partitioning step, the method chooses the best binary split (cutoff) to maximize the difference in the outcome of interest. The following cutoffs were estimated for the

normalized MPI-SVaMA for 1-month mortality prediction: 0–0.41 (low risk), 0.42–0.53 (moderate risk), 0.54–1 (severe risk), whereas for the normalized MPI-SVaMA for 1-year mortality prediction the cutoffs were 0–0.33 (low risk), 0.34–0.47 (moderate risk), 0.48–1 (severe risk). To calculate the MPI-SVaMA at 1 month and at 1 year, software for Windows may be downloaded (available for free) at the following address: <http://www.operapadrepio.it/impi/svamasetup.exe>.

Statistical Analysis

Patients' baseline characteristics were reported as means $\pm$ SD or frequencies and percentages for continuous and categorical variables, respectively. Baseline comparisons between men and women were assessed using Mann-Whitney or Pearson chi-square statistics for continuous and categorical variables, respectively. Mortality incidence rates (IR) for 100 person-months and 100 person-years over 1 month and 1 year of follow-up were also reported. Poisson regression models were assessed to test differences in IR between men and women and to assess a linear trend in IR between MPI-SVaMA grades. Hazard ratios (HRs) and 95% confidence intervals (95% CIs) estimated from univariate proportional hazards regression models, and for each defined risk category, were also shown. A forward variable selection analysis was performed for both 1-month and 1-year mortality to assess which domains should be used to build the prediction model. The discriminatory power of the MPI-SVaMA indices for 1-month and 1-year mortality prediction was assessed by estimating the Survival C-index,¹² along with their 95% CIs. The model's calibration (ie, the weights for agreement between observed outcomes and predictions) was assessed by estimating the difference between the mean predicted probability and the observed probability, derived using the Kaplan-Meier method, for each quintile of predicted probabilities. Ten or more percentage points' difference between predicted and observed probabilities evidenced poor calibration, whereas a difference of less than 10 percentage points evidenced good calibration.²

All statistical analyses were performed using SAS version 9.1 (SAS Institute, Cary, NC). For RECPAM analysis, an SAS macro routine written by one of the authors (F.P.) was used.

Results

Study Population

A total of 12,020 subjects 65 years or older (mean age 81.84 ± 7.97 years) were included in the study; 7605 (63.3%) were women and 4415 (36.7%) were men. The overall study population was divided into 2 cohorts through a computerized randomization: (1) the Development Cohort included 7876 subjects (mean age 81.79 ± 8.05 years), 4967 women (63.1%) and 2909 (36.9%) men and (2) the Validation Cohort included 4144 subjects (mean age 81.95 ± 7.83 years), 2638 women (63.7%) and 1506 (36.3%) men (Table 2).

In both cohorts, the most prevalent main diagnoses were dementia (31.06% and 30.48% in the development and validation cohort, respectively), cancer (22.91% and 23.55% in the development and validation cohort, respectively), immobilization syndrome (10.88% and 11.66% in the development and validation cohort, respectively), cardiovascular disease

(7.53% and 7.89% in the development and validation cohort, respectively), neurologic disorders (6.98% and 6.90% in the development and validation cohort, respectively), and stroke (5.33% and 5.12% in the development and validation cohort, respectively). In both cohorts, the distribution of main diagnoses was significantly different between men and women ($P < .0001$). Women showed significantly higher cognitive (VCOG, $P < .0001$) and social (VSOC $P < .0001$) impairment than men, whereas men demonstrated higher nursing care needs (VIP $P < .0001$) than women. No relevant differences between men and women were observed in the ADL (VADL), the Barthel mobility score (VMOB), and the risk of pressure sores (VPIA) (Table 2).

Mortality Rates and MPI-SVaMA

The overall mortality incidence rates were 17.7% and 18.3% for 100 person-months (development and validation cohort, respectively) over 1 month and 70.9% and 72.3% for 100 person-years (development and validation cohort respectively) over 1 year of follow-up. In both development and validation cohorts, mortality incidence rates were significantly higher in men than women after 1 month (26.4% vs 13.0%, $P < .0001$ and 28.6% vs 12.8%, $P < .0001$) and after 1 year of follow-up (109% vs 53.9%, $P < .0001$ and 115.8% vs 53.8%, $P < .0001$).

In both cohorts, men showed a significantly higher MPI-SVaMA mean value than women both at 1-month ($P < .0001$) and at 1-year ($P < .0001$) follow-up.

As expected, a significant linear trend between MPI-SVaMA in grades and mortality incidence rates for 100 person-months was observed at 1 month both in the development cohort (incidence rates: 2.0% vs 12.4% vs 54.4% in low, moderate, and severe MPI-SVaMA grades, respectively, P for trend $< .0001$) and in the validation cohort (incidence rates: 2.1% vs 12.8% vs 54.4% for low, moderate, and severe grades, respectively, P for trend $< .0001$).

Similarly, a significant linear trend between MPI-SVaMA in grades and mortality incidence rates for 100 person-years was observed at 1 year both in the development cohort (incidence rates: 19.0% vs 69.4% vs 299.3% for low, moderate, and severe MPI-SVaMA grades, respectively, P for trend $< .0001$) and in the validation cohort (incidence rates: 19.5% vs 68.4% vs 302.5% for low, moderate, and severe MPI-SVaMA grades, respectively, P for trend $< .0001$).

HRs, along with their 95% CIs, were estimated for each MPI-SVaMA grade (low grade was considered as reference class) for mortality at 1 month and 1 year. In the development cohort, the HRs for MPI-SVaMA at 1 month were 6.01, 95% CI 4.61–7.85 ($P < .001$) and 26.17, 95% CI 20.49–33.42 ($P < .001$) in moderate and severe grades versus low, respectively. The HRs for MPI-SVaMA at 1 year were 3.38, 95% CI 3.04–3.76 ($P < .001$) and 11.81, 95% CI 10.71–13.02 ($P < .001$) in moderate and severe grades versus low, respectively. In the validation cohort, the HRs for MPI-SVaMA at 1 month were 6.12, 95% CI 4.24–8.85 ($P < .001$) and 25.71, 95% CI 18.33–36.06 ($P < .001$) for moderate and severe grades versus low, respectively. The HRs for MPI-SVaMA at 1 year were 3.29, 95% CI 2.84–3.81 ($P < .001$) and 11.55, 95% CI 10.11–13.20 ($P < .001$) for moderate and severe grades versus low, respectively.

Accuracy and Calibration of the MPI-SVaMA

The numbers of death events at 1 month were 1264/7876 patients (16.0%) and 681/4144 patients (16.4%) in the development and the validation cohorts, respectively. At 1 year, the numbers of death events were 3398/7876 patients (43.1%) and 1816/4144 patients (43.8%) in the development and the validation cohorts, respectively. The survival C-indices of MPI-SVaMA for 1-month mortality risk prediction were 0.828 (95% CI 0.817–0.838) and 0.832 (95% CI 0.818–0.845) in the development and the validation cohorts, respectively. Survival C-indices of MPI-SVaMA for 1-year mortality risk prediction, were 0.791 (95% CI 0.784–0.798) and 0.792 (95% CI 0.783–0.802) in the development and the validation cohorts, respectively. The complete overlapping of survival C-indices between the 2 cohorts indicated the reliability of the statistical analyses.

Table 3 reports the differences between predicted and observed mortality probabilities of both MPI-SVaMA indices in the development and the validation cohorts, respectively. Results evidenced a good calibration of MPI-SVaMA mortality indices in both cohorts (all differences were <10%).

Discussion

The study reported the development and validation of the MPI-SVaMA, a predictive tool of mortality based on information collected through a standardized multidimensional assessment in two large and independent cohorts of community-dwelling older subjects. It is evident that this MPI-SVaMA is a prognostic tool with a very good prognostic accuracy to predict 1-month mortality (survival C-index of 0.83) and a good prognostic accuracy was maintained also in predicting 1-year mortality (survival C-index of 0.79). In addition, the results obtained in the development cohort were almost perfectly replicated in the validation cohort, evidencing the high reproducibility of these findings. Moreover, the MPI-SVaMA was well calibrated (ie, showed a very close agreement between the estimated and the observed mortality). The clear advantage of this instrument is to be based on the standardized CGA included in the SVaMA, which is a multidimensional instrument potentially correlated to a reduction in mortality, functional disability, and cognitive impairment of older subjects according to the most recent evidence in clinical geriatric practice.^{13,14} Indeed, the SVaMA is the official recommended multi-dimensional assessment schedule presently running in many Italian Regional Health Care Systems.

As a CGA instrument, the SVaMA includes information on demographics (age and gender), clinical status (main clinical diagnosis, risk of pressure sores, drug use, and nursing care needs), cognitive and functional status, mobility and social status, including cohabitation, presence of care-assistance network, economic income, and presence of architectural barriers at home. All information was of paramount importance to identify the set of variables that needed to be included in the cumulative prognostic index to better define the mortality risk of older subjects. Thus, the MPI-SVaMA was developed on nine domain variables, including age, sex, main diagnosis, and five standardized scales [Barthel Index (containing activities of daily living and mobility), SPMSQ, Exton-Smith Scale, Nursing Care Needs and Social Support Network] that have been previously validated in several

populations and are well known worldwide, thus no further specific training was required by the healthy workers.

The methodological and mathematical models used to develop the MPI-SVaMA were very similar to those used to develop the 8-domain MPI for hospitalized older patients, the only differences being the inclusion of some different domains considering the different setting of subjects included in the study (ie, community-dwelling instead of hospitalized older subjects). Considering that the most consistent predictors of mortality in older persons include functional status and comorbidities,¹⁵ the MPI for hospitalized older patients has been validated in older patients with specific acute diseases, such as pneumonia,¹⁶ heart failure,¹⁷ gastrointestinal bleeding,¹⁸ transient ischemic attack,¹⁹ and also chronic diseases, such as dementia,²⁰ liver cirrhosis,²¹ and chronic kidney disease.²² Almost 65% of the community-dwelling subjects included in the present study, however, had dementia, cancer, or immobility syndrome and almost 25% of subjects had cardiovascular, cerebrovascular, neurologic, and respiratory disorders as main diagnoses; thus, we included a correction factor in the mathematical model to obtain the accurate computation of mortality risk by the MPI-SVaMA in subjects, whatever main diagnosis they had. Indeed, the 1-month and 1-year accuracy of the MPI-SVaMA, as evaluated by the C-survival index was very similar to the C-survival index values reported for the MPI in hospitalized older patients with acute diseases or a relapse of chronic diseases.^{3,4}

The MPI-SVaMA may be expressed as both a continuous value and in 3 grades of severity risk according to calculated cutoffs; thus, it is possible to have immediate information on the degree of mortality risk (mild, moderate, and severe) as well as a more detailed and accurate assessment of risk of the subject.

Several prognostic instruments to predict mortality have been described and validated in community-dwelling older populations. A recent systematic review of prognostic indices that predicted absolute risk of mortality in older patients, identified six validated indices for community-dwelling older adults that estimated mortality risk from 1 year to 5 years.³ Gagne et al²³ developed and validated a comorbidity score to predict 1-year mortality in two large cohorts of Medicare low-income elders with drug coverage through a pharmacy-assistance program in the United States. The index was based on 20 items that combined conditions of the Charlson and the Elixhauser comorbidity indices. Although the discrimination was good (1-year C-statistics of 0.79 in both the cohorts), the calibration showed a higher than 10% difference between predicted and observed mortality in the higher-risk subjects. The 15-month index developed by Mazzaglia et al²⁴ was a 7-item questionnaire for screening of older people at risk for death by primary care physicians. The index was developed in 2470 primary care older patients and validated in 2926 similar patients, all residing in the city of Florence, Italy. The model was well calibrated and showed a C-index value of 0.75 in both the cohorts, but it predicted a very narrow range of mortality compared with other examined indices (0% to 10% of mortality risk). Similar accuracy (C-statistics of 0.76 and 0.74 in the development and validation cohorts, respectively) was demonstrated by the 2-year mortality index developed by Carey et al²⁵ for community-dwelling elderly individuals aged 70 years and older in the United States. The index was based on a 6-item self-reported questionnaire that evaluated functional status, age, and

gender. The same authors developed and validated a 3-year mortality index in 2232 and 1667 functionally impaired, nursing home-eligible community-dwelling adults who were 55 years and older living in the United States.²⁶ The index was based on an 8-item questionnaire evaluating age, gender, need for assistance in toileting and dressing, and the presence of four comorbidities (ie, neoplasms, congestive heart failure, chronic obstructive pulmonary disease, and renal insufficiency), and showed only a moderate accuracy (C-statistics 0.66 and 0.69 in the development and validation cohorts, respectively). Lee et al²⁷ developed a 4-year mortality index in a sample of 11,701 community-dwelling adults older than 50 years from the eastern, western, and central United States and validated in 8009 subjects from the southern United States. The index was based on a 12-item self-reported questionnaire; it was well calibrated and demonstrated very good discrimination (C-statistics of 0.84 and 0.82 in the development and validation cohorts, respectively). The 5-year mortality index developed by Schonberg et al²⁸ was based on an 11-item self-reported questionnaire; it was developed in 16,077 subjects older than 65 years who responded to the 1997–2000 National Health Interview Survey (NHIS) and validated in 8038 subjects drawn from the same database. The index was well calibrated and showed good discrimination (C-statistics of 0.75 in both the cohorts). Compared with all these predictive tools that were mainly based on comorbidity,²³ or functional status,^{24,25} or on a combined approach,^{26–28} the MPI-SVaMA differs in some crucial points: (1) the MPI-SVaMA was the only prognostic tool completely based on a CGA; (2) all the data were collected directly by a multidisciplinary team, including doctors, a social worker, and a nurse; (3) no patients were excluded on the basis of incapacity of self-report; and (4) the clinical and functional scores used to calculate the prognostic index have been specifically developed and validated in older subjects. Indeed, although considering the intrinsic limitation of an indirect comparison among different prognostic instruments, the MPI-SVaMA demonstrated comparable^{23,27} or higher^{24,25,26,28} discrimination as determined by the survival C-index values. To our knowledge, moreover, the MPI-SVaMA is the only highly accurate and well-calibrated predictive tool for mortality based on a multidimensional assessment that was performed by an interdisciplinary team, including a public health district physician, a GP, a nurse, a social worker, and a geriatrician (ie, all the personnel involved in the decision making of health care management and strictly integrated to the National Health Service Network). Very recently, it has been reported that a comprehensive multidimensional approach may be very effective in identifying and evaluating frail older subjects, according to a multidimensional operational definition of frailty in clinical practice,^{29,30} as multisystemic changes occur in older individuals that determine an increased risk for adverse health outcomes, including death. Indeed, the MPI demonstrated a significant higher predictive power for short- and long-term all-cause mortality than other frailty instruments in hospitalized older patients.³¹ Very interestingly, the MPI-SVaMA was an accurate predictive tool also for another adverse health outcome traditionally linked to frailty, such as institutionalization (data not shown). Taken together, all these findings support the concept that considering multidimensional aggregate information may be very important for predicting mortality in older patients with the most common conditions leading to death,³² and that it may be useful for the identification of more adequate management of patients during the last period of life.³³ A limitation of the study is that we included older subjects who attended the SVaMA evaluation so as to be eligible for health care assistance programs

(ie, home services or institutionalization), so a generalization to other populations or settings of the present findings needs to be validated.

Conclusion

We developed and validated an accurate and well-calibrated instrument to predict mortality in community-dwelling older subjects. To determine, however, whether use of the MPI-SVaMA is better than usual care to facilitate clinical decision making, further impact studies are needed.

References

1. Siontis GCM, Tzoulaki I, Ioannidis JPA. Predicting death. An empirical evaluation of predictive tools for mortality. *Arch Intern Med* 2011;171:1721–1726. [PubMed: 21788535]
2. Yourman LC, Lee SJ, Schonberg MA, et al. Prognostic indices for older adults. A systematic review. *JAMA* 2012;307:182–192. [PubMed: 22235089]
3. Pilotto A, Ferrucci L, Franceschi M, et al. Development and validation of a multidimensional prognostic index for one-year mortality from comprehensive geriatric assessment in hospitalized older patients. *Rejuvenation Res* 2008;11:151–161. [PubMed: 18173367]
4. Sancarlo D, D'Onofrio G, Franceschi M, et al. Validation of a modified Multidimensional Prognostic Index (m-MPI) including the Mini Nutritional Assessment Short-form (MNA-SF) for the prediction of one-year mortality in hospitalized elderly patients. *J Nutr Health Aging* 2011;15:169–173. [PubMed: 21369662]
5. Gallina P, Saugo M, Antoniazzi M, et al. Validazione della Scheda per la Valutazione Multidimensionale dell'Anziano (SVaMA). *Tendenze nuove* 2006;3: 229–263.
6. Pfeiffer E A short portable mental status questionnaire for the assessment of organic brain deficit in elderly patients. *J Am Geriatr Soc* 1975;23:433–441. [PubMed: 1159263]
7. Bliss MR, McLaren R, Exton-Smith AN. Mattresses for preventing pressure sores in geriatric patients. *Mon Bull Minist Health Public Health Lab Serv* 1966;25:238–268. [PubMed: 6013600]
8. Mahoney FI, Barthel D. Functional evaluation: the Barthel index. *Md State Med J* 1965;14:56–61.
9. Shah S, Vancly F, Cooper B. Improving the sensitivity of the Barthel Index for stroke rehabilitation. *J Clin Epidemiol* 1989;42:703–709. [PubMed: 2760661]
10. Ciampi A Generalized regression tree. *Computational Statistics and Data Analysis* 1991;12:57–78.
11. Addante F, Sancarlo D, Copetti M, et al. Effect of obesity, serum lipoproteins, and apolipoprotein E genotypes on mortality in hospitalized elderly patients. *Rejuvenation Res* 2011;14:111–118. [PubMed: 21595502]
12. Pencina MJ, D'Agostino RB. Overall C as a measure of discrimination in survival analysis: model specific population value and confidence interval estimation. *Statistics in Medicine* 2004;23:2109–2123. [PubMed: 15211606]
13. Ellis G, Whitehead MA, O'Neill D, et al. Comprehensive Geriatric Assessment for older adults admitted to hospital. *Cochrane Database Syst Rev* 2011;(7): CD006211.
14. Stuck AE. Comprehensive geriatric assessment for older adults. *BMJ* 2011;343: d6799. [PubMed: 22034147]
15. Gill TM. The central role of prognosis in clinical decision making. *JAMA* 2012; 307:199–200. [PubMed: 22235093]
16. Pilotto A, Addante F, Ferrucci L, et al. The Multidimensional Prognostic Index (MPI) predicts short and long-term mortality in older patients with community-acquired pneumonia. *J Gerontol A Biol Sci Med Sci* 2009;64A: 880–887.
17. Pilotto A, Addante F, Franceschi M, et al. A Multidimensional Prognostic Index (MPI) based on a comprehensive geriatric assessment predicts short-term mortality in older patients with heart failure. *Circ Heart Fail* 2010;3: 14–20. [PubMed: 19850698]

18. Pilotto A, Ferrucci L, Scarcelli C, et al. Usefulness of the comprehensive geriatric assessment in older patient with upper gastrointestinal bleeding: A two year follow-up study. *Dig Dis* 2007;25:124–128. [PubMed: 17468547]
19. Sancarolo D, Pilotto A, Panza F, et al. A Multidimensional Prognostic Index (MPI) based on a comprehensive geriatric assessment predicts short- and long-term all-cause mortality in older hospitalized patients with transient ischemic attack. *J Neurol* 2012;259:670–678. [PubMed: 21947223]
20. Pilotto A, Sancarolo D, Panza F, et al. The Multidimensional Prognostic Index (MPI), based on a comprehensive geriatric assessment predicts short- and long-term mortality in hospitalized older patients with dementia. *J Alzheimers Dis* 2009;18:191–199. [PubMed: 19584441]
21. Pilotto A, Addante F, D'Onofrio G, et al. The Comprehensive Geriatric Assessment and the multidimensional approach. A new look at the older patient with gastroenterological disorders. *Best Pract Res Clin Gastroenterol* 2009;23: 829–837. [PubMed: 19942161]
22. Pilotto A, Sancarolo D, Aucella F, et al. Addition of the Multidimensional Prognostic Index to the estimated Glomerular Filtration Rate improve prediction of long-term all-cause mortality in older patients with Chronic Kidney Disease. *Rejuvenation Res* 2012;15:82–88. [PubMed: 22352434]
23. Gagne JJ, Glynn RJ, Avorn J, et al. A combined comorbidity score predicted mortality in elderly patients better than existing scores. *J Clin Epidemiol* 2011; 64:749–759. [PubMed: 21208778]
24. Mazzaglia G, Roti L, Corsini G, et al. Screening of older community-dwelling people at risk for death and hospitalization: The Assistenza Socio-Sanitaria in Italia project. *J Am Geriatr Soc* 2007;55:1955–1960. [PubMed: 17944891]
25. Carey EC, Walter LC, Lindquist K, Covinsky KE. Development and validation of a functional morbidity index to predict mortality in community-dwelling elders. *J Gen Intern Med* 2004;19:1027–1033. [PubMed: 15482555]
26. Carey EC, Covinsky KE, Lui LY, et al. Prediction of mortality in community-living frail elderly people with long-term care needs. *J Am Geriatr Soc* 2008;56: 68–75. [PubMed: 18031487]
27. Lee SJ, Lindquist K, Segal MR, Covinsky KE. Development and validation of a prognostic index for 4-year mortality in older adults. *JAMA* 2006;295: 801–808. [PubMed: 16478903]
28. Schonberg MA, Davis RB, McCarthy EP, Marcantonio ER. Index to predict 5-year mortality of community-dwelling adults aged 65 and older using data from the National Health Interview Survey. *J Gen Intern Med* 2009;24:1115–1122. [PubMed: 19649678]
29. Sourial N, Wolfson C, Bergman H, et al. A correspondence analysis revealed frailty deficits aggregate and are multidimensional. *J Clin Epidemiol* 2010;63: 647–654. [PubMed: 19880286]
30. Gobbens RJJ, van Assen MAL, Luijkx KG, Wijnen-Sponselee MT. Determinants of frailty. *J Am Med Dir Assoc* 2010;11:356–364. [PubMed: 20511103]
31. Pilotto A, Rengo F, Marchionni N, et al. Comparing the prognostic accuracy for all-cause mortality of frailty instruments: A multicentre 1-year follow-up in hospitalized older patients. *PLoS One* 2012;7:e29090. [PubMed: 22247767]
32. Pilotto A, Panza F, Ferrucci L. A Multidimensional Prognostic Index in common conditions leading to death in older patients. *Arch Intern Med* 2012;172: 594–595. [PubMed: 22493470]
33. Gill TM, Gahbauer EA, Han L, Allore HG. Trajectories of disability in the last year of life. *N Engl J Med* 2010;362:1173–1180. [PubMed: 20357280]

Table 1

Estimated Domain Weights Used to Compute the MPI-SVaMA Indices for 1-Month and 1-Year Mortality Prediction

Domains	Category	Weights for MPI-SVaMA at 1 Month	Weights for MPI-SVaMA at 1 Year
Age, y		0.00331	0.01351
Sex	Female (reference)	0	0
	Male	0.31464	0.3413
Main diagnosis	Dementia (reference)	0	0
	Cancer	2.22093	1.99569
	Hip fracture	−0.65872	−0.54763
	Stroke	0.20318	0.0099
	Cardiovascular disease	0.38855	0.30945
	Respiratory disease	0.39394	0.2596
	Neurological disorder	−0.14409	−0.10899
	Immobilization syndrome	0.43482	0.21911
	Other	0.69991	0.34769
Nursing care need	VIP	0.02741	0.02771
Cognitive status	VCOG (SPMSQ)	0.01772	0.00799
Pressure sore risk	VPIA (Exton-Smith Scale)	0.02104	0.02858
Activities of daily living	VADL (Barthel-Index)	0.01098	0.00662
Mobility	VMOB (Barthel-Index)	0.02617	0.01645
Social support	VSOC	0.0007367	0.0000994

MPI-SVaMA, Multidimensional Prognostic Index based on the Standardized Multi-dimensional Assessment Schedule (Scheda per la Valutazione Multidimensionale delle persone adulte e Anziane); VADL, activities of daily living; VCOG, cognitive functions; VIP, nursing care needs; VMOB, mobility; VPIA, pressure sores risk; VSOC, social support network.

Table 2

Baseline Characteristics of Patients in the Development and Validation Cohorts, Divided According to Gender

Variable	Development Cohort (n = 7876)			P Value	Validation Cohort (n = 4144)			P Value
	All	Females	Males		All	Females	Males	
Patients, n (%)	7876 (100)	4967 (63.1)	2909 (36.9)	—	4144 (100)	2638 (63.7)	1506 (36.3)	—
Age, y	81.79 ± 8.05	83.19 ± 7.79	79.39 ± 7.91	<.0001	81.95 ± 7.83	83.22 ± 7.56	79.72 ± 7.79	<.0001
Main diagnosis, n (%)								
Dementia	2446 (31.06)	1783 (35.90)	663 (22.79)	<.0001	1263 (30.48)	901 (34.15)	362 (24.04)	<.0001
Cancer	1804 (22.91)	800 (16.11)	1004 (34.51)		976 (23.55)	452 (17.13)	524 (34.79)	
Ipokinetic syndrome	857 (10.88)	615 (12.38)	242 (8.32)		483 (11.66)	355 (13.46)	128 (8.50)	
Cardiovascular disease	593 (7.53)	401 (8.07)	192 (6.60)		327 (7.89)	222 (8.42)	105 (6.97)	
Neurologic disease	550 (6.98)	350 (7.05)	200 (6.88)		286 (6.90)	178 (6.75)	108 (7.17)	
Stroke	420 (5.33)	261 (5.25)	159 (5.47)		212 (5.12)	127 (4.81)	85 (5.64)	
Respiratory disease	210 (2.67)	107 (2.15)	103 (3.54)		84 (2.03)	47 (1.78)	37 (2.46)	
Hip fractures	196 (2.49)	152 (3.06)	44 (1.51)		94 (2.27)	79 (2.99)	15 (1.00)	
Other diseases	800 (10.16)	498 (10.03)	302 (10.38)		419 (10.11)	277 (10.50)	142 (9.43)	
VIP	5.54 ± 7.63	4.71 ± 7.14	6.94 ± 8.20	<.0001	5.43 ± 7.35	4.78 ± 7.00	6.59 ± 7.81	<.0001
VCOG	5.34 ± 3.74	5.65 ± 3.63	4.82 ± 3.86	<.0001	5.33 ± 3.68	5.64 ± 3.58	4.78 ± 3.80	<.0001
VPIA	4.38 ± 6.00	4.31 ± 5.97	4.49 ± 6.05	.1652	4.52 ± 6.15	4.45 ± 6.11	4.64 ± 6.21	.3755
VADL	40.13 ± 19.55	40.45 ± 19.52	39.58 ± 19.59	.0448	40.11 ± 19.43	40.04 ± 19.51	40.22 ± 19.28	.8966
VMOB	28.26 ± 13.31	28.49 ± 13.19	27.87 ± 13.50	.0672	28.12 ± 13.34	28.10 ± 13.28	28.14 ± 13.45	.7744
VSOC	148.12 ± 67.74	151.91 ± 68.17	141.66 ± 66.50	<.0001	150.83 ± 68.18	154.51 ± 68.01	144.39 ± 68.03	<.0001
MPI-SVaMA 1-month	0.45 ± 0.19	0.41 ± 0.17	0.52 ± 0.19	<.0001	0.45 ± 0.19	0.41 ± 0.17	0.52 ± 0.19	<.0001
MPI-SVaMA 1-year	0.39 ± 0.19	0.35 ± 0.17	0.47 ± 0.20	<.0001	0.40 ± 0.20	0.35 ± 0.18	0.48 ± 0.20	<.0001
Mortality 1-mo, ev/pm (ir%)	1264/7126 (17.7)	600/4614 (13.0)	664/2512 (26.4)	<.0001	681/3729 (18.3)	313/2443 (12.8)	368/1286 (28.6)	<.0001
Mortality 1-y, ev/py (ir%)	3398/4793 (70.9)	1790/3319 (53.9)	1608/1475 (109)	<.0001	1816/2512 (72.3)	949/1763 (53.8)	867/749 (115.8)	<.0001

Data are reported as means ± SD frequencies and percentages. Two-sided *P*values refer to Mann-Whitney or Pearson chi-square statistics, for continuous and categorical variables, respectively. ev/pm, events/person-months; ev/py, events/person-years; ir%, incidence rates per 100 person-months (or person-years); MPI-SVaMA, Multidimensional Prognostic Index based on the Standardized Multidimensional Assessment Schedule (Scheda per la Valutazione Multidimensionale delle persone adulte e Anziane); VADL, activities of daily living; VCOG, cognitive functions; VIP, nursing care needs; VMOB, mobility; VSOC, social support network.

Table 3

Observed and Predicted Mortality Rate for Each Quintile of the Predicted Probabilities, for MPI-SVaMA Indices at 1-Month and 1-Year Mortality Prediction, in the Development Cohort (n = 7876) and in the Validation Cohort (n = 4144)

MPI-SVaMA	Quintile	Development Cohort			Validation Cohort		
		Observed Mortality, %	Predicted Mortality, %	Difference, %	Observed Mortality, %	Predicted Mortality, %	Difference, %
MPI-SVaMA at 1 month	1	1.03	2.07	1.04	0.61	1.97	1.36
	2	2.69	4.82	2.13	3.30	4.68	1.38
	3	8.40	8.80	0.40	7.19	8.85	1.66
	4	20.20	15.62	4.58	20.60	15.92	4.68
	5	48.48	48.60	0.12	50.72	50.29	0.43
MPI-SVaMA at 1 year	1	11.87	14.57	2.70	9.60	14.62	5.02
	2	21.20	24.96	3.76	22.94	25.24	2.29
	3	36.35	37.69	1.34	40.43	38.38	2.05
	4	66.44	58.18	8.26	64.41	59.44	4.97
	5	90.21	91.93	1.71	91.45	92.75	1.30

MPI-SVaMA, Multidimensional Prognostic Index based on the Standardized Multidimensional Assessment Schedule (Scheda per la Valutazione Multidimensionale delle persone adulte e Anziane).